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Paradigmatic Associations and Individual Variability in Early Lexical–Semantic Networks: Evidence From a Free Association Task

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Between 6 and 9 years of age, children's free associations shift from syntagmatic to paradigmatic relationships. *Syntagmatic relations* are words that are syntactically adjacent, thematically related (*summer–vacation*), or both; *paradigmatic relations* are words from the same grammatical class, taxonomic category (*summer–winter*), or both. Infant researchers have reliably found evidence for the activation of paradigmatic relationships by 24 months. Because of a lack of data from children aged 3 to 5 years, the developmental trajectory of paradigmatic relations is unclear. With age-appropriate stimuli, this work is among the first to collect free association data for children under 5. Children (n = 60; age range = 3–8 years) and adults (n = 60; age range = 18 to 43 years) were instructed to respond to a prime word with the first word that came to mind. Unifying the data from previous studies with infants and older children, our data suggest that paradigmatic relations are present in early childhood but also increase in prevalence with age. Several exploratory analyses revealed that younger children gave more varied responses, suggesting that early lexical–semantic networks are more idiosyncratic. We also found preliminary evidence that responses varied by grammatical class and gender across age groups, with implications for both theory and experimental design. By continuing data collection across the life span and making the dataset public, future work will further elucidate the development of lexical–semantic networks from early childhood onward.

Keywords: semantic development, lexical–semantic networks, free association, paradigmatic relationships

Adult word knowledge is organized into a web of relations such that when we hear a word, related words come to mind. For example, when we hear "summer," we automatically activate words like *winter* and *vacation*. This spreading activation through the structure of our lexicon allows us to generate related words, sentences, and concepts quickly and accurately (Collins & Loftus, 1975; McNamara, 2005). Although researchers have long studied the structure of adult lexical–semantic knowledge, we are just beginning to understand how this structure develops in infancy and childhood (see Wojcik, 2018 for a review).

Behavioral experiments across several tasks (e.g., free association word production and forced-choice pointing) have provided evidence that between the ages of 6 and 9 years, lexical associations for nouns, verbs, and adjectives shift from primarily syntagmatic to paradigmatic (McNeill, 1963; Nelson, 1977; Nelson & Nelson, 1990; Palermo, 1971; Smiley & Brown, 1979). *Syntagmatic relations* are between words that are syntactically adjacent (e.g., *summer–vacation*), related thematically (e.g., *dog–leash*), or both; *paradigmatic relations* are between words from the same grammatical class, taxonomic category, or both, and thus, typically, can replace one another syntactically (e.g., *summer–winter*). Paradigmatic pairs can be antonyms, synonyms, or sub-/superordinates. There are multiple theories for why young children shift over time to the more adultlike activation of paradigmatic associates. The proposed mechanisms include conceptual reorganization, lexical reorganization, or differences in task strategy or interpretation (Nelson, 1977; Smiley & Brown, 1979; Waxman & Namy, 1997).

Although there is general consensus that the syntagmatic–paradigmatic shift occurs in the early school years, there is emerging evidence for paradigmatic relations in the infant lexicon. With children younger than 3 years of age, researchers have begun to use looking-time measures to investigate whether target word processing is affected by the presence of a related prime word that is played beforehand (see Wojcik, 2018 for a review of this type of work). Using these implicit tasks, researchers have reliably found evidence for the activation of both syntagmatic and paradigmatic relations by 24 months of age (e.g., Arias-Trejo & Plunkett, 2013; Wojcik & Saffran, 2013, 2015), and there is some recent evidence that children activate words that are paradigmatically related (e.g., *car–stroller*) at 6 months of age (Bergelson & Aslin, 2017). However, implicit semantic priming tasks have not been used with

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children over the age of 2.5 years, so it is unclear how this evidence of early paradigmatic associations relates to the production and pointing task data with children 5 years of age and older.

The lack of data about lexical–semantic relations in children aged 3 to 5 years old points to a problem for researchers investigating how word networks develop (e.g., Jardak & Byers-Heinlein, 2019; Sloutsky, Yim, Yao, & Dennis, 2017). Before investigating mechanisms, we must first describe the phenomenon of interest. The syntagmatic–paradigmatic classification system is an ideal tool to use to describe lexical–semantic development because it is broadly applicable and theory-neutral, unlike other classification systems for word relations. For example, the thematic (e.g., *dog–leash*)–taxonomic (e.g., *dog–cat*) distinction (see Murphy, 2001) is encompassed by the syntagmatic–paradigmatic distinction, but the former stems from the theory that early word relations are based on conceptual representations, and thus it ignores co-occurrence-based relations like *stand–up.* The associative–semantic distinction used in priming studies, including those with infants (Arias-Trejo & Plunkett, 2013), also overlaps with the syntagmatic–paradigmatic distinction, but because associative relations are defined by adult free association responses, and semantic relations are defined by overlapping conceptual features, pairs that are both associated and semantically related (e.g., *bunny–rabbit*) cannot be studied (see Hutchison, 2003 for a discussion of this methodological issue). More importantly, this methodological issue stems from an implicit theoretical assumption of the associative–semantic distinction, which suggests that word relations derived from free association responses are qualitatively different from word relations based on conceptual overlap. Researchers are actively investigating the representations that underlie early word networks, such as the influence of lexical co-occurrence versus conceptual similarity (Sloutsky et al., 2017), though we do not yet have a comprehensive description of lexical–semantic relations across childhood. The syntagmatic–paradigmatic distinction is a theory-neutral classification system that allows for this descriptive work.

As with the syntagmatic–paradigmatic distinction, the free association task is uniquely suited for the task of describing early lexical–semantic relations. The three main methods that have been used in this endeavor, implicit priming, forced-choice picture match, and free association, all have different task demands and contexts. First, implicit priming tasks and forced-choice tasks require researchers to choose a small number of word pairs (usually 4 to 16) that they want to investigate. For example, Arias-Trejo and Plunkett (2013) chose prime-target word pairs that were either paradigmatically related (dog-bear) or syntagmatically related (e.g., *water–bottle*) and investigated whether 2-year-old children were faster to process the target word if it was preceded by the prime.[1] Waxman and Namy (1997) created triads of a target image, a syntagmatic associate, and a paradigmatic associate, and toddlers had to match the target to one of its associates. These methods, then, are best used for testing hypotheses about specific relations rather than naturalistically exploring which relations are implicitly activated during word processing. The use of predetermined relations factors into conclusions about early lexical–semantic networks, as researchers may be missing common types of relations that simply have not been tested because of either logistical difficulties surrounding the imageability of certain associates (how do you depict adjectives or abstract nouns?) or certain pairs not being relevant to tested hypotheses.

Second, there are differences in the modality of stimuli presentation across tasks that might affect which relations are activated. For instance, some implicit priming tasks (e.g., Arias-Trejo & Plunkett, 2013) and forced-choice picture tasks (e.g., Waxman & Namy, 1997) provide both word labels and images of their referents. The presence of referent images in these latter tasks could lead to more paradigmatic responses. For example, an image of a dog could activate paradigmatically associated animals more readily than just hearing "dog" as a result of feature overlap among referents from the same category. That is, because the participant is seeing four legs, two eyes, and a tail, he or she might activate other animals with those features.

Free association tasks only provide a lexical prime cue, and participants can produce any word that they want (usually with the instruction to say the first word that comes to mind), which leads to several strengths. First, free association tasks allow researchers to capture the lexical–semantic organization of children across ages without any explicit or implicit probes of specific item associations. Thus, free association tasks result in data that has minimal experimenter bias. Second, although free association responses may be shaped by individual differences, normative data from a sample has the potential to give the best picture of the overall structure (and likely the most emergent structure given a specific age despite variability due to everyday experience). This indeed has been the case for free association tasks used with adult populations (De Deyne, Navarro, & Storms, 2013; Nelson, McEvoy, & Schreiber, 2004). In sum, the exploratory, context-free nature of free association has the unique power to provide descriptive data on the development of lexical–semantic networks that can shape future studies that can be more directed, using priming, forced-choice, and other probe-specific methods.

However, free association tasks have seldom been used with children under the age of 5 to 6 years. When used with preschool-aged children, these tasks often result in responses that are difficult to fit into the syntagmatic–paradigmatic framework, such as rhymes (Cronin, 2002) or repeating the prime with "no" beforehand (Heidenheimer, 1975; Sheng, McGregor, & Marian, 2006; see Nelson, 1977 for a discussion of task limitations with younger populations). Additionally, despite the fact that many of the earliest investigations of the shift leave theoretical room for the existence of paradigmatic associations before the age of six, particularly for nouns (Nelson, 1977; Palermo, 1971), the lack of data for younger children has led to a common misconception that younger children's word associations are purely syntagmatic. For example, Sloutsky et al. (2017) suggested that paradigmatic associations develop later, "appearing at around 6 years of age" (p. 6).

In summary, although there is evidence for a paradigmatic shift in associations at school age, infant studies have shown evidence for paradigmatic associations by 2 years of age, and researchers have not investigated word associations in children between the ages of 3 and 5 years. The free association task has the potential to bridge the gap in our understanding of lexical–semantic network development because of its ability to capture both normative data

[1] See the previous discussion of the associative–semantic terminology used in this study.

and individual differences across a wide age range. The current study aims to better understand the syntagmatic–paradigmatic shift by testing 3- to 8-year-old children in a toddler-friendly free association task. Furthermore, the current project is part of a larger undertaking to create a free, public database of association norms across early childhood, much like adult databases (De Deyne et al., 2013; Nelson et al., 2004). This database will provide descriptive data on early semantic networks that will allow researchers to test theories of language acquisition and processing across development. It will also help researchers design controlled materials for language retrieval and processing tasks with children, since association norms, much like age of acquisition and frequency, can affect reaction time and other measures (see Nelson & Goodmon, 2002).

The Current Project

The goals of the current project were to (a) develop the procedure and stimuli for a free association task with items appropriate for children as young as 3 years of age, (b) begin data collection for a database of association norms for children between the ages of 3 and 8 years of age, and (c) investigate the development of the syntagmatic–paradigmatic shift in children younger than 5 years of age. We also conducted exploratory analyses of three common measures in the adult free association literature (percentage of associations, percentage of idiosyncratic responses, and strength of associations) to generate new hypotheses about the characteristics of the development of early lexical–semantic networks.

To address the first and second goals, we chose test words based on their frequency in child speech via the Child Language Data Exchange System (CHILDES; Bååth, 2010), a corpus of transcribed child language, including speech to children. To maximize the likelihood that children in our age range would produce associations for the test words, we needed to compile a list of words that would likely be familiar to younger children. For this purpose, many studies use comprehension norms (typically based on parental report), it is possible that children have associations for words that they hear frequently before they have referential meanings for those words. For example, because of the frequent co-occurrence of certain words in speech, a child might associate the word *after* with the word *lunch*, even before the child knows what *after* means. Thus, frequency in the input, rather than comprehension rate, is a more appropriate factor to consider when creating items for experiments interested in early lexical networks. After creating a list of frequent words, we created a script for the free association task that could be used with any age, then narrowed down the words and edited the script on the basis of piloting to create a task that children both tolerated and understood.

After data collection and analysis, we formatted the data to make it easy to access by other researchers, and we created a project page to share the data via the Open Science Framework (osf.io/qat7w). The site serves as a temporary repository of the data until a user-friendly website can be created.

To address the last goal, we collected data from a predetermined sample size of 60 children (as well as 60 adults). We collected data from an approximately equal number of female and male participants to test whether there was an effect of gender on paradigmatic responses in our task. This variable was included because of evidence suggesting that girls' vocabulary development outpaces that of boys' (Bornstein & Cote, 2005; Bornstein, Hahn, & Haynes, 2004; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991), and there is some evidence that vocabulary size correlates with lexical–semantic organization (Wojcik & Werker, 2016).

Method

Participants

We collected data from 60 typically developing, English-speaking children (33 girls), aged 3 to 8 (M = 4.85 SD = 1.27). The sample size was based on the high end of previous similar sample sizes, which ranged from 24 (Sheng et al., 2006) to 59 (Cronin, 2002). Additionally, power analysis for our effect of interest (a three-group ANOVA main effect) was based on Cronin (2002), who found that a large effect size in a similar task n = 60 would give us 76% power (Faul, Erdfelder, Buchner, & Lang, 2009). Participants were recruited and tested in the community at family-friendly locations such as farmer's markets, public libraries, and children's museums, and they were compensated with a small toy. Thirty-eight additional participants were tested but were excluded due to lack of understanding of the task did not provide usable answers for at two thirds of the practice trials (16 participants), ending the study early (18 participants), not meeting our selection criteria (two participants), or experimenter error (two participants). Sixty adult participants (31 female), aged 18 to 43 (M = 21.64, SD = 3.97), were also tested. Participants were recruited from a campus student center, and they were compensated with a candy bar. Ethnicity and socioeconomic status were not queried, although the participants were sampled from a primarily White, middle-class to upper-middle class community. The experiment was approved by the Skidmore College Institutional Review Board (Project title: *Understanding How Children Learn Language*; Protocol number: 1608–528).

Materials

A pilot study was conducted (n = 12) using the 100 most frequent words spoken to children under the age of 8 (from CHILDES; Bååth, 2010). Words included in the current experiment were those that elicited a comprehensible response (as decided by a trained coder) from greater than 50% of the participants.[2] The final list of 65 words comprised 25 nouns, 17 adjectives, 12 verbs, and six additional words classified as "other" (e.g., *no*, *yes*; see Appendix A for the full stimuli list and characteristics). Words that described people, places, things, or ideas were tagged as "noun"; words that could modify nouns were tagged as "adjective," and words that described actions were tagged as "verb"; all other words were categorized as "other." A second coder tagged the words to assess reliability, and there was 97% agreement between the two coders. There were also three practice items (*book*, *hair*, and *talk*). To reduce the experiment time (based on piloting), eight orders of 32 or 33 words were created. Each list comprised a random selection of 12 to 13 nouns,

[2] Comprehensible responses were any related word (i.e., phonological or semantic neighbor) broadly construed. Negations (e.g. responding "not hungry" to the prime word *hungry*) were coded as comprehensible.

eight to nine adjectives, six verbs, and three other types of words. Each individual word appeared in four orders.

A Zoom H2n audio recorder (Zoom North America; Hauppauge, NY) was used to record each testing session. Paper scoring sheets were used to record child responses during the study. Praat software (Boersma & Weenink, 2017) was used for offline transcription and coding of audio recordings.

Procedure

Participants were randomly assigned to an order and tested individually. The two experimenters first introduced themselves and explained that they would be playing a game called "Word Blast." The first experimenter (E1) then explained the rules to the second experimenter (E2): "I'm going to say a word and you're going to say the very first word that pops into your head. There's no right or wrong answer! That's the fun part. Ready to play?" E1 then presented three practice items: *daddy*, *later*, and *light.* E2 responded *mommy*, *today*, and *heavy*, respectively, to demonstrate a range of possible relations in his or her answer.

After getting the child's assent or adult's consent, E1 conducted three practice trials with the words *book*, *hair*, and, *talk.* The same practice items were used across all orders. Participants were provided with positive feedback after each answer. The instructions were explained again if the child did not respond to any given practice trial.

After the practice trials, E1 proceeded with all the words in the assigned order. No feedback was given. If participants did not answer on any given trial, E1 repeated the instructions. During the entire session, audio was recorded, and E2 wrote down the participants' responses. Trained coders listened to the audio and transcribed each answer. It was decided before data collection that if the transcribed answer differed from the answer recorded by E2, a third party would listen to the recording to make the final decision; however, there was no disagreement, and thus this procedure was not implemented.

Tagging procedure. After transcription, researchers exported the coded information into an Excel document and tagged each response for whether it was comprehensible (usable). Responses were counted as "usable," depending on whether the answer signified the participant was doing the correct task. For example, a usable answer in response to the prime word *cat* would be "dog" or "black," whereas an unusable answer would be "I don't know," no response, or a repeat of the prime. Part of speech categories were noun, verb, adjective, onomatopoeia, and other. To code the response category, researchers were instructed to first focus only on the response of the child. However, if the word had multiple possible part of speech tags, the researcher was instructed to look to the prime word so as to decide. For example, *fall* could be a noun (season) or a verb, but if the prime word is *winter*, then researchers assumed that *fall* was a noun.

Possible response types were syntagmatic, paradigmatic, or both (e.g., *story–book*, *kitty–cat*, or *train–car*), "not X" (negation), rhyme, or other based on the relation between the prime word and the participant's response. Tagging procedures for paradigmatic–syntagmatic relations were based on Sheng et al. (2006). A response was tagged as paradigmatic if it could replace another word in a sentence and still make sense grammatically and semantically (e.g., *morning–night*, *walked–ran*), and thus could be an antonym, synonym, or sub-/supercoordinate. The response was classified as syntagmatic if the prime word and the response occurred adjacent to one another in a sentence (e.g., *play–with*, *ball–pit*) or had a thematic relation (e.g., *dog–leash*). Some responses were classified as both syntagmatic and paradigmatic, such as a child responding to *bunny* with *rabbit*. Any child's response that had a *not, no*, or *do not* before the response was classified as not X. If the experimenter word and the child's response rhymed and were not paradigmatic or syntagmatic, then researchers classified them as rhyme. Remaining responses (e.g., *towel* in response to *chair*) were classified as other.

Data preparation. All test trial responses coded as not usable (436 out of 3,900 total trials across children and adults) were excluded. The mean number of usable trials per participant was 31.71 (range = 13–33). The mean number of unusable trials was 0.70 for adults, 2.76 for older children (age range = 6–8 years), and 5.21 for younger children (age range = 3–5 years). The number of unusable trials was significantly different across age groups, $F(2, 117) = 24.39$, $p < .001$. Tukey post hoc tests found no significant difference in unusable trials between older children and adults ($p = .06$) and a significant difference between younger and older children ($p = .03$).

Across all 1,601 usable responses from the 60 children, 66 were coded as not X (M per participant = 1.10), and 191 were coded as rhymes (M per participant = 3.18), and 257 were coded as other (M per participant = 4.28). The mean number of not X responses was 0.08 for adults, 1.29 for older children, and 1.02 for younger children. Twelve of the 60 children gave one or more not X response, 10 of whom were younger children. The mean number of rhyme response was 0 for adults, 2.64 for older children, and 3.42 for younger children. Thirty-five children gave one or more rhyme response, 26 of whom were younger children. Last, the mean number of other responses was 0.92 for adults, 2.88 for older children, and 4.83 for younger children. Fifty-three children gave one or more other response, 39 of whom were younger.

To calculate the proportion of paradigmatic responses for each participant, we summed the number of responses coded as paradigmatic (including those coded as both paradigmatic and syntagmatic) and divided that number by the participant's total usable trial count.[3] This proportion was used as the dependent variable in all subsequent analyses. Participants were categorized as adult, older children (age range = 6–8 years), or younger children (age range = 3–5 years). Because of the current study's focus on the understudied population of children younger than 5 years old, there was a greater number of younger children ($n = 43$; 24 girls) than older children ($n = 17$; nine girls). Some analyses used age as a continuous variable, but analyses comparing children with adult participants used age as a categorical variable because of the absence of data between the ages of 8 and 18.

Results

Data were analyzed in R (Version 3.4.2; R Core Team, 2018). Data and analysis scripts are available on OSF (osf.io/qat7w).

[3] Based on a reviewer suggestion, we also ran the main analyses without the 65 responses coded as both paradigmatic and syntagmatic. The pattern of results remained the same and are presented in full via the analysis scripts posted on OSF (osf.io/qat7w).

After testing for homogeneity of variance (Levene's test, $p = .14$) and the normality of the residuals (Shapiro-Wilk, $p = .29$), a 3 (age: younger, older, adult) × 2 (gender: male, female) between-participants ANOVA was conducted (see Figure 1) on the proportion of paradigmatic responses. There was a significant main effect of gender, $F(1, 114) = 4.29$, $p = .04$, $\eta^2 = 0.02$, such that female participants gave a higher proportion of paradigmatic responses ($M = 0.56$, $SD = 0.27$) than did male participants ($M = 0.50$, $SD = 0.26$). There was also a significant main effect of age, $F(2, 114) = 40.87$, $p < .001$, $\eta^2 = 0.41$. The interaction between age and gender was not significant, $F(2, 114) = 1.31$, $p = .27$.

Tukey post hoc comparisons were run to explore the age effect, finding that older children gave a higher proportion of paradigmatic responses ($M = 0.52$, $SD = 0.28$) than did younger children ($M = 0.32$, $SD = 0.21$, $p = .001$), and adults gave a higher proportion of paradigmatic responses ($M = 0.69$, $SD = 0.18$) than did older children ($p = .01$). Although the interaction was not significant, it is worth noting that for female participants, there was a significant difference between younger and older children ($p = .008$) but not between older children and adults ($p = .91$); whereas, for male participants, there was not a significant difference between younger and older children ($p = .69$), but there was a significant difference between older children and adults ($p = .02$). Because the interaction was not significant, however, these comparisons should be interpreted with caution.

To further investigate the development of paradigmatic associations in childhood, we regressed the proportion of paradigmatic responses on age (as a continuous variable in years) and gender, using only the 60 child participants (see Figure 2). Overall, age and gender accounted for 16% of the variance in proportion paradigmatic responses, $F(3, 56) = 2.91$, $p = .04$, adjusted $R^2 = 0.09$. Age was a significant predictor ($\beta = 0.36$, $t = 2.18$, $p = .03$, partial $r^2 = 0.08$), such that for every 1-year increase in age, paradigmatic responses went up by 7%. Neither gender ($\beta = 0.15$, $t = 0.30$, $p = .77$, partial $r^2 = 0.06$) nor the interaction between age and gender ($\beta = -0.40$, $t = -0.79$, $p = .43$, partial $r^2 = 0.01$) were significant (see Table 1).

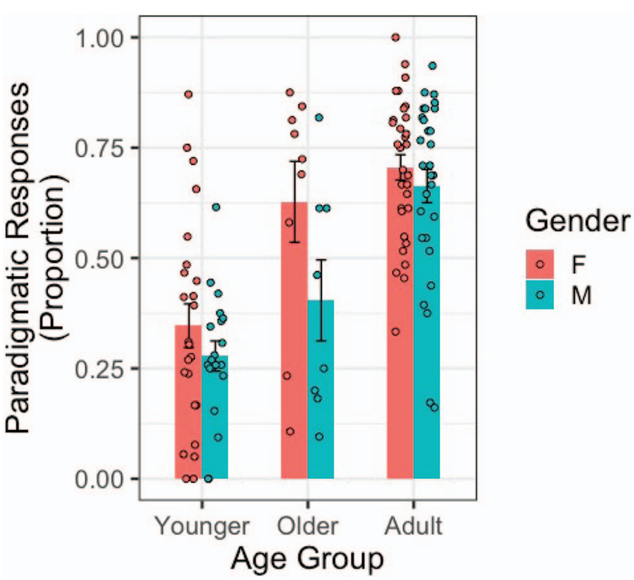

Figure 1. The proportion of paradigmatic responses by age group and gender. Points represent raw data, jittered horizontally for readability. Error bars represent one standard error from the mean. See the online article for the color version of this figure.

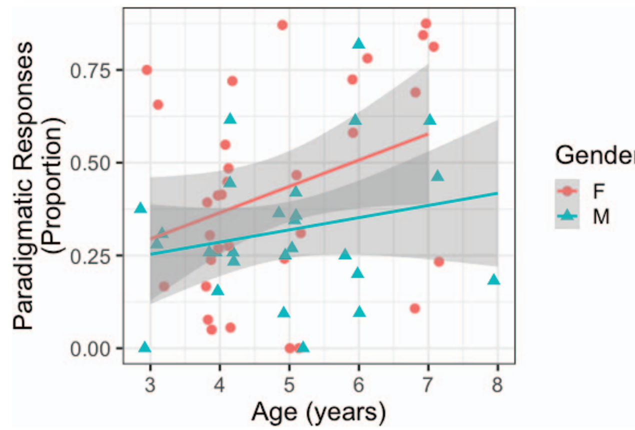

Figure 2. The proportion of paradigmatic responses by age in years for the child participants. Points represent raw data, jittered horizontally for readability. The line represents the linear regression between age and proportion of paradigmatic responses for each gender. The confidence band represents the 95% confidence interval. See the online article for the color version of this figure.

Exploratory item analyses were also run for each age group in order to test whether the proportion of paradigmatic responses was correlated with the age of acquisition of the prime words (based on MacArthur-Bates Communicative Developmental Inventory production norms; Jørgensen, Dale, Bleses, & Fenson, 2010) and the log frequency of the words in speech to children (calculated from CHILDES; Bååth, 2010). Neither age of acquisition nor frequency were correlated with proportion paradigmatic associations for the younger or older children (see Appendix B and Appendix C). However, for the adult data, the log frequency ($r[64] = .29$, $p = .020$) was positively correlated with proportion paradigmatic responses (see Appendix A).

We also explored whether there was an effect of grammatical category on the proportion of paradigmatic responses (see Figure 3). Note that three participants, all in the younger age group, were excluded from this analysis for not contributing usable data for each grammatical category. A 3(age group: younger, older, adult) × 4 (prime grammatical category: noun, adjective, verb, or other) mixed-design ANOVA revealed a significant main effect of age, $F(2, 114) = 32.91$, $p < .001$, as expected from the previous analysis. There was also a significant main effect of part of speech,

Table 1
Summary of Multiple Regression of the Proportion of Paradigmatic Responses on Age and Gender

Variable	B	SE B	β	t	p	Partial r^2
Age	.07	.03	.37	2.18	.03	.08
Gender	.07	.24	.15	.30	.77	.06
Age × Gender	−.04	.05	−.40	−.79	.43	.01

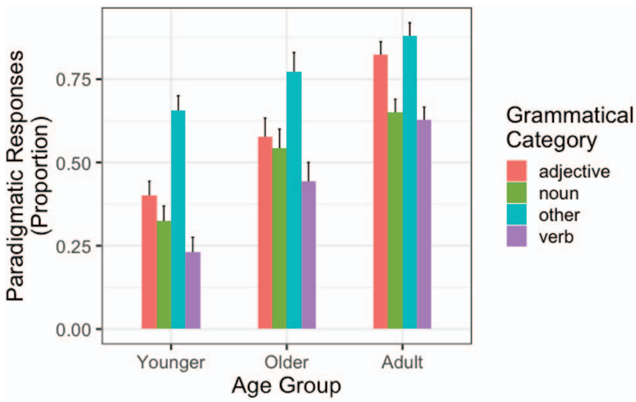

Figure 3. The proportion of paradigmatic responses by age group and grammatical category of the prime word. Error bars represent one standard error from the mean. See the online article for the color version of this figure.

$F(3, 342) = 50.42$, $p < .001$, and a significant interaction, $F(6, 342) = 2.86$, $p < .01$. Tukey post hoc analyses showed that for adults, adjectives elicited more paradigmatic responses than nouns or verbs ($ps < .001$), but not than words classified as other ($p = .90$).[4] Words classified as other elicited more paradigmatic responses than nouns or verbs ($ps < .001$). For older children, words classified as other elicited more paradigmatic responses than nouns ($p = .03$) and verbs ($p < .001$), but not more than adjectives ($p = .12$), and there were no significant differences between adjectives, verbs, and nouns. For younger children, adjectives elicited more paradigmatic responses than verbs ($p = .01$), but not nouns ($p = .86$), and words classified as other elicited more paradigmatic responses than adjectives, nouns, and verbs ($ps < .001$). In sum, for all age groups, words classified as other elicited proportionally more paradigmatic responses, and for adults only, adjectives elicited a similarly high proportion of paradigmatic responses.

Last, we explored the patterns in responses across age groups based on traditional association strength calculations (e.g., Macizo, Gómez, Ariza, & Bajo, 2000). First, for each age group, we calculated the percentage of associates for each prime word by dividing the number of responses given by two or more participants by the number of participants providing data for that prime and multiplying the result by 100. A one-way analysis of variance (ANOVA) comparing the percentage of associates across age groups found a significant effect of age group, $F(2, 170) = 36.02$, $p < .001$, $\eta^2 = 0.30$. Tukey post hoc tests found that the percentage of associates was significantly lower for adults ($M = 17.05$, $SD = 10$) than for either older ($M = 34.27$, $SD = 2.84$) or younger ($M = 31.38$, $SD = 12.73$) children ($ps < .001$). There was no significant difference between older and younger children ($p = .42$). In other words, on average, the variability in responses was higher for children than adults. However, it is notable that for both child age groups, there were some prime words for which there were no responses given by more than one child (see Appendix D).

Second, we compared the percent of idiosyncratic responses for each prime (responses given by only one participant) across age groups with a one-way ANOVA, finding a significant effect of age, $F(2, 193) = 49.85$, $p < .001$, $\eta^2 = 0.34$. Tukey post hoc comparisons revealed there was a higher proportion of idiosyncratic responses for younger children ($M = 0.64$, $SD = 0.21$) than older children ($M = 0.60$, $SD = 0.29$, $p < .001$) and for older children than adults ($M = 0.28$, $SD = 0.16$, $p < .001$).

Third, we compared the strength of the first associate for each prime (i.e., the response given by the greatest number of participants) across age groups with a one-way ANOVA, finding a significant effect of age, $F(2, 170) = 17.24$, $p < .001$, $\eta^2 = 0.17$. Tukey post hoc comparisons revealed that the first associate was significantly stronger for older children ($M = 0.89$, $SD = 0.18$) than younger children ($M = 0.74$, $SD = 0.23$; $p < .01$), but that adults' first associate had the lowest mean strength ($M = 0.64$, $SD = 0\ .25$), significantly lower than younger children ($p = .04$; see Appendix E).

Discussion

The current project represents the start of data collection for a large public database of free association norms in early childhood. Understanding how free association responses change during the preschool age range will bridge the literature on lexical–semantic development from infancy to early childhood, thus providing a description of how these networks develop. Therefore, we aimed to create a procedure and stimuli set that could be used with children as young as 3 years of age. Although we did find that adults and older children contributed more usable trials, younger children still completed an average of 27/33 trials. Notably, younger children did not, on average, provide more rhyme responses than did older children, and in fact, they provided fewer not X responses than did older children. Thus, by using frequent words in child-directed speech to develop appropriate stimuli for a younger age group, we successfully collected free association data from children under 5 years of age. The current complete dataset can be found on the Open Science Framework (osf.io/qat7w), and data collection is ongoing in order to build a larger database that can be used by researchers to both test novel hypotheses as well as design developmental studies that aim to control for associations between items.

In addition to creating an age-appropriate stimuli list and word association database, we also aimed to investigate the syntagmatic–paradigmatic shift in children younger than 5 years of age in order to clarify the early developmental trajectory of lexical–semantic networks along this dimension. By creating a shorter, age-appropriate stimuli list, we were able to demonstrate that paradigmatic responses are present at ages three to four, before the canonical school-age paradigmatic shift. There was also a significant increase in the proportion of paradigmatic responses from ages 3 to 5 to ages 6 to 8. Furthermore, age significantly predicted proportion paradigmatic responses when treated as a continuous variable, suggesting a linear increase in paradigmatic associations that begins before school age.

Although it is unlikely that we will be able to test children 2 years of age and younger in the task due to the cognitive and language production demands, the current studies shed some light on the emergence of paradigmatic relations in lexical–semantic networks. In the current study, 3- to 5-year-old children provided paradigmatic associations for 31% of items on average, compared

[4] There were six prime words classified as other: *morning*, *first*, *today*, *tomorrow*, *no*, and *yes*.

with 52% for 6- to 8-year-old children and 69% for adults. Thus, although young children do not produce as many paradigmatic responses as older children and adults, consistent with the idea of a paradigmatic shift across childhood (Nelson, 1977), paradigmatic responses are present across grammatical classes in children as young as three years, consistent with infant priming studies that find early evidence for paradigmatic associations in lexical–semantic networks (Wojcik, 2018).

One could conclude that the lower percentage of paradigmatic responses for the younger children contradicts the evidence of paradigmatic relation priming in infant implicit priming tasks (e.g., Arias-Trejo & Plunkett, 2013). It is first worth noting that in the Arias-Trejo and Plunkett (2013) data, the priming effect for paradigmatic trials was quantitatively smaller than that for syntagmatic trials. Additionally, although young children in the current study produced an average of 31% paradigmatic responses (not 0%), just because a child's first response is not paradigmatic in a free association task does not mean that a paradigmatic link does not exist (see Waxman & Namy, 1997 for a related argument). A strength of the free association method is that it allows us to expose the most salient lexical–semantic links for children rather than simply testing whether specific relations are activated in specific contexts, as priming and forced-choice tasks do. Indeed, it is possible that particularly when connections are sparse in the early lexicon and inhibitory mechanisms are underdeveloped (Huang & Snedeker, 2011; Luna, 2009), children are less affected by context and top-down strategies. Thus, responses in the free association task for young children, in particular, may provide us with a window into the nearest association in the network, rather than a task or context-specific response that may be a result of a longer, more directed search. Our results thus suggest that while early lexical–semantic networks include paradigmatic associations, perhaps the strongest links for many early words are syntagmatic (see Sloutsky et al., 2017 for a similar argument). Likewise, the higher percentage of paradigmatic responses in adults does not suggest that syntagmatic links do not exist, but perhaps that they are weaker.

It is also worth noting that for children, adjectives did not elicit more paradigmatic responses than nouns. This finding is at odds with previous free association data from 5- and 6-year-old children which found that for the younger age group, adjectives elicited the highest proportion of paradigmatic responses, perhaps due to canonical antonym relations (e.g., *good–bad*, *big–small*) for this grammatical class (Cronin, 2002). However, in the current study, across age groups, words that were neither nouns, verbs, nor adjectives elicited the highest proportion of paradigmatic responses. There were only six prime words in the other group: *morning*, *first*, *today*, *tomorrow*, *no*, and *yes*. Like adjectives, each of these words has one primary antonym: *morning–night*, *first–last*, *today–tomorrow*, *no–yes.* The high proportion of paradigmatic responses for these words supports the hypothesis that antonymy is an early organizational feature of the lexicon, but it may be that that the antonymic relations for adjectives are still developing throughout early childhood.

The high proportion of paradigmatic responses for the six words categorized as other also suggests that researchers should broaden their focus beyond nouns, verbs, and adjectives when investigating the early lexicon. Forced-choice and free association tasks tend to focus on these three categories (e.g., Cronin, 2002; Waxman & Namy, 1997), and infant priming studies have typically only used noun stimuli (e.g., Arias-Trejo & Plunkett, 2013). The current findings suggest that in order to better understand lexical–semantic structure, researchers should study all types of words, not just imageable nouns and verbs.

The presence of paradigmatic responses even in the youngest age group, and particularly to words were not classified as nouns, adjectives, or verbs, does not in and of itself speak to the associations, representations, and experiences that underlie these associations. Although early paradigmatic relations may result from links based on conceptual similarity (see, e.g., Wojcik & Saffran, 2013), it is possible that some early paradigmatic relations may arise from co-occurrences in speech to children (see Sloutsky et al., 2017; Wojcik & Saffran, 2015). For example, if children participate in activities, such as book reading, that focus on opposites, they will hear those opposite word labels close together in time, potentially leading to a label–label association. One strength of using the paradigmatic–syntagmatic distinction to understand changes in word associations is that it is theory-neutral. By first describing changes in lexical–semantic association, we hope that this work will provide a foundation for future work to tease out the mechanisms, such as co-occurrence statistics or feature overlap, that underlie trajectories that the current data present.

Our last major finding is that in our exploratory analyses of the distribution of responses, there was a linear pattern such that older participants gave more homogeneous answers: The percentage of idiosyncratic answers and the percentage of associates (conceptually, the number of more common responses) decreased from the youngest group to adulthood. Interestingly, in their free association data with 8- to 13-year-old children and adults, Macizo et al. (2000) found a peak in idiosyncratic responses and percentage of associates at 11 to 13 years of age before reaching their lowest points in adulthood. Although the magnitude of the percentages cannot be compared across data sets because of differences in the stimuli lists and language, the combined data patterns suggest that there are multiple peaks and troughs in the variability of responses across development. It is possible, for example, that variability dips when children enter school and begin to participate in more standardized activities, before picking up again during adolescence as leisure activities become more varied. It is also possible that as vocabulary size grows, the characteristics of the network shift nonlinearly due to changes in the strength and number of associations. We will continue to collect data across the life span, expanding the stimuli list for older ages, to better understand the full developmental picture.

However, our preliminary evidence for higher variability in responses for younger children suggests that younger children have more idiosyncratic lexical–semantic networks, with implications for both theories of semantic network development and experimental design. For example, recent work suggests that words are more likely to be acquired if they have many semantic associates (Hills, Maouene, Riordan, & Smith, 2010). If children have more variable networks than adults, there may be idiosyncratic attractor spaces in early networks that could have cascading effects on vocabulary structure. In terms of experimental design, researchers interested in early semantic relations may want to customize study materials for each participant.

As more data is collected for the public database, we hope to better understand the variability across items in the syntagmatic–

paradigmatic shift. The fact that both age of acquisition and frequency were positively correlated with the proportion of paradigmatic responses in the adult data is notable and consistent with prior work (e.g., Steyvers & Tenenbaum, 2005). However, exploratory item analyses of the child data did not yield significant correlations between either of those word characteristics and the proportion of paradigmatic responses. It is possible, though, that by testing items with a greater range in frequency, a correlation would emerge. Words that are more frequent may have deeper conceptual meanings for children or may appear in sentence frames that result in paradigmatic associations (see Asr, Willits, & Jones, 2016, for a co-occurrence based model of semantic development). Indeed, if this is the case, by choosing very frequent words, we may have inflated the proportion of paradigmatic responses. As the database grows, future analyses should further examine possible predictors of paradigmatic response by item and test a wider range of items.

In addition to item effects, future studies should also continue to explore variability across children in the syntagmatic–paradigmatic shift. We did not find a significant interaction between age and gender, however, exploratory post hoc analyses suggest that girls may shift to paradigmatic responses earlier than boys. We found that while the largest increase in paradigmatic responses for girls was between the younger and older age group, for boys it was from the older children to adult age group. These findings should be interpreted with caution due to the lack of a significant interaction in the omnibus ANOVA, however, future experiments should continue to test for gender differences. One possibility is that age is a proxy for vocabulary size in the current and other experiments on the syntagmatic–paradigmatic shift. If that is the case, then an earlier shift for girls may be explained by the fact that girls tend to have larger vocabularies in early childhood than boys (Bornstein & Cote, 2005; Bornstein et al., 2004; Huttenlocher et al., 1991). We did not collect vocabulary data for the current studies, and so this hypothesis will be tested in future experiments.

By selecting age-appropriate stimuli, the current project is one of the first to collect free association data for children between the ages of three and five. Our data suggest that the shift from syntagmatic to paradigmatic associations may begin earlier than previously thought and also that paradigmatic associations are present in lexical–semantic networks across early childhood. We also found evidence for early variability in associations, as well as differences in associations by grammatical class and gender that have implications for theory and experimental design. Data collection with these stimuli will continue with the eventual goal of creating a large public database of free association data. We hope that as the database grows, future analyses will continue to shed light on the trajectory of lexical–semantic networks across early childhood, for both individual words and individual children.

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(*Appendices follow*)

Appendix A

Paradigmatic Response Proportions for Adults by Prime With Prime Word Characteristics

Paradigmatic proportion	Prime	Grammatical category	AoA (months)	Frequency (log)	*n*
.96	BOY	noun	19.92	3.44	28
.96	TOMORROW	other	29.25	2.87	28
.96	BIG	adjective	20.60	3.66	26
.93	WHITE	adjective	26.65	2.80	27
.90	AFTER	adjective	29.35	3.12	31
.90	MAN	noun	21.79	3.30	30
.89	COLD	adjective	18.88	2.93	28
.89	GIVE	verb	25.23	3.49	28
.89	HOT	adjective	15.58	2.90	28
.89	TIGER	noun	22.53	3.02	28
.89	FIRST	other	26.94	3.30	27
.88	BETTER	adjective	25.51	3.34	32
.88	CAT	noun	17.72	3.01	32
.88	YES	other	18.09	3.93	32
.86	BAD	adjective	22.66	2.99	28
.85	NEW	adjective	27.09	3.12	27
.85	OPEN	verb	21.11	3.11	27
.85	FIX	verb	22.71	2.88	26
.84	NO	other	14.38	4.31	25
.84	TODAY	other	29.22	3.37	31
.82	OLD	adjective	29.29	3.01	33
.81	GOOD	adjective	21.73	3.97	27
.81	OUTSIDE	noun	18.37	2.99	32
.81	STOP	verb	22.22	3.02	32
.81	DINNER	noun	21.86	2.92	31
.79	RED	adjective	22.60	3.09	28
.78	GREEN	adjective	24.41	3.03	27
.77	NIGHT	noun	22.46	3.15	31
.77	STAND	verb	25.56	2.81	31
.76	HARD	adjective	27.60	3.01	33
.74	MORNING	other	24.86	3.13	31
.73	WASH	verb	21.77	2.79	26
.72	LUNCH	noun	22.73	2.87	25
.70	KITTY	noun	15.33	2.64	30
.70	RUN	verb	22.22	2.79	33
.68	WALK	verb	21.00	2.86	28
.68	HAPPY	adjective	22.40	2.79	31
.67	FIND	verb	24.69	3.25	30
.67	STORY	noun	22.82	3.05	27
.66	DOG	noun	13.91	3.18	32
.66	HAND	noun	18.84	3.11	32
.65	MOUTH	noun	18.35	3.03	26
.65	DIRTY	adjective	19.00	2.76	31
.65	PRETTY	adjective	21.45	3.21	31
.65	SIT	verb	18.94	3.45	31
.63	LONG	adjective	29.80	3.14	32
.56	TRAIN	noun	19.80	2.96	32
.54	SING	verb	24.05	2.81	26
.53	TABLE	noun	22.26	3.15	32
.52	HOUSE	noun	21.73	3.49	27
.52	NOSE	noun	16.13	2.95	27
.48	SOCK	noun	17.16	2.39	31
.44	CHAIR	noun	19.00	3.12	27
.43	PAPER	noun	21.00	3.03	28
.42	COW	noun	18.60	2.82	33
.42	EAT	verb	18.51	3.60	26
.40	FOOD	noun	22.57	2.79	25

(*Appendices continue*)

Appendix A (*continued*)

Paradigmatic proportion	Prime	Grammatical category	AoA (months)	Frequency (log)	*n*
.38	CUP	noun	18.29	2.93	26
.38	FALL	verb	21.52	2.96	32
.38	MILK	noun	18.15	3.14	32
.36	PICTURE	noun	22.69	2.94	25
.35	CLOSE	verb	24.33	2.84	31
.33	HURT	verb	23.16	3.00	30
.32	RIDE	verb	21.77	2.94	25
.31	DRAW	verb	24.80	2.80	32
.00	HORSE	noun	18.56	2.97	1

Note. Paradigmatic proportion is calculated across all adult participants. AoA = age of acquisition based on MacArthur-Bates Communicative Developmental Inventory (MBCDI) production norms (Jørgensen, Dale, Bleses, & Fenson, 2010); log frequency is calculated from the CHILDES database of speech to children (Bååth, 2010). For grammatical category, words that described people, places, things, or ideas were tagged as "noun"; words that could modify nouns were tagged as "adjective," and words that described actions were tagged as "verb"; all other words were categorized as "other."

Appendix B

Paradigmatic Response Proportions for Younger Children (3 to 5 Years Old) by Prime With Prime Word Characteristics

Paradigmatic proportion	Prime	Grammatical category	AoA (months)	Frequency (log)	*n*
.85	YES	other	18.09	3.93	13
.77	TODAY	other	29.22	3.37	22
.75	MORNING	other	24.86	3.13	16
.72	KITTY	noun	15.33	2.64	18
.70	OPEN	verb	21.11	3.11	20
.67	NO	other	14.38	4.31	18
.65	BOY	noun	19.92	3.44	17
.60	HAPPY	adjective	22.40	2.79	15
.56	FIRST	other	26.94	3.30	16
.56	OUTSIDE	noun	18.37	2.99	16
.56	TOMORROW	other	29.25	2.87	18
.52	BIG	adjective	20.60	3.66	21
.50	COLD	adjective	18.88	2.93	18
.50	DOG	noun	13.91	3.18	18
.50	GREEN	adjective	24.41	3.03	18
.50	RED	adjective	22.60	3.09	16
.50	STORY	noun	22.82	3.05	16
.47	LONG	adjective	29.80	3.14	19
.47	DIRTY	adjective	19.00	2.76	15
.44	OLD	adjective	29.29	3.01	16
.43	CAT	noun	17.72	3.01	21
.41	TIGER	noun	22.53	3.02	17
.40	DINNER	noun	21.86	2.92	15
.38	CLOSE	verb	24.33	2.84	16
.38	HOT	adjective	15.58	2.90	16
.33	NOSE	noun	16.13	2.95	18
.33	TABLE	noun	22.26	3.15	18
.32	AFTER	adjective	29.35	3.12	19
.32	MAN	noun	21.79	3.30	19
.32	WHITE	adjective	26.65	2.80	19
.31	HARD	adjective	27.60	3.01	16
.29	BAD	adjective	22.66	2.99	17
.29	RUN	verb	22.22	2.79	17
.29	STOP	verb	22.22	3.02	17
.29	FOOD	noun	22.57	2.79	14

(*Appendices continue*)

Appendix B (*continued*)

Paradigmatic proportion	Prime	Grammatical category	AoA (months)	Frequency (log)	*n*
.26	MOUTH	noun	18.35	3.03	19
.25	LUNCH	noun	22.73	2.87	16
.24	NIGHT	noun	22.46	3.15	21
.24	GOOD	adjective	21.73	3.97	17
.24	HAND	noun	18.84	3.11	17
.24	NEW	adjective	27.09	3.12	17
.23	TRAIN	noun	19.80	2.96	22
.22	FALL	verb	21.52	2.96	18
.22	MILK	noun	18.15	3.14	18
.22	SIT	verb	18.94	3.45	18
.19	DRAW	verb	24.80	2.80	16
.19	GIVE	verb	25.23	3.49	16
.19	RIDE	verb	21.77	2.94	16
.18	COW	noun	18.60	2.82	22
.18	SING	verb	24.05	2.81	17
.17	SOCK	noun	17.16	2.39	12
.15	PAPER	noun	21.00	3.03	13
.15	STAND	verb	25.56	2.81	13
.15	CUP	noun	18.29	2.93	20
.14	WALK	verb	21.00	2.86	14
.13	FIX	verb	22.71	2.88	15
.13	BETTER	adjective	25.51	3.34	16
.13	WASH	verb	21.77	2.79	16
.11	FIND	verb	24.69	3.25	18
.07	HURT	verb	23.16	3.00	15
.06	PICTURE	noun	22.69	2.94	18
.06	PRETTY	adjective	21.45	3.21	18
.05	CHAIR	noun	19.00	3.12	19
.05	HOUSE	noun	21.73	3.49	19
.00	EAT	verb	18.51	3.60	16

Note. Paradigmatic proportion is calculated across all younger participants. AoA = age of acquisition based on MacArthur-Bates Communicative Developmental Inventory (MBCDI) production norms (Jørgensen et al., 2010); log frequency is calculated from the CHILDES database of speech to children (Bååth, 2010). For grammatical category, words that described people, places, things, or ideas were tagged as "noun"; words that could modify nouns were tagged as "adjective," and words that described actions were tagged as "verb"; all other words were categorized as "other."

Appendix C

Paradigmatic Response Proportions for Older Children (6 to 8 Years Old) by Prime With Prime Word Characteristics

Paradigmatic proportion	Prime	Grammatical category	AoA (months)	Frequency (log)	*n*
1.00	BIG	adjective	20.60	3.66	4
1.00	OUTSIDE	noun	18.37	2.99	8
.89	BOY	noun	19.92	3.44	9
.88	KITTY	noun	15.33	2.64	8
.88	STAND	verb	25.56	2.81	8
.86	FIRST	other	26.94	3.30	7
.83	GREEN	adjective	24.41	3.03	6
.83	TODAY	other	29.22	3.37	6
.80	HAPPY	adjective	22.40	2.79	10
.80	MORNING	other	24.86	3.13	10
.75	FIND	verb	24.69	3.25	8
.75	OPEN	verb	21.11	3.11	8
.75	TOMORROW	other	29.25	2.87	8
.75	WHITE	adjective	26.65	2.80	4

(*Appendices continue*)

Appendix C (*continued*)

Paradigmatic proportion	Prime	Grammatical category	AoA (months)	Frequency (log)	*n*
.73	YES	other	18.09	3.93	11
.71	COLD	adjective	18.88	2.93	7
.70	HARD	adjective	27.60	3.01	10
.70	OLD	adjective	29.29	3.01	10
.70	SIT	verb	18.94	3.45	10
.67	DINNER	noun	21.86	2.92	9
.67	DOG	noun	13.91	3.18	6
.67	HOT	adjective	15.58	2.90	6
.67	RUN	verb	22.22	2.79	6
.67	STORY	noun	22.82	3.05	6
.67	TABLE	noun	22.26	3.15	9
.63	AFTER	adjective	29.35	3.12	8
.63	BETTER	adjective	25.51	3.34	8
.63	CAT	noun	17.72	3.01	8
.63	DIRTY	adjective	19.00	2.76	8
.63	MILK	noun	18.15	3.14	8
.63	RED	adjective	22.60	3.09	8
.60	FOOD	noun	22.57	2.79	5
.60	NO	other	14.38	4.31	5
.57	MAN	noun	21.79	3.30	7
.50	BAD	adjective	22.66	2.99	8
.50	CUP	noun	18.29	2.93	6
.50	HAND	noun	18.84	3.11	8
.50	LUNCH	noun	22.73	2.87	6
.50	MOUTH	noun	18.35	3.03	6
.50	NIGHT	noun	22.46	3.15	6
.50	NOSE	noun	16.13	2.95	8
.50	TIGER	noun	22.53	3.02	8
.44	WALK	verb	21.00	2.86	9
.43	GOOD	adjective	21.73	3.97	7
.40	COW	noun	18.60	2.82	10
.40	HOUSE	noun	21.73	3.49	5
.40	LONG	adjective	29.80	3.14	10
.38	SING	verb	24.05	2.81	8
.38	TRAIN	noun	19.80	2.96	8
.33	CLOSE	verb	24.33	2.84	9
.33	EAT	verb	18.51	3.60	6
.33	HURT	verb	23.16	3.00	6
.33	SOCK	noun	17.16	2.39	6
.33	STOP	verb	22.22	3.02	6
.33	WASH	verb	21.77	2.79	6
.29	RIDE	verb	21.77	2.94	7
.25	GIVE	verb	25.23	3.49	8
.22	CHAIR	noun	19.00	3.12	9
.22	PAPER	noun	21.00	3.03	9
.17	FALL	verb	21.52	2.96	6
.17	NEW	adjective	27.09	3.12	6
.13	FIX	verb	22.71	2.88	8
.11	DRAW	verb	24.80	2.80	9
.00	PICTURE	noun	22.69	2.94	2
.00	PRETTY	adjective	21.45	3.21	8

Note. Paradigmatic proportion is calculated across all younger participants. AoA = age of acquisition based on MacArthur-Bates Communicative Developmental Inventory (MBCDI) production norms (Jørgensen et al., 2010); log frequency is calculated from the CHILDES database of speech to children (Bååth, 2010). For grammatical category, words that described people, places, things, or ideas were tagged as "noun"; words that could modify nouns were tagged as "adjective," and words that described actions were tagged as "verb"; all other words were categorized as "other."

(*Appendices continue*)

Appendix D

Percentage of Associates for Each Prime by Age Group

Prime	Younger	Older	Adult
after	33.33	20.00	8.70
bad	50.00	33.33	4.35
better	—	50.00	13.79
big	11.11	50.00	9.09
boy	10.00	12.50	4.00
cat	27.27	40.00	7.41
chair	37.50	50.00	16.67
close	20.00	50.00	42.86
cold	30.77	40.00	11.54
cow	41.67	50.00	25.00
cup	30.00	50.00	30.00
dinner	28.57	33.33	18.52
dirty	28.57	20.00	9.52
dog	14.29	50.00	8.70
draw	40.00	33.33	42.11
eat	—	50.00	27.27
fall	33.33	—	28.57
find	50.00	50.00	38.89
first	22.22	33.33	8.00
fix	40.00	—	26.67
food	40.00	—	31.25
give	—	—	14.29
good	33.33	33.33	10.00
green	27.27	40.00	19.05
hand	33.33	50.00	23.81
happy	22.22	12.50	8.70
hard	33.33	28.57	8.70
hot	28.57	25.00	7.41
house	20.00	—	23.08
hurt	50.00	—	27.27
kitty	16.67	20.00	16.67
long	12.50	25.00	5.56
lunch	27.27	—	23.81
man	42.86	50.00	8.00
milk	40.00	33.33	27.27
morning	18.18	16.67	22.73
mouth	50.00	50.00	33.33
new	33.33	—	4.35
night	33.33	33.33	12.00
no	9.09	33.33	5.00
nose	42.86	—	27.78
old	33.33	28.57	8.00
open	13.33	25.00	4.35
outside	11.11	14.29	10.71
paper	50.00	—	31.58
picture	—	—	31.58
pretty	33.33	—	15.00
red	50.00	33.33	13.64
ride	50.00	—	23.53
run	42.86	33.33	19.23
sing	—	—	23.53
sit	40.00	16.67	13.04
sock	50.00	50.00	16.67
stand	25.00	16.67	8.70
stop	40.00	—	4.76
story	20.00	33.33	10.00
table	33.33	16.67	16.67

(*Appendices continue*)

Appendix D (*continued*)

Prime	Younger	Older	Adult
tiger	25.00	—	20.00
today	7.14	25.00	12.50
tomorrow	20.00	25.00	16.00
train	50.00	50.00	29.41
walk	33.33	40.00	15.00
wash	50.00	50.00	14.29
white	33.33	—	4.35
yes	9.09	20.00	4.17

Note. Percentages were calculated by dividing the number of responses given by two or more participants by the total number of participants providing data for that prime and multiplying the result by 100. Thus, the more variable the responses, the higher the percentage. Dashes indicate that there were no responses given by two or more participants for that age group.

Appendix E

Association Strength for Top Two Associates by Age Group

Prime (assoc. #)	Younger (associate, strength)	Older (associate, strength)	Adult (associate, strength)
after (1)	before, .67	before, 1	before, .78
after (2)	afternoon, .33	—	later, .22
bad (1)	sad, 1	good, 1	good, 1
better (1)	—	worse, 1	worse, .59
better (2)	—	—	worst, .21
big (1)	small, 1	small, 1	small, .77
big (2)	—	—	little, .23
boy (1)	girl, 1	girl, 1	girl, 1
cat (1)	dog, .64	dog, .60	dog, .93
cat (2)	hat, .18	bat, .40	meow, .07
chair (1)	hair, .38	grass, 1	sit, .50
chair (2)	sit, .38	—	seat, .28
close (1)	open, 1	nose, .50	far, .21
close (2)	—	open, .50	shoes, .21
cold (1)	hot, .38	hot, .6	hot, .69
cold (2)	warm, .31	warm, .4	warm, .19
cow (1)	milk, .25	cat, .50	milk, .38
cow (2)	moo, .25	horse, .50	moo, .21
cup (1)	drink, .60	mug, 1	water, .35
cup (2)	milk, .20	—	drink, .25
dinner (1)	lunch, .57	breakfast, .50	lunch, .56
dinner (2)	eat, .43	lunch, .50	breakfast, .15
dirty (1)	clean, .71	clean, 1	clean, .90
dirty (2)	not dirty, .29	—	mommy, .1
dog (1)	cat, 1	cat, 1	cat, .91
dog (2)	—	—	love, .09
draw (1)	color, .60	color, 1	write, .21
draw (2)	paper, .40	—	picture, .16
eat (1)	—	drink, 1	drink, .27
eat (2)	—	—	food, .27
fall (1)	winter, .67	—	down, .50
fall (2)	leaves, .33	—	spring, .21
find (1)	hunt, .50	lose, .50	look, .22
find (2)	ok, .50	lost, .50	lose, .17
first (1)	second, .56	second, .67	last, .68
first (2)	last, .44	last, .33	second, .32
fix (1)	mix, .60	—	break, .40
fix (2)	hammer, .4	—	broken, .33

(*Appendices continue*)

Appendix E (*continued*)

Prime (assoc. #)	Younger (associate, strength)	Older (associate, strength)	Adult (associate, strength)
food (1)	eat, .60	—	eat, .50
food (2)	plate, .40	—	drink, .12
give (1)	—	—	take, .76
give (2)	—	—	get, .14
good (1)	bad, 1	bad, 1	bad, .90
good (2)	—	—	better, .10
green (1)	blue, .45	blue, .60	yellow, .48
green (2)	grass, .36	red, .40	blue, .29
hand (1)	chicken, 1	foot, 1	foot, .48
hand (2)	—	—	finger, .14
happy (1)	sad, .78	sad, 1	sad, .78
happy (2)	mad, .22	—	smile, .22
hard (1)	soft, .67	easy, .57	soft, .70
hard (2)	not hard, .33	soft, .43	easy, .30
hot (1)	cold, .71	cold, 1	cold, .93
hot (2)	stop, .29	—	tea, .07
house (1)	mouse, 1	—	home, .62
house (2)	—	—	car, .23
hurt (1)	book, .50	—	pain, .45
hurt (2)	not hurt, .50	—	injure, .27
kitty (1)	dog, .58	cat, 1	cat, .62
kitty (2)	cat, .42	—	doggy, .17
long (1)	short, 1	short, 1	short, 1
lunch (1)	eat, .45	—	dinner, .43
lunch (2)	dinner, .36	—	food, .24
man (1)	girl, .43	woman, 1	woman, .92
man (2)	can, .29	—	women, .08
milk (1)	water, .60	water, 1	cow, .45
milk (2)	drink, .40	—	water, .36
morning (1)	night, .82	night, 1	night, .41
morning (2)	afternoon, .18	—	afternoon, .32
mouth (1)	house, .50	talk, 1	teeth, .21
mouth (2)	teeth, .50	—	eat, .17
new (1)	old, 1	—	old, 1
night (1)	morning, 1	morning, 1	day, .76
night (2)	—	—	morning, .16
no (1)	yes, 1	yes, 1	yes, 1
nose (1)	mouth, .43	—	mouth, .33
nose (2)	eyes, .29	—	smell, .33
old (1)	new, .50	young, .71	young, .64
old (2)	young, .50	new, .29	new, .36
open (1)	close, .87	close, 1	close, 1
open (2)	door, .13	—	—
outside (1)	inside, 1	inside, 1	inside, .86
outside (2)	—	—	nature, .07
paper (1)	cut, .50	—	plastic, .32
paper (2)	draw, .50	—	pen, .21
picture (1)	—	—	frame, .37
picture (2)	—	—	photo, .21
pretty (1)	not pretty, 1	—	ugly, .60
pretty (2)	—	—	beautiful, .30
red (1)	pink, 1	blue, .67	blue, .82
red (2)	—	bed, .33	color, .09
ride (1)	side, 1	—	horse, .47
ride (2)	—	—	car, .29
run (1)	sun, .43	walk, 1	walk, .62
run (2)	fast, .29	—	fast, .12
sing (1)	—	—	song, .35
sing (2)	—	—	dance, .29

(*Appendices continue*)

Appendix E (*continued*)

Prime (assoc. #)	Younger (associate, strength)	Older (associate, strength)	Adult (associate, strength)
sit (1)	stand, .60	stand, 1	stand, .61
sit (2)	down, .40	—	down, .30
sock (1)	walk, 1	shoe, 1	shoe, .46
sock (2)	—	—	foot, .38
stand (1)	sit, 1	sit, 1	sit, .91
stand (2)	—	—	up, .09
stop (1)	go, .60	—	go, 1
stop (2)	op, .40	—	—
story (1)	book, .80	book, 1	book, .90
story (2)	read, .20	—	teller, .10
table (1)	chair, .67	chair, 1	chair, .78
table (2)	eat, .33	—	cloth, .11
tiger (1)	lion, .62	—	lion, .60
tiger (2)	roar, .38	—	cat, .20
today (1)	tomorrow, 1	tomorrow, 1	tomorrow, .75
today (2)	—	—	yesterday, .17
tomorrow (1)	today, .80	today, 1	today, .60
tomorrow (2)	yesterday, .20	—	later, .16
train (1)	choo choo, 1	car, 1	car, .35
train (2)	—	—	bus, .29
walk (1)	talk, .67	run, .60	run, .65
walk (2)	run, .33	talk, .40	talk, .25
wash (1)	water, 1	clean, 1	clean, .52
wash (2)	—	—	dry, .33
white (1)	black, .67	—	black, 1
white (2)	fright, .33	—	—
yes (1)	no, 1	no, .80	no, 1
yes (2)	—	nes, .20	—

Note. Dashes indicate that there were no responses given by two or more participants for that age group.

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