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Disentangling the roles of age and knowledge in early language acquisition: A fine-grained analysis of the vocabularies of infant and child language learners

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ABSTRACT

The words that children learn change over time in predictable ways. The first words that infants acquire are generally ones that are both frequent and highly imageable. Older infants also learn words that are more abstract and some that are less common. It is unclear whether this pattern is attributable to maturational factors (i.e., younger children lack sufficiently developed cognitive faculties needed to learn abstract words) or linguistic factors (i.e., younger children lack sufficient knowledge of their language to use grammatical or contextual cues needed to figure out the meaning of more abstract words). The present study explores this question by comparing vocabulary acquisition in 53 preschool-aged children (M = 51 months, range = 30–76 months) who were adopted from China and Eastern Europe after two and half years of age and 53 vocabulary-matched infant controls born and raised in English speaking families in North America (M = 24 months, range = 16–33 months). Vocabulary was assessed using the MB-CDI Words and Sentences form, word frequency was estimated from the CHILDES database, and imageability was measured using adult ratings of how easily words could be pictured mentally. Both groups were more likely to know words that were both highly frequent and imageable (resulting in an over-additive interaction). Knowledge of a word was also independently affected by the syntactic category that it belongs to. Adopted preschoolers' vocabulary was slightly less affected by imageability. These findings were replicated in a comparison with a larger sample of vocabulary-matched controls drawn from the MB-CDI norming study (*M* = 22 months, range = 16–30 months; 33 girls). These results suggest that the patterns of acquisition in children's early vocabulary are primarily driven by the accrual of linguistic knowledge, but that vocabulary may also be affected by differences in early life experiences or conceptual knowledge.

1. Introduction

A central challenge for theories of language development is understanding why children learn what they do, when they do. Children differ greatly in their interests, personalities, and early life experiences, yet there is a remarkable degree of consistency in the paths by which they acquire language, including which words are learned earlier and which are learned later (Fenson et al., 1994; Gentner & Boroditsky, 2001; Hansen, 2017; Swingley & Humphrey, 2018; Smolík, 2019; Braginsky et al., 2019; Coffey et al., 2024). Snedeker, Geren, & Shafto (2007) describe two broad classes of explanations for these patterns and shifts.

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Developmental theories attribute changes in children's language to biological maturation and/or broader changes in their cognitive abilities that are independent of their experience with a particular language (Lenneberg, 1967; Cromer, 1974; Gleitman, 1981; Shore, O'Connell, & Bates, 1984; Wexler, 1999). Under these theories, language development proceeds similarly across individuals because the youngest children face cognitive constraints that limit what they can learn. As these constraints are lifted (due to processes that are independent of language learning *per se*), children are able to learn words for more diverse concepts and create longer utterances resulting in the signature patterns and stages of early language development.

Contingent-acquisition theories, in contrast, attribute qualitative changes in children's language to their cumulative knowledge of, and experience with, the specific language they are acquiring (Gleitman, 1990; Bates & Goodman, 1997; Gillette et al., 1999; Snedeker & Gleitman, 2004; Conboy & Thal, 2006; Kachergis, Marchman & Frank, 2022). From this perspective, a language is a puzzle that is solved in essentially the same way by children across a wide range of ages. Some parts of the puzzle can be solved early, with no prior knowledge of the language. Other parts of the puzzle require building off of what you have already learned, creating complex contingencies that determine the order in which words are learned and constructions are mastered. This accounts both for the similarity in what the youngest learners acquire, and the similarity in how their language changes over time. Critically, this distinction between developmental theories and contingent acquisition is orthogonal from questions about the degree to which language acquisition is constrained by evolution (the nativist-empiricist debate) or whether these constraints are domain-general, specific to the domain of language, or specific to other domains that are relevant to communication, like event conceptualization and naive psychology.[1]

It is difficult to tease apart developmental hypotheses from contingent acquisition in typical populations: infants are cognitively immature and know very little of their native language, while toddlers are more advanced in both ways. Correlational approaches run into the problem that individuals who are more advanced along one dimension tend to be more advanced along the other for reasons orthogonal to the question at hand (Spearman, 1904; Price et al., 2000). Prior work has sought to disentangle these factors by comparing language acquisition in children who are adopted internationally between the ages of two and five (Snedeker, Geren, & Shafto, 2007; 2012). These children rapidly lose their native language as they learn the language of their adopted parents (Ventureyra, Pallier, & Yoo, 2004; Roberts et al., 2005). Like infants they acquire the new language by hearing it spoken by their caregivers in the context of daily activities with no access to bilingual informants. Exploring language acquisition in this population allows us to determine which aspects of the acquisition trajectory are linked to cognitive development and maturation and which aspects reflect contingencies in the acquisition puzzle.

To date, several features of early language production have been found to be best explained by contingent acquisition (Snedeker, Geren, & Shafto, 2007; 2012). Like typical infants, adopted preschoolers begin by producing one-word utterances and start producing word combinations when their vocabulary reaches about 100 words. Adopted preschoolers show systematic shifts in the syntactic composition of their vocabularies like infants (from social words and nouns to predicates and closed-class items). In contrast, one critical change in early language acquisition appears to be developmentally driven: internationally adopted children learn words far faster than infants acquiring their first language, suggesting that the increase in learning rate that is observed in typical infants reflects general maturation of the perceptual and cognitive processes that underlie word learning.

The previous cited work with adopted children, however, has examined vocabulary in very coarse terms, by looking only at its syntactic composition. Many other factors affect when children learn a word: while the average child says *ball* by 15 months of age, the average 30-month-old hasn't yet learned the word *country*, even though both words are nouns (Fenson et al., 1994; data from Frank et al., 2017). The contingent-acquisition hypothesis predicts that the factors that make specific words hard or easy to learn will have similar effects across age, such that individual words will be acquired in approximately the same order in both infants and adopted preschoolers.

The present paper tests that hypothesis by building statistical models to predict the acquisition of individual words in both populations. This work focuses on two factors that are powerful predictors of word learning in typically situated infants: imageability and frequency (Gentner, 1982; Gillette et al., 1999; Ma et al., 2009; McDonough et al., 2011; Hao et al., 2015; Hansen, 2017; Smolík, 2019; Braginsky et al., 2019). Imageability is the ability to picture the concept associated with a word in one's mind, and it is almost perfectly correlated with the related concept of concreteness (Coffey et al., 2024). Young children are more likely to learn words that are more imageable and more frequent. In fact, early in acquisition these factors interact such that children primarily acquire words that are *both* highly imageable and highly frequent, resulting in an over-additive interaction (Coffey et al., 2024). As children get older and their vocabularies grow, the effect of imageability and the interaction grow smaller, as children begin to learn more abstract words.

These patterns are compatible with both developmental and contingent-acquisition theories. The present study seeks to tease them apart by exploring these effects in a sample of internationally adopted preschoolers and a set of vocabulary-matched infants who are acquiring English. In the remainder of the introduction, we: 1) summarize the previous research on how imageability and frequency shape early word learning and how this changes as vocabulary grows; 2) explore how developmental and contingent-acquisition hypotheses might account for these patterns; and 3) lay out the goals of the present study.

[1] Evolution in this context is not synonymous with natural selection. There are nativist theorists who eschew the notion that language is an adaptation selected for and refined over time while proposing that language is attributable to a shift in gene frequencies over time resulting in innate trait that differentiated humans from earlier hominids (see e.g., Bolhuis, Tattersall, Chomsky & Berwick, 2014; see, Pinker & Bloom, 1990 for a defense of natural selection).

1.1. Models predicting the acquisition of individual words

There is substantial evidence that both imageability and frequency predict the age at which children begin using a word. In these studies, the age of acquisition is determined by looking at a large cross-sectional sample of parent reports and calculating the age at which 50 % of parents report that their child produces that word. Imageability is typically assessed by asking adults to rate how the ease with which a word can be pictured in one's mind (Paivio, Yuille, & Madigan, 1968). It predicts the mean age at which a word is acquired by infants both within and across syntactic categories and regardless of whether frequency is also included in the analysis (Ma et al., 2009; McDonough et al., 2011; Hao et al., 2015; Hansen, 2017; Smolík, 2019). The frequency of a word in child-directed speech also predicts the age of acquisition, but only in models that control for imageability or syntactic category or look at a restricted set of words (Goodman et al., 2008; Hao et al., 2015; Hansen, 2017; Smolík, 2019). This is because the most frequent words in a language are typically closed class words, which are extremely low in imageability and are acquired late. Studies of this kind have failed to find any interaction between frequency and imageability (Hansen, 2017; Smolík, 2019).

One limitation of this approach is the use of a summary variable (median age of acquisition) that does not correspond to any underlying cognitive state or behavior in an individual. A word can have a median age of acquisition of 24 months because nearly no child says it before then (a sharp curve) or because children vary in when they use it, with the median just happening to fall at 24 months (a shallower curve).

In contrast, binomial or logistic models seek to predict the probability of an individual child knowing an individual word at a given time. This allows us to examine the effects of both child and word level predictors, to explore questions like how the effects of frequency and imageability change with age (or time). Critically, the dependent variable in these models maps onto a clear underlying psychological construct (i.e., whether a specific child knows a specific word).

This approach has confirmed many of the findings of the earlier studies and provided new insights into vocabulary acquisition. Braginsky et al. (2019) constructed mixed effects logistic regression models for ten languages (including English) based on parent report data for 8- to 30-month-old children. Across languages, children were more likely to comprehend and produce words that were more frequent and higher in concreteness. The size of both effects increased with age (or language experience). Recently, Coffey et al. (2024) used a logistic design to examine productive vocabulary in 1461 16- to 30-month-old children drawn from the MacArthur Bates Communicative Development Inventory norming study (Fenson et al., 1994; 2007). They conducted a stepwise comparison of mixed-effects logistic regression models that introduced frequency, imageability, the frequency-by-imageability interaction, and syntactic category membership (social words, nouns, predicates, and closed-class items) as predictors. As in previous studies, there were reliable main effects of imageability and frequency which increased with age (or language experience). In addition, they found a large positive interaction between frequency and imageability such that words that were both imageable and frequent were acquired far more often than words that had only one of these properties. This interaction also persisted after including syntactic category membership in the model. Critically, the size of the interaction *decreased* with child age, such that children were more likely to learn less imageable but more frequent words, and more imageable but less frequency words, as they grew older.

1.2. Developmental and contingent-acquisition theories provide alternative explanations for these effects

Coffey et al. (2024) interpret these findings as reflecting the interplay of input and accessibility. Imageability, they argue, is a proxy for how accessible a word's meaning is for the learner. Frequency is a measure of how likely a child is to encounter a word. Each encounter provides evidence about the meaning of the word, but only to the degree that this meaning is accessible. As a result, there is an early and strong over-additive interaction, such that the effect of frequency is greater for more imageable words. This interaction becomes smaller over time. The authors suggest that the interaction becomes smaller over time due to a weakening of the constraint on accessibility, which allows children to benefit from frequency to learn less imageable words, resulting in a more diverse and abstract vocabulary. Critically, this explanation is consistent with both developmental hypotheses and contingent acquisition hypotheses, depending on what the underlying process is that leads to less imageable word meanings becoming more accessible to the learner.

Under a developmental account, imageability could be a proxy for how *conceptually* accessible a word is to a child. For example, 16-month-olds might be able to represent concrete concepts like *ball* and *dog*, but not more abstract concepts like *not*, *sad,* or *later* (Huttenlocher, Smiley, & Ratner, 1983; O'Grady, 1987). Within the set of learnable (i.e., imageable) words, children would be more likely to encounter and thus learn words that are more frequent, resulting in the observed interaction. But as children's conceptual knowledge grows, either through biological maturation or experience with the world, they would be able to learn the more complex or abstract vocabulary items that they encounter, and thus the interaction between imageability and frequency would become less predictive of which words they are able to learn. In this case, we would expect to see reduced or absent effects of the frequency-by-imageability interaction for the internationally adopted preschoolers, who, by hypothesis, have the maturity and cognitive resources to grasp the concepts encoded by the abstract words acquired by two-year-olds. After all, these children would have learned many similar words in their birth language.

Under a contingent-acquisition account, imageability serves as a proxy for how *contextually* accessible the meaning of a word is for a child. In the absence of linguistic knowledge, young children must initially rely on extralinguistic cues to a word's meaning (e.g., co-presence, gesture, and eye-gaze) (Gillette et al., 1999; Snedeker & Gleitman, 2004). These cues pick out regions in space and the objects that occupy them and thus provide the most support for highly imageable words, like nouns for types of objects or animals. Picking out the intended meaning of a verb from extralinguistic context alone is less likely to be successful, especially if that verb is abstract (Snedeker & Gleitman, 2004). Thus, early on, the likelihood of learning a word during a given instance of exposure is greater for imageable words, resulting in the frequency-imageability interaction. But with larger vocabularies and more linguistic knowledge, children can use more cues, such as co-occurring vocabulary and grammar, to infer word meaning. These cues are particularly helpful for closing in on the meaning of abstract words (Snedeker & Gleitman, 2004). For this reason, children with more linguistic experience can use their experience to acquire more abstract words leading to the observed decline in the frequency-imageability interaction and the observed increase in the effect of frequency. On this hypothesis, we would expect to see similar effects in preschool-aged adopted children that are matched in English language vocabulary to the typically situated infants.

1.3. Current study

The present study looks at the predictors of word learning in internationally adopted preschoolers (2;6–5), comparing them with typically situated infants acquiring their first language. The preschoolers are in the early stages of learning English (0–12 months after arrival) and matched to infants based on vocabulary size. The study addresses two questions.

First, do we observe the same pattern of effects in adopted children as we do in non-adopted children? Specifically, do we see main effects of frequency, imageability and an over-additive interaction of frequency and imageability in adopted children? This question will be tested by constructing a statistical model for the adopted sample to explore the patterns within this population. If we found that adopted children, like typical infants, also show positive effects of frequency and imageability, and critically an over-additive interaction between these variables, it would provide further support for the contingent acquisition hypothesis. If any of these effects were absent in the adopted sample, it would suggest that this pattern is not attributable to intrinsic features of the learning problem but instead reflects developmental changes.

Second, are the sizes of these effects the same in the adopted children and vocabulary-matched infants? This question will be tested by constructing a model that includes both adopted preschoolers and typically developing infants who are matched on vocabulary size. Because the groups are matched on vocabulary, we do not expect to find an overall difference between them (a main effect of group). Instead, our analysis focuses on whether the critical effects of frequency, imageability and the interaction of frequency and imageability differ between the groups (resulting in interactions between these variables and group). The absence of such interactions would provide strong support for the contingent-acquisition hypothesis. Finding differences in the magnitude of these effects between the groups would suggest that some part of the effect is not attributable to intrinsic features of the learning problem, but instead is linked to factors that differ between the groups. For example, if older children had greater access to more abstract concepts, we would expect to find smaller effects of imageability and a smaller frequency-imageability interaction.

Note that there are two additional ways in which the adopted preschoolers differ from the infants: 1) they began acquiring at least one other language before acquiring English; and 2) they learn words more rapidly in the early stages of acquiring English and thus have had less input than vocabulary matched peers (Snedeker, Geren, & Shafto, 2007). Thus, differences in the size of effects could be attributable to these differences, a point we will return to in our Discussion.

2. Methods

2.1. Participants

Participants consisted of 53 adopted children and 53 non-adopted infant controls. The adopted children had come to North America from either China (n = 30) and Eastern Europe (n = 23), between the ages of 2;1 and 5;9 years (M = 43 months). Data collection occurred within 18 months of arrival (M = 7.5 months) and the children were between the ages of 2;6 and 6;4 at that time (M = 51 months). The children (34 female, 19 male) were believed to have mainly been exposed to Russian, Mandarin, or Cantonese. Information on educational attainment was available for 52 of the families. Most of the primary caregivers had completed college (83 %) and many also had a graduate or professional degree (29 %). Their partners (n = 44) were primarily college graduates (91 %) with graduate or professional degrees (61 %).

This sample was drawn from data collected between 2001 and 2007 for previous studies of language acquisition in internationally adopted children (Snedeker, Geren, & Shafto, 2007; 2012). Participants were recruited through internet and community-based groups for parents who were waiting to adopt or who had recently adopted. Children were eligible for the study if they had been adopted within the last eighteen months, had not been exposed to English prior to adoption, and had little exposure to a language other than English language after adoption. Children were excluded if they were reported as having a major development disorder (e.g., Down Syndrome, ASD) or a sensorimotor impairment that might have affected language learning (e.g., hearing loss, cleft palate).

Controls were vocabulary-matched English-speaking infants born and raised in the U.S. in monolingual English households (M = 24 months, range = 16–33 months, 31 female, 22 male). For each adoptee, an infant with the same vocabulary size was selected from data collected by the second author between 1995 and 2007. These participants were recruited from laboratory databases in the Philadelphia and Boston metro areas with characteristics typical of university convenience samples. Information on educational attainment was available only for the data collected after 2002 (n = 30). Most of the primary caregivers had completed college (91 %) and many had advanced degrees (60 %). Their partners (n = 29) were primarily college graduates (83 %) with advanced degrees (69 %).

2.2. Measures

2.2.1. Expressive vocabulary

Children's vocabulary was measured using the MacArthur Bates Communicative Development Inventory Words and Sentences form (MB-CDI: WS). The MB-CDI: WS is a parent-reported vocabulary checklist of children's expressive vocabulary appropriate for children between the ages of 16 and 30 months. While the adopted sample falls outside of this age range, previous studies have used the MB-CDI: WS to assess vocabulary in older children with language learning impairments or delayed language access (e.g., Singer-Harris et al., 1997; Thal et al., 1999), and the use of MB-CDI: WS in this population was validated in a prior study (Snedeker, Geren, & Shafto, 2012). The checklist consists of 680 lexical items organized into 22 semantic categories (e.g., "Outside Things", "Games and Routines", etc.). Parents indicate whether their child had ever produced this word previously. Families were mailed the form and were given instructions on how to fill it out and mail it back to the lab. For children with multiple vocabulary assessments, we selected a single assessment that 1) could be matched to an infant control by vocabulary size and 2) provided a sufficient range of vocabulary sizes allowing us to explore word-level predictors at different points in language development. Because infant controls were matched on the basis of vocabulary, both groups had nearly identical vocabulary means and ranges (Adopted: M = 356.5, SD = 183.4, range: 14–612; Controls: M = 358.7, SD = 181.9, range: 23–613).

2.2.2. Frequency in child-directed speech

The frequency of each word was taken from Coffey et al. (2024), who calculated it based on speech directed to children under 30 months of age in the CHILDES database (MacWhinney, 2000). Frequency counts were not collected for nine words: three would have required hand coding of the corpora (e.g., "child's own name") and six were multi-word utterances that were likely to be produced differently across families and contexts (e.g., "gonna get you!"). In addition, coders identified 135 potentially polysemous words and used a sampling procedure to estimate the frequency of the intended meaning (see Coffey et al., 2024 for details). All frequencies were then converted to log scale.

One might wonder whether frequency estimates based on children under 30 months would reflect typical speech directed to adopted preschoolers. We chose this measure for three reasons. First, when we collected these frequency estimates, we also collected parallel data from CHILDES on speech directed to children over 30 months. We found that the log frequency values in these two samples were very highly correlated ($R^2 = 0.87$). Second, the adopted preschoolers in our sample had a language level similar to 16- to 30-month-olds and were primarily learning English from their caregivers in the home, thus parallel input to younger children might better capture their experience. Third, we wanted to use the same word-level predictors for both the infants and the preschoolers to ensure the models were comparable.

2.2.3. Imageability ratings

To obtain imageability ratings for all words on the checklist, 30 adult participants were recruited and surveyed on Amazon's Mechanical Turk. Imageability was defined as the ease with which a word arouses a mental image or sensory experience. For example, *apple* is a highly imageable word, while *fact* which does not easily produce a mental image is not (Paivio, Yuille, & Madigan, 1968). Each participant was asked to rate the imageability of 340 MB-CDI items, or half of the inventory, on a seven-point Likert scale. Words were presented one at a time and syntactic category information was provided for potentially ambiguous words.

2.2.4. Syntactic category membership

Words fell into one of four syntactic categories based on their semantic classification, in accordance with previous studies (Bates et al., 1994; Caselli et al., 1995): nouns (Animals, Vehicles, Toys, Food and Drink, Clothing, Body Parts, Small Household Items, Furniture, Outside Things, and Places to Go), predicates (Action Words, Descriptive Words), closed-class words (Time Words, Pronouns, Question Words, Prepositions, Quantifiers, Helping Verbs, and Connecting Verbs), and social words (Sound Effects, Games and Routines, and People). Syntactic category was entered into the analysis as a categorical variable, with closed-class items as the contrast case. To increase the coverage of the analysis, we deviated from the classification schema of previous studies by including two previously excluded categories, Time Words and Places to Go, as closed-class items and nouns respectively. The words in each of these sections largely fall within these syntactic categories and appear to develop along the same time course (Snedeker, Geren, & Shafto, 2007; 2012). In addition, some social words, such as names for people, are typically considered nouns in the adult lexicon. We coded them as social words for three reasons. First, this was the coding scheme used in prior analyses (Bates et al., 1991; Coffey et al., 2024). Second, based on this coding scheme, Bates et al. (1991) had proposed that social words were typically produced earlier than nouns, and it was this observation that we hoped to explore further in our analyses. Third, many of these words are also initially used by children as proper names rather than common nouns ("Mommy" vs. "a mommy") and therefore may not require the same degree of generalization as other nouns.

3. Results

3.1. Overview of analyses

Mixed effects logistic regression models were constructed using *glmer* in the R package *lme4* (R Core Team, 2017; Bates et al., 2015). Children's vocabulary was coded as a binary variable (1 if the child says the word; 0 otherwise) and used as the response variable. Two analyses were performed. The first analysis consisted of a base model containing imageability and log-frequency as main effects, and random intercepts by subject and by item. Imageability-by-frequency was added next, followed by the syntactic category of the word (with closed-class items serving as the contrast case). At each step, model fit was assessed using log-likelihood ratio testing. In the second analysis, the base model contained imageability, log-frequency, imageability by frequency, and group membership (1 if adopted; -1 if control). This analysis was conducted to explore possible by-group differences in the effects of imageability and frequency on word-learning. By-group interactions were added in the following order: imageability-by-group, frequency-by-group, and the three-way interaction imageability-by-frequency-by-group. All models were fitted using Nelder-Mead optimization (Nelder & Mead, 1965), consistent with previous studies (Coffey et al., 2024). Continuous variables were centered and standardized. Standardized logistic regression coefficients as well as odds ratios are reported for all predictors. Additionally, the Akaike information criterion (AIC) and Bayesian information criterion (BIC) are reported for each model in their respective tables. Finally, Nakagawa's marginal R^2 measure was used to provide an approximate measure of absolute goodness of fit for each model (Nakagawa, Johnson, & Schielzeth, 2017). This measure estimates the variance explained by fixed effects in a mixed-effects model and is roughly equivalent to a standard R^2. The R package *performance* was used to calculate this value (Lüdecke et al., 2021).

3.2. Summary statistics

Mean values for imageability, frequency, and word knowledge by syntactic category can be found in Table 1.

3.3. Do we find an interaction between imageability and frequency?

To examine both the main effects of and the interaction between imageability and frequency, we constructed and evaluated mixed-effects logistic regression models in a stepwise fashion, inputting an additional predictor at each step and examining the improvement in model fit (Table 2). Separate models were fit for the adopted sample and for the control sample.

In the base model for the adopted sample, imageability ($\beta = 0.94$, $SE = 0.06$, $OR = 2.56$; $p < 0.001$) and frequency ($\beta = 0.87$, $SE = 0.06$, $OR = 2.39$; $p < 0.001$) were significant predictors of word knowledge (Model 1). Adding the frequency by imageability interaction term significantly improved model fit ($\chi^2(1) = 57.06$, $p < 0.001$) (Model 2). The interaction term was significant and positively predictive of word knowledge ($\beta = 0.42$, $SE = 0.05$, $OR = 1.52$; $p < 0.001$) (Fig. 1). To see whether a word's syntactic category was independently predictive of word knowledge, syntactic category membership (i.e., nouns, predicates, and social words) was added as a predictor to Model 2, with closed-class items serving as the contrast case (Model 3). The addition of syntactic categories to the model was found to improve fit ($\chi^2(3) = 88.13$, $p < 0.001$). Importantly, the frequency by imageability interaction remained a significant predictor controlling for syntactic category membership ($\beta = 0.31$, $SE = 0.06$, $OR = 1.36$; $p < 0.001$). Social words, nouns, and predicates were all more likely to be known than closed-class words in order of magnitude, as has been found in previous studies of early word-learning (Bates et al., 1994).

Each of these models was fit to the control sample, which produced the same pattern of results: words that were more imageable and frequent were more likely to be known, there is a significant interaction between frequency and imageability, which remains significant after controlling for syntactic categories.

Fig. 1 graphically summarizes the effects of frequency, imageability and their interaction (Model 2). Darker red tones pick out the words that are known by the greatest number of children, while darker blue tones represent the words known by the fewest. Children in both groups are more likely to know words that are frequent and words that are imageable (red in the upper right) and less likely to know words that are uncommon and words that are abstract (blue on the lower left). If these effects were additive, we would see parallel stripes of color, instead the over-additive interaction results in a bull's eye pattern indicating that children are particularly likely to learn words that are both frequent and imageable and do worse than we might expect with words that have just one of these properties. Fig. 1 also hints at a possible difference between the two groups: for infants, words with very low imageability are known by very few children (darker blue on the left side of the graph) while adopted children seem to be doing a little better with these words (lighter blue). Our next analysis explores whether there are any reliable differences between these groups.

3.4. Do effects of frequency and imageability differ across groups?

A comparative analysis of adoptees and controls was conducted (Table 3). Model 1 included group, frequency and imageability as factors. Group had no main effect, as expected since the groups were matched on total vocabulary size on the MB-CDI. As expected, adding frequency by imageability to this model improves fit ($\chi^2(1) = 53.81$, $p < 0.001$) (Model 2). In addition, imageability by group was found to improve model fit ($\chi^2(1) = 89.81$, $p < 0.001$); specifically, the imageability of a word had a weaker effect in the adopted preschoolers than in the infant controls ($\beta = -0.1$, $SE = 0.01$, $OR = 0.9$; $p < 0.001$) (Model 3).

Table 1
Summary word statistics by syntactic category: number of items on the MB-CDI, mean log frequency and imageability (standard deviation in parentheses), and average proportion known by adopted preschoolers and controls.

	Total	Social	Nouns	Predicates	Closed
# of Words	671	57	334	166	114
Frequency	5.37 (1.85)	5.19 (1.9)	4.64 (1.46)	5.65 (1.66)	7.2 (1.73)
Imageability	4.89 (1.85)	4.72 (1.6)	6.32 (0.45)	4.03 (1.17)	2.03 (1.07)
Proportion known					
Adopted	0.523	0.63	0.56	0.54	0.35
Controls	0.527	0.65	0.59	0.5	0.32

Table 2
Comparison of mixed effects logistic regression models predicting word knowledge in adopted preschoolers (left) and infant controls (right).

	Adopted			Control		
	Model 1	Model 2	**Model 3**	Model 1	Model 2	**Model 3**
Intercept	0.06	0.27	**−1.42***	0.15	0.34	**−1.57***
(Std. Err)	(0.29)	(0.29)	**(0.36)**	(0.3)	(0.3)	**(0.37)**
Imageability	0.94***	0.78***	**0.29**	1.22***	1.07***	**0.41***
	(0.06)	(0.07)	**(0.11)**	(0.07)	(0.07)	**(0.12)**
Frequency	0.87***	0.95***	**1.05***	0.98***	1.05***	**1.18***
	(0.06)	(0.06)	**(0.06)**	(0.07)	(0.07)	**(0.07)**
Frequency x Imageability		0.42***	**0.31***		0.4***	**0.32***
		(0.05)	**(0.06)**		(0.06)	**(0.06)**
Social			**2.58***			**3.08***
			(0.27)			**(0.3)**
Noun			**2.07***			**2.49***
			(0.28)			**(0.32)**
Predicate			**1.53***			**1.48***
			(0.2)			**(0.23)**
AIC	29,518	29,463	**29,381**	28,213	28,172	**28,078**
BIC	29,560	29,514	**29,457**	28,255	28,223	**28,154**
Marginal R^2	0.08	0.10	**0.12**	0.11	0.13	**0.15**
Improved Fit? ANOVA χ^2		Yes 57.06***	**Yes 88.13***		Yes 42.78***	**Yes 100.36***

'$p < 0.1$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Best fitting model bolded.
AIC: Akaike information criterion; BIC: Bayesian information criterion.
Marginal R^2: fixed effects only; χ^2 = likelihood ratio test.

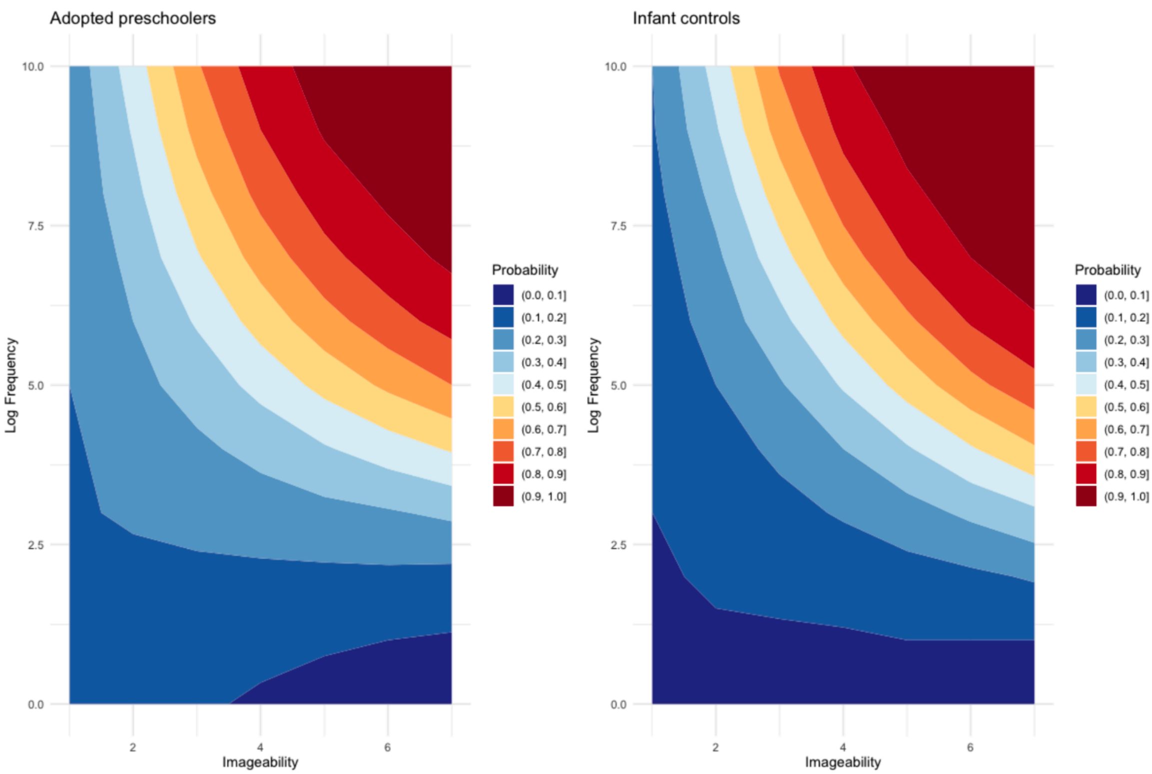

Fig. 1. Contour plots illustrating the probability words are known given their imageability and log frequency for adopted preschoolers (left) and infant controls (right), using Model 2 from Table 2. See text for interpretation.

Table 3
Comparison of mixed effects logistic regression models contrasting patterns of word knowledge in adopted preschoolers vs. infant controls.

	Model 1	Model 2	**Model 3**	Model 4	Model 5
Intercept	0.1	0.3	**0.3**	0.3	0.3
(Std. Err)	(0.21)	(0.21)	**(0.21)**	(0.21)	(0.21)
Group	−0.03	−0.03	**−0.03**	−0.04	−0.02
	(0.2)	(0.2)	**(0.2)**	(0.2)	(0.2)
Imageability	1.05***	0.9***	**0.91*****	0.91***	0.91***
	(0.06)	(0.06)	**(0.06)**	(0.06)	(0.06)
Frequency	0.91***	0.98***	**0.98*****	0.98***	0.98***
	(0.06)	(0.06)	**(0.06)**	(0.06)	(0.06)
Frequency x Imageability		0.4***	**0.4*****	0.4***	0.4***
		(0.05)	**(0.05)**	(0.05)	(0.05)
Imageability x Group			**−0.1*****	−0.12***	−0.13***
			(0.01)	(0.01)	(0.01)
Frequency x Group				−0.03**	−0.03*
				(0.01)	(0.01)
Imageability x Frequency x Group					0.02*
					(0.01)
AIC	57,416	57,365	**57,277**	57,272	57,270
BIC	57,471	57,429	**57,350**	57,355	57,361
Marginal R^2	0.1	0.11	**0.11**	0.11	0.11
Improved Fit? ANOVA χ^2		Yes 53.81***	**Yes 89.81*****	Yes 6.64**	Yes 4.35*

'$p < 0.1$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Best fitting model bolded.
AIC: Akaike information criterion; BIC: Bayesian information criterion.
Marginal R^2: fixed effects only; χ^2 = likelihood ratio test.

The final two models improved the fit based on AIC but resulted in an increase in BIC suggesting we might be overfitting our data set. By the chi-squared test on likelihood, we found that adding the frequency by group interaction improved model fit ($\chi^2(1) = 6.64$, $p < 0.01$) (Model 4) and adding the three-way interaction term (imageability by frequency by group) improved model fit ($\chi^2(1) = 4.35$, $p < 0.05$) (Model 5). Specifically, in the final model, word frequency was a slightly weaker predictor for the older children ($\beta = -0.03$, $SE = 0.01$, $OR = 0.97$; $p < 0.05$) and the frequency by imageability interaction was slightly larger ($\beta = 0.02$, $SE = 0.01$, $OR = 1.02$; $p < 0.05$). The imageability by group interaction persisted in this model ($\beta = -0.13$, $SE = 0.01$, $OR = 0.97$; $p < 0.001$).

3.5. Are these findings replicable using a different control group?

Because the infant control group was pulled from other data sets rather than from a representative sample, we decided to conduct a second analysis with a new control group to determine how generalizable our findings were. For each child in the adopted sample, a vocabulary-matched child was randomly drawn from the MacArthur Bates Communicative Development Inventory norming study (Fenson et al., 1994; 2007). Our random sample consisted of 53 typically developing, English monolingual children between the ages of 1;4 and 2;6 ($M = 22$, $SD = 3.84$; 33 girls). Children in this data set were from a range of socioeconomic groups, with maternal education ranging from 9-18 years ($M = 14.13$, $SD = 2.46$; 33 having completed college). The data was obtained from the WordBank online database (Frank et al., 2017).

We reran the analyses comparing adoptees and controls using this new sample (Table 4). Model 1 included group, frequency and imageability as factors. As expected, adding frequency by imageability to this model improved fit ($\chi^2(1) = 56.39$, $p < 0.001$) (Model 2). Critically, we found essentially the same pattern of differences (and similarities) across the groups. Adding a group by imageability interaction improved model fit ($\chi^2(1) = 42.46$, $p < 0.001$) and resulted in decreases in both AIC and BIC. Once again, adopted preschoolers' word knowledge was somewhat less strongly predicted by imageability ($\beta = -0.07$, $SE = 0.01$, $OR = 0.93$; $p < 0.001$) (Model 3). The two remaining models resulted in an increase in the BIC, as before. Adding frequency by group interaction also failed to improve model fit by the chi-squared test ($\chi^2(1) = 1.85$, $p = 0.17$) (Model 4). Adding the three-way interaction term resulted in a small improvement over Model 4 ($\chi^2(1) = 4.33$, $p = 0.04$) (Model 5). In short, as in the previous analysis, the interaction between group and imageability resulted in a better model for both comparisons and regardless of which measure of model fit is used. In contrast, the other interactions, which were initially present only when the AIC criterion was adopted, disappeared when a new control group was selected.

In summary, we were able to replicate the principal findings of our original analysis using a new control group drawn from a potentially more representative sample of children. Namely, frequency by imageability remains a significant predictor of word knowledge across groups controlling for syntactic categories, and adopted preschoolers' vocabularies are relatively less affected by word imageability.

Table 4
Comparison of mixed effects logistic regression models contrasting patterns of word knowledge in adopted preschoolers vs. infant controls drawn from WordBank.

	Model 1	Model 2	**Model 3**	Model 4	Model 5
Intercept	0.07	0.27	**0.27**	0.27	0.27
(Std. Err)	(0.21)	(0.21)	**(0.21)**	(0.21)	(0.21)
Group	0.0	0.0	**0.0**	0.0	0.01
	(0.2)	(0.2)	**(0.2)**	(0.2)	(0.2)
Imageability	1.01***	0.86***	**0.86*****	0.86***	0.86***
	(0.06)	(0.06)	**(0.06)**	(0.06)	(0.06)
Frequency	0.89***	0.96***	**0.96*****	0.96***	0.96***
	(0.06)	(0.06)	**(0.06)**	(0.06)	(0.06)
Frequency x Imageability		0.4***	**0.4*****	0.4***	0.4***
		(0.05)	**(0.05)**	(0.05)	(0.05)
Imageability x Group			**−0.07*****	−0.08***	−0.09***
			(0.01)	(0.01)	(0.01)
Frequency x Group				−0.02	−0.01
				(0.01)	(0.01)
Imageability x Frequency x Group					0.02*
					(0.01)
AIC	57,691	57,637	**57,596**	57,597	57,594
BIC	57,746	57,701	**57,670**	57,679	57,686
Marginal R2	0.09	0.10	**0.11**	0.11	0.11
Improved Fit? ANOVA χ^2		Yes 56.39***	**Yes 42.46*****	No 1.85	Yes 4.33*

'$p < 0.1$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Best fitting model bolded.
AIC: Akaike information criterion; BIC: Bayesian information criterion.
Marginal R^2: fixed effects only; χ^2 = likelihood ratio test.

4. Discussion

The current study found that many factors that predict vocabulary acquisition in infants who are learning their first language, also predict vocabulary acquisition in preschool-aged children who are learning English via immersion after transnational adoption. In both cases, children are more likely to learn words that are more imageable and more frequent and are particularly likely to learn words that have both of these properties, leading to an over-additive interaction between frequency and imageability. These effects persist after controlling for syntactic category membership, which is also predictive of vocabulary. This study also found that the imageability was a weaker predictor of word production in adopted preschoolers than in infants (as evidenced by the interaction of imageability and group). These patterns persisted when the control group was replaced with a new group of vocabulary-matched infants drawn from a more representative sample of first-language learners. Thus, our interpretation of this data must account for both the strong similarities between the two groups (the effects of imageability, frequency, and their interaction) as well as the observed difference (in the strength of the imageability effect).

These similarities suggest that many of the factors that shape early word learning are not specifically attributable to the cognitive immaturity of young infants. Critically, the stability of the interaction between frequency and imageability across these groups demonstrates that even older and more knowledgeable children benefit more from each encounter with a highly imageable word than from each encounter with a less imageable one. Earlier work by Coffey and colleagues demonstrated that the size of the imageability by frequency interaction decreases as infants grow older and their vocabularies increase (Coffey et al., 2024). The present findings suggest that this shift is the result of the child's changing knowledge of their language, rather than cognitive development or linguistic maturation per se. Thus, these findings are consistent with contingent acquisition hypotheses. In contrast, the observed difference between the preschool adoptees and the infant learners in the magnitude of the imageability effect raises the possibility that there are differences between infant and preschool language learners that might potentially be related to cognitive development. Perhaps there are concepts that cannot be entertained by an 18-month-old but are readily available to a three-year-old, and these concepts might well be less imageable. In Section 4.1 below we explore this possibility along with several alternative hypotheses. We conclude that the difference in the imageability effect appears to reflect the input to and interests of children of different ages, as well as differences in how adopted children acquire some conceptually tricky words for abstract categories like time and comparison. The remainder of the discussion explores how our findings bear on theories of word learning (Section 4.2).

4.1. *How do we explain differences in imageability between groups?*

Imageability was found to be less predictive of vocabulary in the adopted preschoolers than in either of the infant control groups. This pattern is compatible with two types of explanations: 1) the difference could reflect qualitative developmental changes in word-learning that make more abstract words (or a specific subsets of abstract words) more accessible to older learners; 2) it could reflect differences in the input and interests of toddlers and preschoolers that result in preschoolers knowing fewer of the concrete nouns and routines on the MB-CDI.

To begin to explore these possibilities, we looked at the words where there was the largest difference between the adopted preschoolers compared to infants in the lab and WordBank control samples. We fit the same mixed-effects logistic regression model as in our main analysis, using group as a categorical predictor (adopted coded as 1 and control as −1) and subject and item as random intercepts. In addition, we fit a random slope of group-by-item. Using these fitted slopes by item, we can calculate the odds that adopted preschoolers know certain words compared to infant controls, and vice versa (Braginsky et al., 2019). The words with the largest bias in either direction are displayed in Fig. 2. Below we explore how these observed differences bear on our hypotheses.

4.1.1. Differences in the experiences of toddlers and preschoolers

A quick glance at these two lists suggests that many of the words that toddlers learn more often than preschoolers are labels for objects (e.g., *crib, bib, diaper, highchair,* and *bottle*) that are a part of the everyday experience of one-year-olds but would be absent from the life of a four-year old unless they had a younger sibling. Other words are part of routines (e.g., *peek-a-boo, belly button* and *baa)* that parents typically do with infants, rather than preschoolers. Conversely, adopted children are more likely to know words that relate to school (e.g., *school*, *teacher, glue*), color terms (*green*), and words for objects and activities that seem more developmentally appropriate for a three-year old than a one-year old (e.g., *camping, underpants, gum*).[2] These differences suggest that the underlying process of acquisition is similar in the two groups, but that differences in input result in differences in outcome.

This difference in the life experiences of toddlers and preschoolers could play a role in the observed interaction between group and imageability. More imageable words are typically more limited in their contexts of use. Concrete nouns (*tiger*) and action verbs (*swim*) are used when the specific entities and activities that they describe are under discussion. Abstract words, like closed class items, evaluative adjectives (*good*), light verbs (*go*), and superordinate nouns (*person*) can pop up across a wide range of contexts. For this reason, there is likely to be more overlap in the abstract words that toddlers and preschoolers hear (and know) than in the concrete words that they hear. If this is true, then we should expect that the MB-CDI, which is intended to capture word learning from 16 to 30 months, would systematically undersample the concrete words that preschoolers learn, resulting in a smaller effect of imageability in this population. This appears to be the case. The adopted children in the present study also provided videotaped speech samples, some of which were analyzed in a previous study (Snedeker, Geren, & Shafto, 2012). In those samples, the children use a variety of concrete words that are not on the MB-CDI (e.g., *whistle*, *kindergarten*, *jail*, *helicopter*, *dinosaur*, and *kangaroo*). The present research design does not allow us to test the degree to which these differences in experience can account for the observed difference in the imageability effect (because we lack systematic data on the acquisition of words that are not on the MB-CDI). However, the data that we do have strongly suggests that differences in children's experiences play some role in the group-level effects.

4.1.2. Age related changes in conceptual accessibility

The second possibility is that the effect of imageability in preschoolers is reduced because they have greater access to the meanings of some of the less imageable words. Increased access could result from having greater cognitive capacity, from having acquired concepts that younger children lack, or from having previous knowledge of a similar word in their birth language. Many of the words that the preschoolers are more likely to acquire (Fig. 2) are consistent with this hypothesis. Specifically, preschoolers showed precocious acquisition of three time words (*tomorrow*, *later,* and *today*), two question words (*why* and *where*) and two terms from the quantifiers and articles section (*much* and *same*). Each of these words can appear in a wide range of contexts and is frequent in speech input, occurring between 128 and 6300 times per 1 million words by our measurement. Thus, infants hear each of these words many times a day, and yet they acquire them quite late (median age of acquisition from 27 to more than 30 months). These words are highly abstract, with imageability ratings ranging from 1.32 to 2.25 (M = 1.8), and semantically complex. While nouns, verbs and adjectives define sets of individuals or relations, closed class terms like these modify propositions, link propositions with empty arguments to possible answers, and compare and quantify sets. To better understand these precociously acquired words, we looked at the other words from the same categories on the MB-CDI to determine whether they were also acquired early.

The first category that we explored was the time words. In their longitudinal study, Snedeker, Geren & Shafto (2012) reported that adopted preschoolers had precocious knowledge of time words, but this advantage was restricted to those words that are primarily used to describe relations between time (*after, before, later, today, tomorrow, tonight,* and *yesterday*). This pattern was also present in the current sample: all seven of the words for relational time had odds ratios that favored the adopted preschools (median odds ratio = 1.51). The words for natural time (*day*, *night*, *morning*, *now*) showed no consistent pattern (median odds ratio = 1). Relational time words have an unusual pattern of acquisition in young children. Most of the words children learn are used appropriately without glaring errors, suggesting that they have mapped them onto roughly the same concepts as adults. In contrast, relational time words are often used incorrectly, suggesting that children have difficulty identifying or constructing their meanings long after they have identified their form, their syntax, and some of their conversational functions. For example, "tomorrow" might be used for "yesterday" or to place an event any time in the future (Harner, 1975; Nelson, 1977). At three, most children are reported to make errors in using the relational time terms on the MB-CDI, but by five years of age their parents say they are using them correctly (Grant & Suddendorf,

[2] These patterns extended beyond the examples given in the table. All color terms had odds ratios favoring the older children (median odds ratio = 1.46), while all body parts and most sound effects had odds ratios favoring infants (median = 0.77 and 0.75 respectively). These differences are consistent with how parents and teachers interact with preschoolers and infants (e.g., practicing color words in preschool and labeling body parts in toddler play groups).

Adopted preschoolers advantaged

	Odds	Adopted	Control
tomorrow (c.)	2.14	60%	28%
underpants (n.)	2.07	68%	37%
later (c.)	1.99	64%	35%
camping (n.)	1.93	26%	7%
school (n.)	1.92	87%	61%
same (c.)	1.91	42%	17%
teacher (s.)	1.90	62%	35%
church (n.)	1.82	64%	39%
glue (n.)	1.80	47%	24%
why (c.)	1.77	53%	29%
gum (n.)	1.74	62%	39%
much (c.)	1.72	30%	12%
green (p.)	1.69	77%	56%
when (c.)	1.66	34%	16%
today (c.)	1.66	51%	30%

Infant controls advantaged

	Odds	Adopted	Control
crib (n.)	2.34	19%	58%
bib (n.)	2.28	34%	70%
peek-a-boo (s.)	2.08	57%	83%
bottle (n.)	2.05	68%	90%
highchair (n.)	2.01	23%	55%
diaper (n.)	1.93	58%	82%
peas (n.)	1.84	36%	63%
puppy (n.)	1.83	57%	79%
cracker (n.)	1.83	68%	87%
bellybutton (n.)	1.78	57%	78%
thank you (s.)	1.77	43%	68%
keys (n.)	1.76	68%	86%
rock (n.)	1.73	53%	75%
baa baa (s.)	1.69	64%	82%
bug (n.)	1.68	60%	79%

Fig. 2. List of words more likely to be known by adopted preschoolers (left) and infant controls (right), ordered by odds of knowing the word (e.g., adopted preschoolers are roughly twice as likely to know *tomorrow* than infant controls). Part of speech is given as (s)ocial, (n)oun, (p)redicate, and (c)losed class.

2011; see also Tillman et al., 2017). Presumably, the adopted preschoolers in our sample found it easier to acquire these words because they had already worked out the meanings of similar words in their birth language (or at least started this process). It's not clear, from our data, whether this initial task requires conceptual change or is simply a very tricky mapping problem. What our findings do suggest is that even for three- to six-year-olds there are savings in relearning these words in a new language.

Next, we examined the question words (*how*, *what*, *when*, *where*, *which*, *who* and *why*). All of these words were more likely to be known by the adopted children (median odds ratio = 1.46). Children ask questions from earliest stages of language development, though the nature of these questions shifts over time (Chouinard, 2007). Prior work on the acquisition of wh-words has focused on the factors that make some of these words easier to learn than others. Although the words that are learned later (*why* and *when*) are more abstract than those that are learned earlier (*what* and *where*), this is not believed to reflect conceptual complexity, both because second language learners also acquire the words in this order and because children who are not using the more complex words seem to express the same concepts in other ways (Bloom, Merkin & Wooten, 1982). Instead, the differences in the order of acquisition are argued to reflect frequency, syntactic complexity, and the verbs that are most often used with the words (Bloom, Merkin & Wooten, 1982; Rowland et al., 2003). This pattern suggests that the difficulty in learning these words has more to do with linguistic packaging than conceptual creation. Our results suggest that children who have already started acquiring one language may have a leg up in solving this packaging problem. Why might question words in particular have a second-language decoding advantage? One possibility is that while the meaning of question words may only be inferable from full sentence contexts (delaying acquisition in L1), question words can be felicitously used as single-word utterances and often receive focal stress, which might allow a learner who is on the lookout for these forms to identify them more quickly.

Finally, we looked at the Articles and Quantifiers category on the MB-CDI, which included the words *same* and *much*. This is a conceptually and linguistically diverse category. We divided the words into two broad categories: 1) determiners (e.g., *the, a, any*) which primarily encode grammatical distinctions and discourse features and 2) logical words which quantify, negate or compare (*none*, *all*, *not*, *same*).[3] The determiners were, on average, slightly more likely to be known by the younger children (median odds ratio = 0.89) with no items having strong biases in either direction. In contrast, the logical words were on average a little more likely to be known by adoptees (median odds ratio = 1.19) with considerable variation across items. The words with more bias included universal quantifiers (*each*, *every*, *all*) and words that invoke comparison (*a lot*, *much* and *same*). The logical words that did not show a bias were the negators (*none* and *not*) and the existential quantifier *some* which is also often used as an indefinite determiner. We are cautious in interpreting these patterns given the ad hoc nature of the coding decisions and the relatively small differences across the set. While two-year-olds are still making errors in their interpretation of quantifiers (Barner et al., 2009), the words that they struggle with the most (*none* and *some*) are not the words that the older children appear to have an advantage acquiring.

4.1.3. Remaining questions about the reduced effect of imageability

The analyses above suggest that the effect of imageability in the adopted preschoolers is smaller for two distinct reasons. First, some of the more imageable words on the MB-CDI simply are not relevant to preschoolers, while some of the highly imageable nouns that our participants were using (*helicopter*, *dinosaur*) are not included on the MB-CDI. Thus, the group difference partially reflects differences in

[3] This section also included a discourse particle (*too*) which we did not include in either group.

children's experiences and how these differences interact with the measure that we used. Diary studies with late learners could help us understand the extent of these effects. Second, we found that the older children were precocious in their acquisition of a small number of abstract and semantically complex words. Critically, the children did not show generally superior knowledge of all closed class words. The words they learned earlier stood out in that they were: not phonologically reduced, did not encode language-specific grammatical features, and, in some cases, belong to conceptual domains where prior evidence suggests that conceptual change occurs during early childhood. The advantages that adopted children have in learning these words could reflect conceptual change, the advantage of having a prior linguistic label, or the ability to remember and relate events that happened over a longer time span. Comparisons of adopted children of different ages and from different linguistic backgrounds could be useful in understanding the nature of the differences.

4.2. How our findings relate to and constrain theories of word learning

The primary finding of the present study is that word learning in older children who are acquiring a new language via immersion is shaped by the many of the same variables that shape early word learning in infants. Specifically, we found that in both groups there were large effects of frequency, imageability and their interaction. In both groups, social words and nouns were acquired before predicates and closed class items, and these effects were independent of the effects of frequency and imageability. True, the imageability effect was somewhat smaller in adopted children (about 75 % as large), but the frequency effects and the interaction were no different in this group.

These striking parallels between the two populations support contingent acquisition theories (Snedeker, Geren, & Shafto, 2007) like syntactic bootstrapping (Gleitman & Gleitman, 1992; Gillette et al., 1999; Snedeker & Gleitman, 2004) which propose that as we gain greater knowledge of a language the way in which we learn changes because we can leverage the knowledge that we already have to acquire words and constructions that were unlearnable before. The novice learner, who knows none of the words in their language, must rely on extralinguistic context and social cues to infer meaning. These cues allow them to decipher some object nouns and social performatives but provide little information about the meaning of verbs or function words (Gillette et al., 1999; Snedeker & Gleitman, 2004; Medina et al., 2011; Gomes et al., 2023). These early acquired nouns provide clues that help the child identify the event under discussion and the perspective that is being taken on that event, which allow them to learn concrete verbs (Snedeker & Gleitman, 2004). Once this backbone of content words is in place, the child can begin to identify the functions of closed class items in their language and use these syntactic markers to acquire more abstract nouns and verbs. Much of the evidence for this hypothesis comes from human simulation studies in which adults are given different kinds of information about the contexts in which words appear in infant directed speech. Adults who are limited to just extralinguistic contexts can typically only infer the meanings of the most imageable words. One criticism of this work is that it uses time scales, stimuli and contexts that abstract away from the messiness and richness of day-to-day life. Research with internationally adopted preschoolers provides complementary evidence from a population that, like the infant, is learning in the context of ongoing family interactions, but like the adult, is more cognitively mature and has prior linguistic experience.

The present study goes beyond prior work on adoption by focusing on the acquisition of individual words and exploring the effects of frequency, imageability and their interaction. We find that both infant learners and child learners are more likely to acquire words that are more frequent and more imageable. In fact, the two variables show an over-additive interaction–words that are both frequent and imageable are acquired more often than one would expect based on either variable alone. Coffey et al. (2024) note that this pattern of effects is predicted by most current theories of language development. The link between a label and concept can only be learned by experience and given the difficulty of inferring (or acquiring) meaning, many such pairings may be needed, resulting in a frequency effect. Not all meanings or referents will be equally accessible to the child, resulting in an imageability effect, and the accessibility of a referent should affect the average informativity of an instance, resulting in an over-additive interaction.

Coffey and colleagues note that there are two broad kinds of explanations for why less imageable words are less available to the child. First, imageability might be a proxy for how conceptually accessible a word is to a young child. While concepts encoded in highly imageable words might be acquired prior to word learning (making them easier to learn), less imageable words might have meanings that children can only conceptualize later in development and therefore cannot be learned early on. Second, imageability might reflect how informative an instance of language exposure is. For example, more imageable words may have more consistent and memorable perceptual correlates. Children who are only starting to learn their language must initially rely on social or extralinguistic cues, which biases them towards more imageable vocabulary items. Older children become less reliant on imageability not because they are more cognitively mature, but because their knowledge of their language has given them access to other sources of information to solve the mapping problem (e.g., word co-occurrence, sentential syntax).

Critically, these two explanations are not mutually exclusive. Our results provide clear evidence for the second explanation (imageability reflects informativity) and more tentative evidence for the first (imageability reflects conceptual access). Specifically, we find that like infants, adopted preschoolers are far more likely to learn words that are imageable and frequent resulting in a strong over additive interaction (Table 2 and Fig. 1). Since preschoolers are substantially more cognitively advanced than the toddlers in the control sample (see Snedeker, Geren, & Shafto, 2012), it is unlikely that this reflects an inability to access the relevant concepts. In fact, many of these children have presumably successfully mapped many of these abstract concepts to words in their birth language. Our findings suggest that they cannot simply apply English labels to these mappings. Rather, their word-learning is limited by their knowledge of English, and they can only create new mappings between English labels and their referents when they have acquired the necessary linguistic representations. Thus, many features of acquisition appear to reflect the child's existing knowledge of their language and the bottlenecks that it creates, rather than conceptual development or maturation.

Nevertheless, our findings also provide some tentative support for the claim that imageability effects are related to conceptual access. The imageability effect in adopted preschoolers is only 75 % as large as it is in the infant controls. This would be expected if the infants lacked access to some of the concepts encoded in these words. The interpretation of this interaction is tricky: as we noted in section 4.1.1 the interaction may be driven, in part, by the contextual specificity of highly imageable words, the differences in the experiences of infants and children and the purpose for which the MB-CDI was designed. However, there are some categories of words, like relative time words and question words, where older children show a strong and consistent advantage suggesting that they might have greater access to these concepts due either to previous linguistic experience or improved cognitive abilities.

5. Conclusions

A perennial challenge of language acquisition research is disentangling the influence of children's cognitive maturation from the influence of their growing linguistic knowledge. While typical populations do not normally permit us to do so, internationally adopted children provide us a unique opportunity to examine patterns of language acquisition removed from the maturational changes they almost always co-occur with. The present study demonstrated that one prediction of contemporary theories of word-learning–that children's first words should be both imageable and frequently encountered–is also true of preschool-aged internationally adopted children learning English through immersion. Our findings suggest that this pattern is a by-product of children's language knowledge rather than the limitations imposed by their age.

Author note

Our data is fully available via https://osf.io/642zh/ OSF: OSF | Disentangling the roles of age and knowledge in early language acquisition: a fine-grained analysis of the vocabularies of infant and child language learners.

CRediT authorship contribution statement

Joseph R. Coffey: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Jesse Snedeker:** Writing – review & editing, Writing – original draft, Supervision, Investigation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data has been shared via an OSF directory linked on the title page

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