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Lexicon Structure and the Disambiguation of Novel Words:

Evidence from Bilingual Infants

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Abstract

In ambiguous word learning situations, infants can use systematic strategies to determine the referent of a novel word. One such heuristic is disambiguation. By age 16-18 months, monolinguals infer that a novel noun refers to a novel object rather than a familiar one (Halberda, 2003), while at the same age bilinguals and trilinguals do not reliably show disambiguation (Byers-Heinlein & Werker, 2009; Houston-Price, Caloghiris, & Raviglione, 2010). It has been hypothesized that these results reflect a unique aspect of the bilingual lexicon: bilinguals often know many translation equivalents, cross-language synonyms such as English *dog* and Mandarin *gǒu*. We studied the role of vocabulary knowledge in the development of disambiguation by relating 17-18 month-old English-Chinese bilingual infants' performance on a disambiguation task to the percentage of translation equivalents in their comprehension vocabularies. Those bilingual infants who understood translation equivalents for more than half the words in their vocabularies did not show disambiguation, while infants who knew a smaller proportion of translation equivalents showed disambiguation just as same-aged monolinguals do. These results demonstrate that the structure of the developing lexicon plays a key role in infants' use of disambiguation.

Keywords: infant development; mutual exclusivity; disambiguation; bilingualism; word learning

Highlights

1. Disambiguation is the heuristic to infer that novel words go with novel objects.

2. We asked if experience with one-to-one mappings influences its development.

3. 18-month-old Chinese-English bilingual infants were tested in a looking paradigm.

4. Only infants who knew few translation equivalents disambiguated a novel word.

5. A one-to-one lexicon structure contributes to the development of disambiguation.

One-to-one Mappings and the Disambiguation of Novel Words: Evidence from

Bilingual Infants

Young children are highly skilled word learners. They are able to take advantage of a wealth of information to figure out a word's meaning, including associative (Smith & Yu, 2008), social (Baldwin & Moses, 2001), and referential (Waxman & Gelman, 2009) information. Children are also able to infer a word's meaning even in contexts where information is very sparse. In a disambiguation task (sometimes referred to as a mutual exclusivity task; Markman & Wachtel, 1988), children are presented with a pair of objects, one familiar with a known name (such as a cup) and another unfamiliar without a known name (such as a spatula). Although they have no prior knowledge of the word spatula, children as young as 16-18 months tend to infer that the novel word refers to the long-handled utensil, rather than the round drinking vessel (Byers-Heinlein & Werker, 2009; Halberda, 2003; Markman, Wasow, & Hansen, 2003). This fast-mapping of words onto referents via disambiguation is thought to be a first step towards the long-term retention of the meanings of novel words (Bion, Borovsky, & Fernald, 2013; Carey & Bartlett, 1978; Horst, McMurray, & Samuelson, 2006; Horst & Samuelson, 2008; Swingley, 2010).

What is the origin of infants' ability to infer the referent of a novel word via disambiguation? One possibility is that one-to-one mappings are inherently preferred by the child's learning system. For example, under Markman & Wachtel's (1988) mutual exclusivity account, children operate under the default assumption that object labels denote mutually exclusive categories, and use this assumption to infer that a novel label could not go with an object that already has a label. It has also been suggested that mutual exclusivity is an emergent property of computational processes that support word learning (Frank, Goodman, & Tenenbaum, 2009; McMurray, Horst, & Samuelson, 2012; Merriman, 1999; Regier, 1996; 2003), or that it might be founded in children's preference for novelty (Horst,

Samuelson, Kucker, & McMurray, 2011). An alternative view is that the development of disambiguation is driven by experience, and that it emerges only once a child has established that each object should have a basic-level label (Mervis & Bertrand, 1994), or has ascertained that adults use different words to refer to different kinds of objects (Diesendruck & Markson, 2001).

There is mounting evidence that early language experience does play a role in the development of disambiguation. Key support for this view is that bilingual and trilingual infants do not show disambiguation from the same age as monolinguals (Byers-Heinlein & Werker, 2009; Houston-Price, Caloghiris, & Raviglione, 2010), and preschool and school-age bilinguals use disambiguation less robustly than monolinguals (Bialystok, Barac, Blaye, & Poulin-Dubois, 2010; Davidson, Jergovic, Imami, & Theodos, 1997; Davidson & Tell, 2005; Diesendruck, 2005; but see also Byers-Heinlein, Chen, & Xu, under review; Frank & Poulin-Dubois, 2002; Merriman & Kutlesic, 1993 for studies that showed similar performance by monolinguals and bilinguals). These group differences amongst children from varying language backgrounds indicate that early language experience can influence the development of disambiguation. However, because studies have yet to investigate exactly what aspect of monolinguals' and bilinguals' experience contributes to observed differences, the specific role that experience plays remains unclear.

One explanation for the difference between monolinguals and bilinguals' development of disambiguation (e.g. Byers-Heinlein & Werker, 2009; Houston-Price et al., 2010; Merriman & Kutlesic, 1993) is that bilinguals regularly learn translation equivalents, pairs of words that are synonyms across the two languages such as English *dog* and Mandarin *gǒu*. Bilinguals' knowledge of translation equivalents results in infants' lexicons having a many-to-one (or at least two-to-one) mapping structure between words and concepts. In contrast, each new word that a monolingual child learns is usually another one-

to-one mapping between a word and a concept. The notion that children's knowledge of one-to-one mappings between words and concepts contributes to the early development of disambiguation in both monolingual and bilingual infants has been called the lexicon structure hypothesis (Byers-Heinlein & Werker, 2009; see also McMurray et al., 2012, for a discussion of the impact of a one-to-many lexicon structure on disambiguation).

The lexicon structure hypothesis predicts that individual children's use of disambiguation will vary according to the extent to which their lexicons have a one-to-one versus a many-to-one mapping structure. As one-to-one mapping between words and concepts is the typical structure of a single language (Clark, 1987; 1990; 1993), monolingual children's use of disambiguation should become more robust with age as their vocabularies grow. Indeed, several studies have found that monolingual children's use of disambiguation increases with age (Bion et al., 2013; Halberda, 2003) and other studies report positive correlations between monolinguals' vocabulary size and their use of disambiguation or related behaviors (Bion, et al., 2013; Houston-Price et al., 2010; Graham, Poulin-Dubois, & Baker, 1998; Mervis & Bertrand, 1994). However, for monolingual children, the extent to which their lexicons are characterized by one-to-one mappings is conflated with age and overall vocabulary size, making such results a weak test of the lexicon structure hypothesis.

Studies of individual differences amongst bilingual children's use of disambiguation can disentangle the effects of age and vocabulary size from the extent to which children's vocabularies have a one-to-one mapping structure. When a bilingual learns a new word, it might be for a previously unlabeled concept and thus be consistent with a one-to-one lexicon structure, or it might be a translation equivalent of an already known word, and thus contribute to a many-to-one lexicon structure. Bilingual children vary widely in the proportion of words for which they know a translation equivalent (David & Wei, 2008; De Houwer, Bornstein, & De Coster, 2006; Pearson, Fernández, & Oller, 1995; Sheng, Lu, & Kan,

2011; Umbel, Pearson, Fernández, & Oller, 1992). However, bilingual children do not seem to systematically learn or avoid translation equivalents, as the proportion of translation equivalents known by bilingual children is equivalent to what would be expected by chance (i.e. the average overlap found in the single-language lexicons of two randomly selected children; Pearson et al., 1995).

Because bilingual children's knowledge of translation equivalents is both highly variable and unsystematic, bilingual children provide a natural experiment for investigating the role of a one-to-one lexicon structure in the development of disambiguation. The lexicon structure hypothesis predicts that individual bilingual children who know many translation equivalents will not show disambiguation at the same age as those individual bilingual children who know few translation equivalents. Further, it predicts that bilingual children who know few translation equivalents will show disambiguation from the same age as monolinguals.

Only two studies to date have reported data that pertain to the relationship between bilinguals' use of disambiguation and their knowledge of translation equivalents, with somewhat equivocal results. Houston-Price and colleagues (2010) reported a non-significant negative correlation between the number of translation equivalents bilinguals knew and their performance on a disambiguation task ($r(19)$ = -.29, p = .23). Frank and Poulin-Dubois (2002) tested children on a task related to disambiguation, their willingness to learn two labels for the same object. They also found a non-significant trend for the children who knew the fewest translation equivalents to be the most likely to avoid mapping two labels to the same object (27-month-olds: $r(24)$= -.27, p = .18; 35-month-olds: $r(26)$ = -.20, p = .30). While the correlations reported in these studies were in the predicted direction, there is thus far no statistically robust evidence that bilinguals' knowledge of translation equivalents influences their use of disambiguation.

The current study sought to examine whether the development of disambiguation is influenced by children's experience with language as a one-to-one versus a many-to-one mapping system by investigating the relationship between bilingual's knowledge of translation equivalents and their use of disambiguation. We studied Chinese-English bilingual infants' disambiguation in a preferential looking task, in which infants heard a novel word and their looking at a novel picture over a familiar distracter was measured (see Byers-Heinlein & Werker, 2009; Halberda, 2003; Houston-Price et al., 2010 for studies using a similar method). To provide a more sensitive test than previous investigations, we studied bilingual infants at the lower limit of the age when monolingual infants reliably show disambiguation in this paradigm, 17-18 months.

We predicted that if experience with one-to-one mappings between words and their referents contributes to the development of disambiguation then 17-18 month-old bilinguals should show systematic variation in their use of disambiguation as a function of their knowledge of translation equivalents. We expected that bilingual infants whose lexicons contained a large proportion of translation equivalents would not show disambiguation, replicating previous results that averaged across bilingual infants (Byers-Heinlein & Werker, 2009; Houston-Price et al., 2010). Importantly, we also expected the novel result that those bilingual infants whose lexicons contained only a small proportion of translation equivalents would disambiguate a novel word, just like same-aged monolinguals. Finally we predicted specificity in this relationship, that bilingual infants' use of disambiguation would not be related to any other aspects of their vocabularies or individual language experience, and knowledge of translation equivalents would not be related to other tasks such as recognizing familiar words. A finding of a specific relationship between bilinguals' use of disambiguation and their knowledge of translation equivalents would be consistent with the lexicon structure hypothesis, that experience with language as

a one-to-one mapping system supports the development of disambiguation, while experience with language as a many-to-one mapping system does not.

Methods

Participants

A total of 20 (12 female) bilingual infants learning English and Chinese (either Cantonese or Mandarin) were included in the study, with a mean age of 17m27d (range: 17m17d to 18m12d). Eight additional infants were tested but excluded from the analyses because the infant was too restless or inattentive to complete the study (4), because the infant had a major health concern (2), or because the infant was not reported to understand any of the familiar English words used in the study (2). Infants were primarily recruited by approaching new parents at a maternity hospital in Vancouver, Canada, at the time of the infant's birth.

Language Background.

All infants came from homes where English and Chinese had been spoken regularly since the infant was born. Fifteen bilinguals were hearing English and Cantonese, and 5 were hearing English and Mandarin. Most parents were ethnically Chinese, and typically one or both parents was Canadian-born or had been born elsewhere but primarily educated in English. The Language Exposure Questionnaire was used to assess how often infants heard each language (Bosch & Sebastián-Gallés, 1997). On average, infants heard English 49% of the time (range: 27% to 75%) and Chinese 49% of the time (range: 25% to 73%). One infant heard a small amount of Korean (7%). To gauge infants' relative exposure to each language, a balance score was calculated for each infant as 50 minus the difference in exposure between the infants' two languages (e.g. infants with perfectly balanced exposure of 50/50 had a score of 50 – 50 = 0, while those with the largest imbalance of 75/25 had a score of 75 – 25 = 50). The mean balance score was 21 (SD = 12; range 0-47), meaning that

the average participant heard their dominant language 60.5% of the time and the other

language 39.5% of the time.

Materials

Vocabulary and Translation Equivalents Measures.

Estimates of infants' English vocabulary size were obtained by asking parents to

complete the Words and Gestures form of the MacArthur-Bates Communicative

Development Inventory (CDI; Fenson et al., 2007) which has shown high validity for

bilinguals (Marchman & Martinez-Sussman, 2002). Estimates of infants' Chinese

vocabularies were obtained via the Mandarin or Cantonese adaptation of the form as

appropriate (Tardif & Fletcher, 2008). The total number of items across the forms was

similar: 396 English, 410 Mandarin, and 388 Cantonese. The use of the Words and Gestures

form allowed measurement of both infants' comprehension and their production

vocabularies. One parent per infant completed the form in each language. Where possible,

this was the parent who was most familiar with the infant's vocabulary in that language,

thus infants varied as to whether the same parent or different parents completed the two

CDIs. In 4 cases, parents failed to return complete CDI forms for one or both languages.

These infants were excluded from the analyses that required CDI data, thus reducing the

sample size to 16 infants in these analyses.

A trilingual research assistant who was a native Cantonese-Mandarin bilingual and

had moved to an English-speaking country in childhood, identified word pairs in the English

and Chinese CDIs that were translation equivalents (e.g. English *dog* and Mandarin *gǒu*/

Cantonese *gáu*). She verified all English-Cantonese pairings with an English-Cantonese

bilingual, and all English-Mandarin pairings with an English-Mandarin bilingual. In some

cases, English and Chinese lexicalize the same concept differently. For example, whereas

English has the single word *brother*, Mandarin has separate words *gēge* for older brother

and *dìdi* for younger brother. Thus, if the child knew the English word *brother* and the

Mandarin words *gēge* and *dìdi*, these three words counted as two pairs because they

lexicalize two different concepts. A total of 297 English-Cantonese pairs and 294 English-

Mandarin pairs were identified.

Stimuli.

Visual stimuli consisted of four brightly-colored objects, three familiar (ball, car, and

shoe) and one novel. The novel object was a slightly modified version of a phototube from

the TarrLab Object DataBank (1996). The objects were presented on a black background in

yoked pairs: car-ball and phototube-shoe. The yoked presentation of the objects followed

the procedure used by several previous studies of disambiguation in infants of this age

(Byers-Heinlein & Werker, 2009; Halberda 2003). The objects appeared in different colors

on different trials to maintain infant interest, and to ensure that infants generalized across

different-colored exemplars of the same category.

All auditory stimuli were recorded in English by a female native speaker.

Conventional English labels were recorded for the familiar objects – *ball*, *car*, and *shoe*. The

nonce word *nil* was recorded as the novel label for the phototube object because it is not a

possible Mandarin or Cantonese word, and although it is a real word for English-speaking

adults, it is unlikely that infants would be familiar with this word. On each trial, the label

was presented in a carrier phrase and then repeated in isolation (e.g., "Look at the ball!

Ball!"). Three different carrier phrases were used for each word, presented quasi-randomly

on different trials, "Look at the ___", "Find the ___", and "Where is the ___".

We examined infants' reported comprehension of the target words on the CDI to

ensure that they were indeed familiar. Comprehension of *ball*, *car*, and *shoe* ranged from 80-

100%. Although infants were never tested using Chinese stimuli, we also examined their

understanding of the Chinese translations of these words. Reported comprehension of the

translations ranged from 94-100% of infants. Therefore, the vast majority of infants were reported to understand the test words in both English (the language of testing) and in Chinese.

Apparatus.

Data were collected using a Tobii 1750 eye tracking system, consisting of a 17" LCD monitor for the presentation of visual stimuli with a built-in eye tracking camera that sampled at a rate of 50 Hz using a corneal reflection technique. Auditory stimuli were presented via computer speakers located behind a black cardboard panel, on either side of the eye tracker. A PC computer running the Tobii Clearview software program both controlled the stimulus presentation and collected the eye tracking data.

Procedure

The experimental procedure followed Halberda (2003), and was identical to Byers-Heinlein & Werker (2009). Infants were tested in a dimly lit, sound-attenuated room. The experimenter controlled the study from a computer and a closed-circuit TV monitor, located in a screened-off area of the same room. Before commencing the study, the experimenter settled the infant on the parent's lap, and positioned the eye tracking monitor approximately 60cm away from the infant's eyes. Parents wore a blindfold or closed their eyes for the duration of the study to avoid influencing the infant. The experimenter first carried out a built-in five-point infant calibration routine, and then began the experimental procedure.

At the beginning of testing, each infant saw a warm-up trial during which a spinning waterwheel appeared sequentially on each side of the monitor. Test trials began immediately following the warm-up. On each trial, infants' baseline preference for the object pair was measured in silence for 3 seconds. Next, an auditory stimulus was played that named one of the objects (e.g., "Look at the ball! Ball!"). The objects then remained in

silence on the monitor, yielding a total duration of 9.5 seconds. After the test phase of the

trial was completed, the unlabeled object disappeared, while the labeled object moved

around on the monitor for 2 seconds with accompanying music. Previous studies of word

comprehension have suggested that such visual feedback is effective to maintain infant

engagement in the task (Killing & Bishop, 2008). The results of past studies using the same

paradigm have found no evidence that this reinforcement drives infants' performance on

the task (Byers-Heinlein & Werker, 2009; Halberda, 2003).

Infants were presented with 24 test trials, in four blocks of six trials per block. The

first and third blocks consisted of known vs. known trials (ball-car), while the second and

fourth blocks consisted of known vs. novel trials (shoe-nil). Each object was labeled on half

of the trials in which it appeared, thus a total of six times. Trials where the familiar object

was named were called familiar label trials and trials where the novel object was named

were called disambiguation trials. Eight stimulus orders were created to counterbalance

side and order of presentation across infants, however the configuration of objects (e.g. ball

on left, car on right) was constant for each infant. A central circular attention-getter was

presented between trials to reorient infants to the screen. The total duration of the study

was approximately 7 minutes.

Infant eye-gaze data were collected by the eye tracker, and each data point was

classified as a look towards the left side object, a look towards the right side object, or

failure to look towards either object. Parents completed the questionnaires following the

experimental session.

<div align="center">**Results**</div>

Vocabulary Measures

Detailed descriptive statistics of infants' comprehension and production

vocabularies in both English and Chinese are presented in Table 1. English and Chinese

vocabularies were calculated by counting the number of words the child was reported to understand and say on the corresponding forms. Total vocabulary was calculated by summing the words the child knew in English and in Chinese. The percentage of infants' vocabularies that constituted translation equivalents was calculated by taking the total number of words for which the infant knew a translation equivalent (each word in a pair such as *dog* and *gǒu* was counted separately), and dividing by the total vocabulary size (see also De Houwer et al., 2006; Pearson et al., 1995 for alternate methods of quantifying translation equivalents). All infants had at least some translation equivalents in their comprehension vocabularies, and all but two had translation equivalents in their productive vocabularies. The total conceptual vocabulary was calculated as the total vocabulary minus the number of redundant words whose meaning was captured by its translation equivalent, providing an index of the number of meanings lexicalized by the infant (Pearson et al., 1993). Thus if the infant knew both *dog* and its translation *gǒu*, this would count for only one concept.

Relationships amongst vocabulary measures were examined. There was a significant correlation between English comprehension and English production, $r(14) = .69$, $p = .003$, but not between Chinese comprehension and Chinese production, $r(14) = .10$, $p = .70$. Children were reported to understand on average 54 ($SD = 95$) more words in Chinese than in English, which was a statistically significant difference $t(15) = 2.249$, $p = .04$, $d = .56$. Infants were reported to produce 10 ($SD = 29$) more words in English than in Chinese, but this difference was not significant, $t(14) = 1.30$, $p = .21$, $d = .33$. No significant correlation was found between comprehension and production for infants' total vocabularies, $r(14) = .25$, $p = .36$, or for their total conceptual vocabularies, $r(14) = .27$, $p = .32$. Further, there was no significant correlation between the number of translation equivalents infants were reported to understand and the number they could produce, $r(14) = .21$, $p = .44$.

Table 1

Infants' Vocabulary Means, Standard Deviations, and Ranges in both Comprehension and

Production Across Several Measures. Missing data were excluded listwise

	Comprehension		Production	
	Mean *(SD)*	Range	Mean *(SD)*	Range
English vocabulary	144 *(76)*	26-255	36 *(29)*	3-109
Chinese vocabulary	198 *(71)*	67-287	26 *(26)*	0-101
Total vocabulary	341 *(112)*	165-496	61 *(47)*	5-155
Total conceptual vocabulary	260 *(68)*	140-351	53 *(40)*	5-132
% words with a known translation equivalent	46 *(14)*	17-66	26 *(17)*	0-71

Experimental Task

As in previous studies (e.g. Byers-Heinlein & Werker, 2009), an analysis window of 360-2000ms after the onset of the target word was identified based on the minimum time needed to process a word and initiate an eye movement (Dahan, Swingley, Tanenhaus, & Magnuson, 2000), and the typical length of time that infants sustain fixation after responding to a word (Dahan et al., 2000; Fernald, Perfors, & Marchman, 2006; Swingley, Pinto, & Fernald, 1999). Infants' responses on familiar label and disambiguation trials were analyzed only in this time window. Any trial where the infant looked 750ms or less at the objects was excluded from the analyses.

An individual baseline score was calculated for each infant, as the proportion of time the infant looked at a particular object during the 3 second silent baseline period, averaged across all trials in which that object was onscreen. Trials during which the infant looked less

than 1 out of the 3 seconds were excluded from the calculation. Infants tended to show

more interest during baseline to the familiar objects as opposed to the novel object, $t(19)$ =

3.00, p = .007, d = .67, a pattern reported in numerous previous studies that have used

similar paradigms (e.g. Byers-Heinlein & Werker, 2009; Mather & Plunkett, 2009; Schafer,

Plunkett, & Harris, 1999; White & Morgan, 2008). Thus, to control for inherent baseline

preferences as in previous work (e.g. Byers-Heinlein & Werker, 2009; Halberda, 2003;

White & Morgan, 2008), all subsequent analyses were conducted with difference scores,

which subtracted infants' individual baseline preference from the proportion of time they

looked at the target object after labeling. A positive difference score therefore indicated

increased looking at the target object after labeling.

      Familiar label trials were analyzed first. A preliminary between-subjects ANOVA

showed that infants' performance on familiar label trials did not vary as a function of object,

$F(2, 38)$ = 1.86, p =. 17, η^2_p = .089, therefore data were collapsed across the three familiar

objects. A one-tailed t-test indicated that infants significantly increased their looking

towards the familiar target upon hearing its label, M = .072, SD = .15, $t(19)$ = 2.15, p = .023, d

= .48. Next, a one-tailed analysis was performed on disambiguation trials to examine

whether, as a group, infants oriented to the novel object upon hearing the novel label.

Replicating previous results, as a group, Chinese-English bilinguals did not show

disambiguation, as there was no significant increase in looking at the novel object upon

hearing the novel label, M = .060, SD = .30, $t(19)$ = .89, p = .19, d = .20. Finally, a correlation

was computed between infants' performance on familiar label and disambiguation trials. No

significant correlation was found, $r(18)$ = -.25, p = .29.

Relationship of Performance to Knowledge of Translation Equivalents

The main hypothesis was that infants' use of disambiguation would be related to their knowledge of translation equivalents. We focused on comprehension of translation equivalents, rather than production of translation equivalents, because comprehension indexes all of the words for which infants have a lexical representation. Three predictions were tested: 1) infants who knew the smallest proportion of translation equivalents would show the best performance on disambiguation trials, 2) knowledge of translation equivalents would not be related to performance on familiar label trials, and 3) performance on novel label trials would not be related to any other individual variable (e.g. vocabulary size, percent exposure to English).

Pearson correlations were computed between infants' performance on both disambiguation and familiar label trials, and all individual variables related to vocabulary size and language exposure (see Table 2 for the correlations discussed below; a complete table of correlations between these variables is available in the online supplementary materials). Correlations were tested for statistical significance both using the traditional parametric technique for computing p-values, and also using an empirical bootstrapping technique for computing 95% confidence intervals. The latter were computed using the boot function in the R statistical package (Canty & Ripley, 2011; Davison & Hinkley, 1997) with 1000 bootstrap replicates per correlation. As predicted, a significant negative correlation indicated that bilingual infants who knew a smaller percentage of translation equivalents showed significantly better performance on disambiguation trials, $r(14) = -.55$, $p = .026$. Further, as predicted, there was no significant correlation between infants' knowledge of translation equivalents and their performance on familiar label trials, $r(14) = .24$, $p = .37$. Their performance on disambiguation trials was also not significantly correlated with any other measure, including vocabulary size in English or Chinese, total vocabulary

size, total conceptual vocabulary size, percent of exposure to each language, or balance of

exposure to each language. Bootstrapped confidence intervals are reported in Table 2, and

they were consistent with the parametric analysis. Namely, those correlations that had a

parametrically-estimated p-value less than .05 had an empirically-estimated confidence

interval that did not contain zero, while those correlations that had parametrically-

estimated p-values greater than .05 had empirically-estimated confidence intervals that did

contain zero.

Table 2

Correlations Between Language Measures in Comprehension Vocabulary and Performance on

Disambiguation and Familiar Label Trials

	Familiar label trial performance		Disambiguation trial performance	
	Pearson's r	Bootstrapped 95% CI	Pearson's r	Bootstrapped 95% CI
% Translation equivalents	.24	[-.46, .66]	-.55*	[-.81, -.14]
English comprehension	.36	[-.31, .76]	-.17	[-.67, .34]
Chinese comprehension	.11	[-.31, .48]	-.31	[-.63, .38]
Total comprehension	.31	[-.14, .67]	-.31	[-.65, .085]
Total conceptual comprehension	.32	[-.10, .66]	-.22	[-.59, .16]
% English exposure	.33	[-.02, .64]	-.09	[-.56, .43]
Balance score	.24	[-.30, .70]	-.12	[-.59, .42]

Note: Bootstrapped 95% confidence intervals showed the same results as

parametrically-derived *p*-values.

p < .05.

As a further test of the main hypothesis, data were analyzed following a median split of the proportion of translation equivalents known by each infant. A low-overlap group of 8 infants was reported to know translation equivalents for less than 50%[1] of their vocabularies (M = 34%), and a high-overlap group of 8 infants knew translation equivalents for 50% or more of their vocabularies (M = 58%). As predicted, on disambiguation trials, the low-overlap group was significantly more likely to disambiguate the novel label than the high-overlap group, $t(14)$ = 3.52, p = .003, d = .18, one-tailed (these data are plotted in Figure 1). Infants in the low-overlap group successfully disambiguated the novel label by increasing looking at the novel object, M = .26, SD = .18, $t(7)$ = 3.89, p = .003, d = 1.44, one-tailed. The infants in the high-overlap group did not show disambiguation as they somewhat decreased attention to the novel object upon hearing the novel label, M = -.17, SD = .29, $t(7)$ = -1.68, ns, one-tailed. Seven out of 8 infants in the low-overlap group had a positive difference score indicating disambiguation, while only 3 out of 8 infants in the high-overlap group showed disambiguation. This difference was statistically significant in a chi-squared test, $\chi^2(1, N = 16)$ = 4.27, p = .039.

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[1] The exact value of the median score was 47%. However, as there were no infants with scores between 47% and 50%, 50% was used as the nominal cutoff.
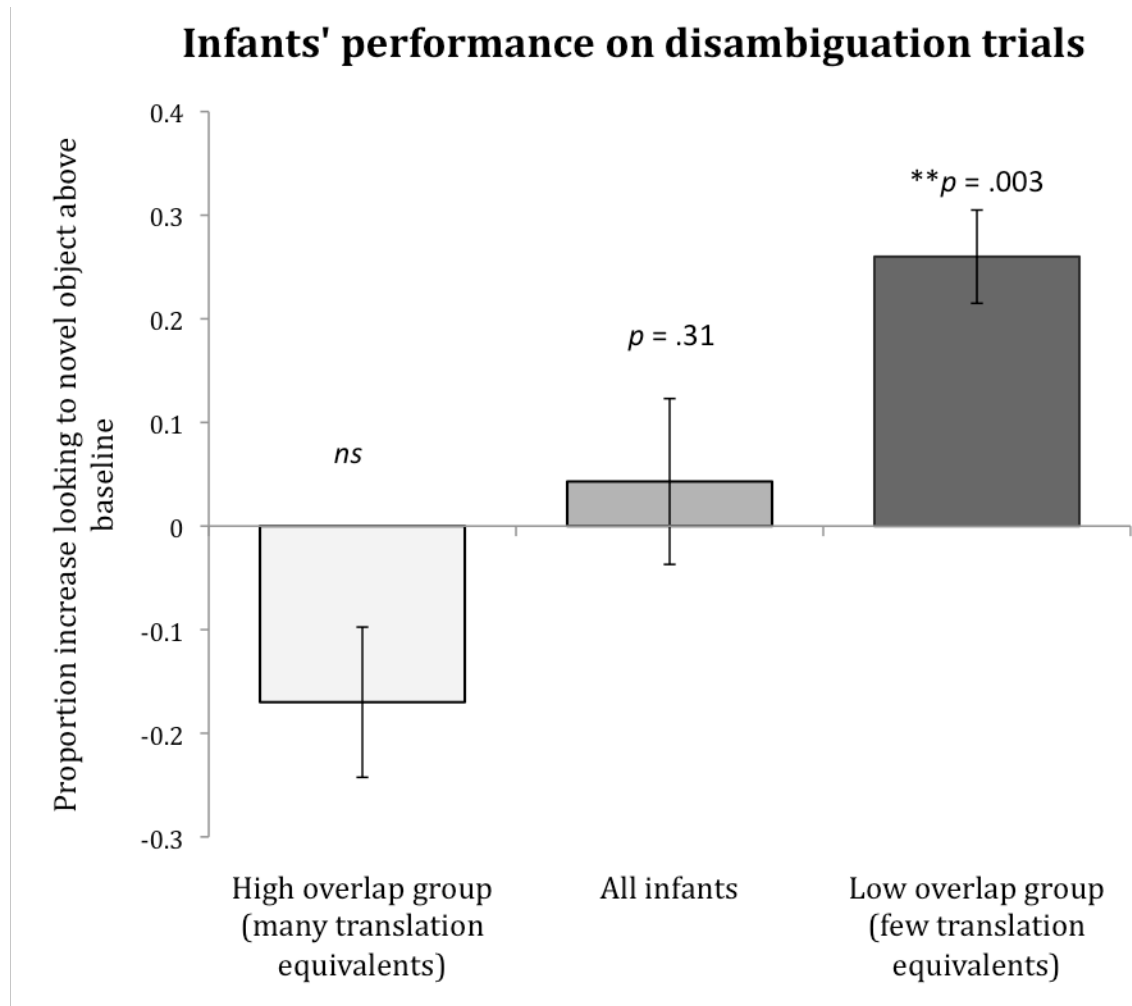
Infants' performance on disambiguation trials

Figure 1 . Bilinguals' average performance on disambiguation label trials, and as a function of overlap group. Longer looking to the novel object (higher proportion) suggests use of disambiguation. T-tests are one-tailed. Error bars represent the standard error of the mean.

Discussion

The current study investigated how early language influences the development of the disambiguation word learning heuristic, infants' tendency to infer that a novel noun refers to a novel rather than with a familiar object. We predicted that bilingual infants' use

of disambiguation would be related to the extent to which their lexicons had a one-to-one

versus a many-to-one mapping structure as operationalized by their knowledge of

translation equivalents. Seventeen and 18-month-old Chinese-English bilingual infants

participated in a preferential looking study conducted in English. Familiar label control

trials asked infants to find the referent of a known noun (e.g. "Look at the ball!"), and infants

were successful on these trials. Disambiguation trials asked infants to find the referent of a

novel noun (e.g. "Look at the nil!") when presented with a novel object and a familiar

distracter. As a group, bilingual infants did not show a significant tendency to disambiguate

the novel noun, replicating previous results (Byers-Heinlein & Werker, 2009; Houston-Price

et al., 2010). However, as predicted, bilingual infants' performance was not homogeneous.

Those infants whose vocabularies contained a smaller proportion of translation equivalents

(< 50%; low-overlap group whose lexicons had primarily a one-to-one structure)

disambiguated the referent of the novel noun, while those whose vocabularies contained a

larger proportion of translation equivalents (> 50%; high-overlap group whose lexicons had

primarily a many-to-one structure) did not. This pattern of difference was robust across

numerous analyses, including correlation, median-split, and chi-squared tests. These results

support the position that infants' knowledge of one-to-one mappings between words and

their referents contributes to their use of disambiguation.

As discussed in the Introduction, several previous studies did not find a significant

correlation between infants' knowledge of translation equivalents and their performance in

disambiguation and related tasks (i.e. Frank & Poulin-Dubois, 2002; Houston-Price et al.,

2010). However, all three correlations reported in these previous studies were in the

predicted negative direction: children who knew more translation equivalents showed less

disambiguation or related behaviors. Thus, from an effects size perspective, the current

results are largely consistent with previous work, albeit with a larger effect. One reason our

results reached statistical significance and those from the previous studies did not, could be

that our infants were younger on average than those in the previous studies. As discussed

later in this paper, by older ages bilingual children do eventually develop disambiguation.

Testing infants in a narrow age window during which monolinguals are known to develop

disambiguation could have increased our power to detect an effect.

It is important for the current interpretation that the data showed specificity in the

relationship between infants' knowledge of translation equivalents and their use of

disambiguation. We found no significant correlation between disambiguation and any other

language measure including amount of exposure to each language, balance of exposure

between the two languages, total vocabulary size, total conceptual vocabulary size, and

vocabulary size in each language. Further, infants' ability to perform a preferential looking

task did not account for the main finding, as infants successfully looked to the familiar

object in response to its label, and performance on disambiguation trials was not correlated

with performance on familiar label trials. Performance on familiar label trials also did not

vary as a function of the proportion of translation equivalents infants knew, suggesting that

knowledge of translation equivalents affected performance on disambiguation trials

specifically, and not on the task in general. Thus, while it is impossible to entirely rule out a

third-variable explanation, particularly given our sample size, we do not find support for

such an explanation in the current data.

Another alternate explanation is that disambiguation and knowledge of translation

equivalents are correlated because bilinguals who adhere strongly to disambiguation avoid

learning translation equivalents, while those who have not developed the disambiguation

heuristic do not. However, this explanation does not predict the overall differences between

monolingual and bilingual infants' use of disambiguation at this age (Byers-Heinlein &

Werker, 2009; Houston-Price et al., 2010). If disambiguation develops independently of

language experience, one would expect just as much individual variation amongst

monolinguals as bilinguals, and thus no group differences. The most parsimonious

explanation for both results is that bilingual infants' knowledge of translation equivalents

underlies both group differences between monolingual and bilingual infants' use of

disambiguation, as well as individual differences amongst bilinguals.

Having ruled out several alternate explanations, we interpret these findings as

support for the lexicon structure hypothesis (Byers-Heinlein & Werker, 2009), that the

development of disambiguation is supported by infants' learning of one-to-one mappings

between words and concepts. For monolinguals, knowledge of one-to-one mappings

increases as their vocabularies grow, explaining why disambiguation and vocabulary size

are correlated in monolingual infants (Bion et al., 2013; Houston-Price et al., 2010; Graham

et al., 1998; Mervis & Bertrand, 1994). Bilinguals regularly learn translation equivalents,

which result in a vocabulary that is characterized by many-to-one mappings between words

and concepts. Our finding that bilinguals do not show disambiguation from the same age as

monolinguals unless they happen to have learned relatively few translation equivalents is

consistent with this interpretation. Our results clarify previous findings with respect to

bilinguals' use of disambiguation. We have demonstrated that the development of

disambiguation is not affected by the learning of two language systems per se, but by the

structure of individual infants' lexicons as they learn words and build their vocabularies

(see also McMurray et al., 2012, for a computational model congruent with the current

empirical results).

A possibility that cannot be ruled out by the current data is that experience instead

influences whether infants use an already-available heuristic (e.g. Markman, 1992). The

current study tested infants at ages 17-18 months as this is the youngest age at which

disambiguation has been reliably shown by monolinguals. If disambiguation does indeed

first develop at this age, then demonstrated differences between monolinguals and bilinguals support the position that the learning of one-to-one mappings is important during the initial development of disambiguation. Yet, there are some hints of early precursors to disambiguation in children who are less than a year old (Dewar & Xu, 2007; Mather & Plunkett, 2010; Xu, Cote, & Baker, 2005). At the same time, these results have been difficult to reconcile with other studies in which 1- and 1.5-year-olds are unsuccessful in disambiguation tasks (Halberda, 2003; Bion et al., 2013). If it is eventually confirmed that infants younger than 17-18 months do show disambiguation, it would be essential to compare monolingual and bilingual infants younger than 17-18 months to investigate whether these groups also differ at earlier ages.

The lexicon structure hypothesis is not the first developmental account of disambiguation to emphasize the role of early word learning. In their novel-name-nameless-category (N3C) account, Mervis and Bertrand (1994) put forward the notion that disambiguation develops when children have the insight that each object has a name. Under N3C, children's seek out a "novel name" when they see an object that exemplifies a "nameless category". However, N3C is not consistent with the current results. The N3C account predicts that just like monolinguals, bilinguals should develop disambiguation as their vocabularies grow, because encountering multiple labels for each object does not negate the notion that each object should have a name. Thus, N3C would predict individual differences amongst bilinguals as a function of their vocabulary size, but not as a function of their knowledge of translation equivalents.

Disambiguation beyond infancy

While this and other studies (Byers-Heinlein & Werker, 2009; Houston-Price et al., 2010) have demonstrated that some bilinguals do not use disambiguation in infancy, there is considerable evidence that older bilinguals do use disambiguation and related word

learning heuristics, although in some cases less consistently than same-aged monolinguals do (Byers-Heinlein et al., under review; Davidson et al., 1997; Davidson & Tell, 2005; Diesendruck, 2005; Frank & Poulin-Dubois, 2002; Merriman & Kutlesic, 1993). Further, there is some evidence that early differences between monolingual and bilingual children's use of disambiguation attenuate across development (Bialystok et al., 2010). How might we reconcile these findings with older bilingual children from our claim that the structure of the lexicon influences the development of disambiguation?

Monolingual children's disambiguation abilities become increasingly sophisticated over development. Thirty-month-old monolinguals, but not younger children, are able to retain mappings between words and objects established through disambiguation (Bion et al., 2013; Horst & Samuelson, 2008). By age 3 children can disambiguate not only the meaning of a novel noun, but also the meaning of a novel verb (Golinkoff, Jacquet, Hirsh-Pasek, & Nandakumar, 1996). Further, preschool children are able to integrate multiple sources of information in their use of disambiguation, for example taking into account information about the class of a word (i.e. count nouns versus proper nouns; Hall, Quantz, & Persoage, 2000). Preschoolers are also able to consider pragmatic information, such as a speaker's knowledge or ignorance, in disambiguating a novel noun (Diesendruck, 2005; Diesendruck, Hall, & Graham, 2006; Diesendruck & Markson, 2001).

It may be that this emerging ability to integrate information from multiple sources eventually allows bilingual children to notice that words and concepts have a one-to-one structure *in each language*. And indeed, preschool and school-aged bilinguals tend to associate a novel noun with a novel object only when the distracter object has a label in that same language (within-language disambiguation), but not when two labels are in different languages (between-language disambiguation; Au & Glusman, 1990). As the lexicon continues to develop (see Curtin, Byers-Heinlein, & Werker, 2011, for a recent discussion of

the organization of the bilingual lexicon), an explicit understanding that they are learning

two languages emerges in bilingual children (see Genesee, Nicoladis, & Paradis, 1995;

Genesee, Boivin, & Nicoladis, 1996, for evidence of pragmatic differentiation of their two

languages by bilingual toddlers). At this point, the structure of their dual lexicon might

support the use of disambiguation appropriately within a language, and may even help

bilingual children actively seek translation equivalents for words they already know and to

learn new words (see Poulin-Dubois, Bialystok, Blaye, Polonia, & Yott, 2013, for work

relating knowledge of translation equivalents to speed of lexical access in bilingual

toddlers).

Conclusions and Future Directions

Our results provide convincing support that the structure of the emerging lexicon in

infancy influences the use of disambiguation. Left unanswered is whether experience

learning words with one-to-one mappings is sufficient for the development of a

disambiguation heuristic (as experience is claimed to be for the development of a shape bias

in early vocabulary, e.g. Perry & Samuelson, 2011), or whether experience works in tandem

with a more general cognitive bias that might be available to both humans and animals (e.g.

MacWhinney, 1989; Markman, 1992). Our results have also raised questions about how

metalinguistic knowledge influences children's use of disambiguation, for example

bilinguals' eventual ability to use disambiguation appropriately in each language.

Subsequent research investigating learners with different types of experience, and at

younger and older ages, will be helpful in pursuing these exciting questions.

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References

Au, T. K., & Glusman, M. (1990). The principle of mutual exclusivity in word learning: To honor or not to honor? *Child Development, 61*(5), 1474-1490. doi:10.1016/j.jecp.2005.03.007

Baldwin, D. A., & Moses, L. J. (2001). Links between social understanding and early word learning: Challenges to current accounts. *Social Development*, *10*(3), 309-329. doi: http://doi.wiley.com/10.1111/1467-9507.00168

Bialystok, E., Barac, R., Blaye, A., & Poulin-Dubois, D. (2010). Word mapping and executive functioning in young monolingual and bilingual children. *Journal of Cognition and Development, 11,* 485-508. doi: 10.1080/15248372.2010.516420

Bion, R., Borovsky, A., & Fernald, A. (2013). Fast mapping, slow learning: Disambiguation of novel word-object mappings in relation to vocabulary learning at 18, 24, and 30 months. *Cognition, 126*(1), 39-53. doi: 10.1016/j.cognition.2012.08.008

Bosch, L., & Sebastián-Gallés, N. (1997). Native-language recognition abilities in 4-month-old infants from monolingual and bilingual environments. *Cognition, 65*(1), 33-69. doi:10.1016/S0010-0277(97)00040-1

Byers-Heinlein, K., Chen, K., & Xu, F. (under review). *Surmounting the Tower of Babel: Monolingual and bilingual 2-year-olds' understanding of the nature of foreign languages.*

Byers-Heinlein, K., & Werker, J. F. (2009). Monolingual, bilingual, trilingual: infants' language experience influences the development of a word learning heuristic. *Developmental Science, 12*(5), 815-823. doi:10.1111/j.1467-7687.2009.00902.x

Canty, A., & Ripley, B. (2011). Boot: Boostrap R (S-Plus) Functions. R package version 1.3-2

Carey, S., & Bartlett, E. (1978). Acquiring a single new word. *Papers and Reports on Child Language Development, 15*, 17-29.

Clark, E. V. (1987). The principle of contrast: A constraint on language acquisition. In B.

    MacWhinney (Ed.), *Mechanisms of language acquisition* (pp. 1-33). Hillsdale, NJ, USA:

    Lawrence Erlbaum Associates, Inc.

Clark, E. V. (1990). On the pragmatics of contrast. *Journal of Child Language, 17*(2), 417-431.

    10.1017/S0305000900013842

Clark, E. V. (1993). *The lexicon in acquisition*. New York, NY US: Cambridge University Press.

Curtin, S., Byers-Heinlein, K., & Werker, J.F. (2011). Bilingual beginnings as a lens for theory

    development: PRIMIR in focus. *Journal of Phonetics, 29*, 492-504.

    doi:10.1016/j.wocn.2010.12.002

Dahan, D., Swingley, D., Tanenhaus, M. K., & Magnuson, J. S. (2000). Linguistic gender and

    spoken-word recognition in French. *Journal of Memory and Language, 42*(4), 465-480.

    doi:10.1006/jmla.1999.2688

Davison, A. C., & Hinkley, D. V. (1997). *Bootstrap methods and their applications*. Cambridge

    University Press, Cambridge.

David, A., & Wei, L. (2008). Individual differences in the lexicl development of French-

    English bilingual children. *International Journal of Bilingual Education and Bilingualism,

    11*(5), 598-618.

Davidson, D., Jergovic, D., Imami, Z., & Theodos, V. (1997). Monolingual and bilingual

    children's use of the mutual exclusivity constraint. *Journal of Child Language, 24*(1), 3-

    24. doi:10.1017/S0305000996002917

Davidson, D., & Tell, D. (2005). Monolingual and bilingual children's use of mutual

    exclusivity in the naming of whole objects. *Journal of Experimental Child Psychology,

    92*(1), 25-45. doi:10.1016/j.jecp.2005.03.007

De Houwer, A., Bornstein, M. H., & De Coster, S. (2006). Early understanding of two words

    for the same thing: A CDI study of lexical comprehension in infant bilinguals.

International Journal of Bilingualism, 10(3), 331-347.

doi:10.1177/13670069060100030401

Dewar, K., & Xu, F. (2007). Do 9-month-old infants expect distinct words to refer to kinds?

Developmental Psychology, 43(5), 1227-1238. doi:10.1037/0012-1649.43.5.1227

Diesendruck, G. (2005). The principles of conventionality and contrast in word learning: An

empirical examination. *Developmental Psychology, 41*(3), 451-463. doi:10.1037/0012-

1649.41.3.451

Diesendruck, G., Hall, D. G., & Graham, S. A. (2006). Children's use of syntactic and pragmatic

knowledge in the interpretation of novel adjectives. *Child Development, 77*(1), 16-30.

doi:10.1111/j.1467-8624.2006.00853.x

Diesendruck, G., & Markson, L. (2001). Children's avoidance of lexical overlap: A pragmatic

account. *Developmental Psychology, 37*(5), 630-641. doi:10.1037/0012-1649.37.5.630

Fenson, L., Marchman, V. A., Thal, D., Dale, P. S., Bates, E., & Reznick, J. S. (2007). *MacArthur-*

Bates communicative development inventories (CDIs) (2nd ed.). Baltimore: Brookes

Publishing.

Fernald, A., Perfors, A., & Marchman, V. A. (2006). Picking up speed in understanding:

Speech processing efficiency and vocabulary growth across the 2nd year.

Developmental Psychology, 42(1), 98-116. doi:10.1037/0012-1649.42.1.98

Frank, M. C., Goodman, N. D., & Tenenbaum, J. B. (2009). Using speakers' referential

intentions to model early cross-situational word learning. *Psychological Science, 20,*

578-585. doi: 10.1111/j.1467-9280.2009.02335.x

Frank, I., & Poulin-Dubois, D. (2002). Young monolingual and bilingual children's responses

to violation of the mutual exclusivity principle. *International Journal of Bilingualism,*

6(2), 125-146. doi:10.1177/13670069020060020201

Genesee, F., Boivin, I., & Nicoladis, E. (1996). Talking with strangers: A study of bilingual children's communicative competence. *Applied Psycholinguistics, 17*(4), 427-442. doi:10.1017/S0142716400008183

Genesee, F., Nicoladis, E., & Paradis, J. (1995). Language differentiation in early bilingual development. *Journal of Child Language, 22*(3), 611-631.

Golinkoff, R. M., Jacquet, R. C., Hirsh-Pasek, K., & Nandakumar , R. (1996). Lexical principles may underlie the learning of verbs. *Child Development, 67*(6), 3101-3119. doi:10.1111/j.1467-8624.1996.tb01905.x

Graham, S. A., Poulin-Dubois, D., & Baker, R. K. (1998). Infants' disambiguation of novel object words. *First Language, 18,* 149-164. doi:10.1177/014272379801805302

Halberda, J. (2003). The development of a word-learning strategy. *Cognition, 87*(1), B23-B34. doi:10.1016/S0010-0277(02)00186-5

Hall, D. G., Quantz, D. H., & Persoage, K. A. (2000). Preschoolers' use of form class cues in word learning. *Developmental Psychology, 36*(4), 449-462. doi:10.1111/1467-8624.00622

Horst, J. S., McMurray, B., & Samuelson, L. K. (2006). Online processing is essential for learning: Understanding fast mapping and word learning in a dynamic connectionist architecture. In R. Sun (Ed.). *Proceedings from the 28th meeting of the Cognitive Science Society* (pp. 339-344).

Horst, J. S., & Samuelson, L. K. (2008). Fast mapping but poor retention by 24-month-old infants. *Infancy, 13*(2), 128-157. doi: 10.1080/15250000701795598

Horst, J. S., Samuelson, L. K., Kucker, S. C., & McMurray, B. (2011). What's new? Children prefer novelty in referent selection. *Cognition*, *118,* 234-244. Doi: 10.1016/j.cognition.2010.10.015

Houston-Price, C., Caloghiris, Z., & Raviglione, E. (2010). Language experience shapes the development of the mutual exclusivity bias. *Infancy, 15,* 125-150. doi:10.1111/j.1532-7078.2009.00009.x

Killing, S. E. A., & Bishop, D. V. M. (2008). Move it! Visual feedback enhances validity of preferential looking as a measure of individual differences in vocabulary in toddlers. *Developmental Science, 11*(4), 525-530. doi:10.1111/j.1467-7687.2008.00698.x

MacWhinney, B. (1989). Competition and lexical categorization. In *Linguistic Categorization* (Corrigan R., et al., eds) p. 195-241, John Benjamin.

Marchman, V. A., & Martinez-Sussman, C. (2002). Concurrent validity of caregiver/parent report measures of language for children who are learning both English and Spanish. *Journal of Speech, Language, & Hearing Research, 45*(5), 983-997. doi:10.1044/1092-4388(2002/080)

Markman, E. M. (1992). Constraints on word learning: Speculations about their nature, origins, and domain specificity. In M. R. Gunnar, M. Maratsos, M. R. Gunnar, M. Maratsos (Eds.) , *Modularity and constraints in language and cognition* (pp. 59-101). Hillsdale, NJ England: Lawrence Erlbaum Associates, Inc.

Markman, E. M., & Wachtel, G. F. (1988). Children's use of mutual exclusivity to constrain the meanings of words. *Cognitive Psychology, 20*, 121-157. doi:10.1016/0010-0285(88)90017-5

Markman, E. M., Wasow, J. L., & Hansen, M. B. (2003). Use of the mutual exclusivity assumption by young word learners. *Cognitive Psychology, 47*(3), 241-275. doi:10.1016/S0010-0285(03)00034-3

Mather, E., & Plunkett, K. (2009). Learning words over time: The role of stimulus repetition in mutual exclusivity. *Infancy, 14*(1), 60-76.

Mather, E., & Plunkett, K. (2010). Novel labels support 10-month-olds' attention to novel objects. *Journal of Experimental Child Psychology, 105,* 232-242. doi: 10.1016/j.jecp.2009.11.004

McMurray, B., Horst, J.S., & Samuelson, L.K. (2012). Word learning emerges from the interaction of online referent selection and slow associative learning. *Psychological Review, 119*(4), 831-877. doi: 10.1037/a0029872

Merriman, W. (1999). Competition, attention, and young children's lexical processing. In B, MacWhinney. *The Emergence of Language* (pp. 331-358). Hillsdale, NJ: Erlbaum.

Merriman, W. E., & Kutlesic, V. (1993). Bilingual and monolingual children's use of two lexical acquisition heuristics. *Applied Psycholinguistics, 14*(2), 229-249. doi:10.1016/j.jecp.2005.03.007

Mervis, C. B., & Bertrand, J. (1994). Acquisition of the novel name-nameless category (N3C) principle. *Child Development, 65*(6), 1646-1662. doi:10.2307/1131285

Pearson, B. Z., Fernández, S., & Oller, D. K. (1993). Lexical development in bilingual infants and toddlers: Comparison to monolingual norms. *Language Learning, 43*(1), 93-120. doi:10.1111/j.1467-1770.1993.tb00174.x

Pearson, B. Z., Fernández, S., & Oller, D. K. (1995). Cross-language synonyms in the lexicons of bilingual infants: One language or two? *Journal of Child Language, 22*(2), 345-368. doi:10.1017/S030500090000982X

Perry, L. K., & Samuelson, L. K. (2011). The shape of the vocabulary predicts the shape of the bias. *Frontiers in Psychology*, *2*(345). doi: 10.3389/fpsyg.2011.00345

Poulin-Dubois, D., Bialystok, E., Blaye, A., Polonia, A., & Yott, J. (2013). Lexical access and vocabulary development in very young bilinguals. *International Journal of Bilingualism*, *17*, (1), 57-70. doi: 10.1177/1367006911431198.

Regier, T. (1996). *The Human Semantic Potential: Spatial Language and Constrained Connectionism,* MIT Press.

Regier, T. (2003). Emergent constraints on word-learning: A computational perspective. *Trends in Cognitive Sciences, 7*(6), 263-268. doi:10.1016/S1364-6613(03)00108-6

Schafer, G., Plunkett, K., & Harris, P. L. (1999). What's in a name? Lexical knowledge drives infants' visual preferences in the absence of referential input. *Developmental Science, 2*(2), 187-194. doi:10.1111/1467-7687.00067

Sheng, L., Lu, Y., & Kan, P.F. (2011). Lexical development in Mandarin-English bilingual children. *Bilingualism: Language and Cognition, 14*(4), 579-587. doi: 10.1017/S1366728910000647

Smith, L. B., & Yu, C. (2008). Infants rapidly learn word-referent mappings via cross-situational statistics. *Cognition, 106*(3), 1558-1568. doi:10.1016/j.cognition.2007.06.010

Swingley, D. (2010). Fast mapping and slow mapping in children's word learning. *Language Learning and Development, 6*, 179-183. doi: 10.1080/15475441.2010.484412

Swingley, D., Pinto, J. P., & Fernald, A. (1999). Continuous processing in word recognition at 24 months. *Cognition, 71*(2), 73-108. doi:10.1016/S0010-0277(99)00021-9

Tardif, T., & Fletcher, P. (2008). *Chinese communicative development inventories user's guide and manual.* Beijing: Peking University Medical Press.

Umbel, V. M., Pearson, B. Z., Fernández, M. C., & Oller, D. K. (1992). Measuring bilingual children's receptive vocabularies. *Child Development, 63*(4), 1012-1020. doi:10.1111/j.1467-8624.1992.tb01678.x

Waxman, S. R., & Gelman, S. A. (2009). Early word-learning entails reference, not merely associations. *Trends in Cognitive Sciences, 13*(6), 258-263. doi:10.1016/j.tics.2009.03.006

White, K. S., & Morgan, J. L. (2008). Sub-segmental detail in early lexical representations. *Journal of Memory and Language, 59*(1), 114-132. doi:10.1016/j.jml.2008.03.001

Xu, F., Cote, M., & Baker, A. (2005). Labeling guides object individuation in 12-month-olds infants. *Psychological Science, 16*(5), 372-377. doi:10.1111/j.0956-7976.2005.01543.x