Numerical Morphology Supports Early Number Word Learning: Evidence from a Comparison of Young Mandarin and English Learners

Introduction

Word learning is a hard problem (e.g., Carey, 1978; Gleitman, 1990; Macnamara, 1972; Markman, 1989; Quine, 1960). Number word learning may seem to be an exception. Indeed, unlike all other words, number words are part of a structure, namely verbal counting, which, when understood, directly reveals their meaning. In other words, it may seem that the problem of number word learning reduces to learning to count, which English learning middle class children do shortly after their second birthday (Gelman and Gallistel, 1978). However, a large body of evidence shows that it is not so; number word meanings do not come for free upon learning to count. Rather, children learn the meanings of the number words for the first four numbers ("one" through "four" in English) in a drawn out process that takes over a year, and acquire the meanings of these four number words before they figure out the numerical significance of counting (Fuson, 1988; Le Corre, Van de Wall, Brannon, & Carey, 2006; Le Corre & Carey, 2007; Sarnecka and Lee, 2009, Wynn 1990, 1992). These facts suggest that children do not deduce the meaning of the first three or four number words from their understanding of counting.

The acquisition of the meanings of the number words for the first four numbers must be achieved simply by hearing the words used in contexts in which they refer to cardinal values of sets. Thus, factors which contribute to learning non-numerical words (e.g., nouns and verbs) could also contribute to number word learning. Much evidence suggests that knowledge of syntax and/or morphology scaffolds the acquisition of the meaning of non-numerical words such as proper names and count nouns (Barner and Snedeker, 2006; Gordon, 1985; Hall, Lee, Bélanger, 2001; Katz, Baker, Macnamara, 1974), adjectives (Waxman, 2002) and verbs (Gleitman, 1990; Fisher, Gleitman, & Gleitman, 1991). Bloom and Wynn (1997) suggested that something similar could be true for the acquisition of number word meanings, proposing that

English-learning children infer that each number word denotes a unique, exact numerosity from the fact that it is the only meaning that is consistent with the syntax and semantics of the different types of phrases where number words occur. Similarly, Barner and colleagues suggest that the distributional overlap between number words and quantifiers contributes to helping children discover the relevant semantic space for number word meanings (Barner, Chow, & Yang, 2009; Barner, Libenson, Cheung, & Takasaki, 2009).

Even more simply, number word learning may be supported by children's knowledge of the meaning of numerical morphology. In many languages, number is obligatorily marked on various parts of speech, most commonly on nouns and verbs (Corbett, 2000). For example, the distinction between singular and plural is marked on English count nouns and on English verbs. Other languages with obligatory numerical morphology make more extensive numerical distinctions. For example, Slovenian and the Najdi dialect of Saudi Arabic make a tripartite distinction between singular, dual and plural (Corbett, 2000; Almoammaer et al., 2013).

How could prior knowledge of the meaning of numerical morphology help children learn number word meanings? Consider the case of singular/plural in English. Given their meaning, singular nouns do not have to be used only when there is a single individual in the situation being talked about. For example, it is acceptable to say "There is a dog walking down the street" when, actually, multiple dogs are walking down the street. Also, when they fall within the scope of a quantifier (e.g., "A few/some/most of the children are eating a (different) hot dog"), singular nouns can be used in situations that involve more than one individual of the type designated by the noun. As for plurals, it is unlikely that they literally mean *more than one* or else one cannot explain why negated plurals (e.g., "No windows were broken") do not mean *less than 2.* Still, in many contexts, speakers do use singular nouns to refer to situations where there is only one individual of the type designated by the noun and plural nouns to refer to situations where there are more than one. Spector (2007) argues that speakers use singular and plural nouns this way as a result of scalar implicatures. Moreover, when we consider the number of individuals introduced in discourse instead of the number present in a situation, then there clearly is a numerical distinction between singular and plural nouns. For example, in “There is a dog walking down the street,” the singular “a dog” introduces a single dog in discourse. Thus, “It is big” is an acceptable continuation of the discourse but “They are big” is not. Similarly, “They are big” is an acceptable continuation of “Some dogs are walking down the street” but “It is big” is not.

There is thus a regular (although imperfect) relation between English singular and plural nouns and the number of things being referred to, and to the number being introduced in discourse. This regularity can provide information that is useful for learning the meaning of the number word “one,” and for distinguishing it from the meaning of number words that denote larger numbers. Indeed, in noun phrases in which “one” is used with an overt noun to express the meaning *one x*, the noun is always in singular form. Likewise, English number words that denote numerosities greater than one always co-occur with a plural noun. Thus, children could use the numerical information provided by numerical morphology to learn that “one” means one, and to learn that the other number words denote numbers greater than one.

Some evidence suggests that this hypothesis could be true. First, some studies suggest that young learners are sensitive to the regular relation between noun numerical morphology and numerosity, before they begin to learn number word meanings. For example, American children learn the meaning of “one” sometime between age 24 and 36 months (Le Corre et al., 2006; Wynn, 1990, 1992). Kouider et al. (2006) showed that, by 24months, English-speaking

American children assume that nouns that are preceded by the singular indefinite determiner "a" and that agree with a singular verb (as in "Look, there is a blicket!") are more likely to refer to one than to more than one individual, and that plural nouns that are preceded by "some" and that agree with a plural verb ("Look, there are some blickets") are more likely to refer to a plurality of individuals (see also Wood, Kouider & Carey, 2009). They also obtain suggestive evidence that, by 24-months, a noun marked with the /-s/ allomorph of the plural is sufficient to indicate reference to a plurality. Similarly, Zapf & Smith (2007) showed that children aged between 18 and 28 months refer to sets of a single object with singular nouns, and to sets of two objects with plural nouns (see also Mervis & Johnson, 1991; Zapf & Smith, 2008). This suggests that young English learners' knowledge of the numerical meaning of singular/plural morphology could help them learn the meaning of the number word "one."

Cross-linguistic comparisons provide evidence that children actually use the numerical information conveyed by numerical morphology to learn number word meanings. Numerical morphology in some Slovenian dialects and in the Najdi dialect of Saudi Arabic makes a tripartite distinction between singular, dual and plural (Almoammer et al., 2013). Almoammer et al. showed that children learning dual-marking Slovenian and Najdi Arabic learn the meaning of the number word for two faster than do English learners, but are not faster at learning number words that denote numbers greater than two. Thus, the cross-linguistic difference in rate of number word learning matches precisely with the differences in numerical morphology between English and Slovenian and Saudi Arabic. Furthermore, knowledge of the meaning of the number word for two is related to knowledge of the meaning of the dual marker. For example, Slovenian children who know the meaning of the number words for one and two use the dual marker correctly 65% of the time, whereas Slovenian children who have not yet learned the meaning of the number word for two use it correctly only some 30% of the time.

To test whether the distinction between singular and plural supports the acquisition of the meaning of the number word for one, cross-linguistic studies have compared number word learning in English and Russian to number word learning in Japanese. Russian, like English, has obligatory singular/plural morphology. Japanese is a classifier language: it does not allow speakers to combine nouns and number words directly. Rather, whenever nouns are quantified with a number word, a particle known as a "classifier" must be added to the number word. Critically, in Japanese, singular/plural marking is optional (Corbett, 2000; Nakanashi & Tomioka, 2004) and rarely used (Sarnecka et al., 2007). Thus, in general, the reference of any given Japanese noun is numerically indeterminate. For example, the very same form can be used to refer to a single chair or to a plurality thereof.

Sarnecka, Kamenskaya, Yamana, Ogura, and Yudovina (2007) compared number word knowledge in 38- month-old English learners, Russian learners, and Japanese learners. They found that whereas virtually all of the English and Russian learners had learned the meaning of the number word for one, only 54% of the Japanese learners had done so. With a different sample, Barner, Libenson, Cheung and Takasaki (2009) replicated Sarnecka's finding. Specifically, whereas 74% of the English two-year-olds in their sample had learned the meaning of the number word for one, only 22% of the Japanese children had done so.

The evidence that Japanese learners are slower to learn the meaning of the number word for one than English and Russian learners is consistent with the hypothesis that knowledge of the numerical information conveyed by singular/plural morphology facilitates the acquisition of the meaning of the number word for one. However, other differences between the Japanese and the

English and Russian groups could explain the delay. First, Japanese has many forms for each number word. Due to heavy linguistic borrowing from the Chinese in ancient times, modern Japanese has two phonologically distinct count lists. One is of Chinese origin, the other is native to Japanese. For numbers one through five, the list of Chinese origin is “ichi”, “ni”, “san”, “shi”, and “go,” whereas the native Japanese list is “hitotsu”, “futasu”, “mittsu”, “yottsu”, and “itsutsu.” Both lists are learned in parallel during the preschool years (Sarnecka et al. 2007). In contrast, English and Russian have only one count list.

Second, Japanese number words must be followed by a classifier. There are many different classifiers because different nouns require different classifiers. The simple fact that Japanese learners have to learn a classifier system but English and Russian learners do not could explain why learning the meaning of number words is more difficult in Japanese. Moreover, in Japanese, classifiers alter the phonological form of the number word to which they attach. This is true both for the number words of Japanese and of Chinese origin. For example, “ichi” (or “one” from the Chinese-derived count list) can alternatively be pronounced as “ippiki”, “ichimai”, “ikko”, or “issatsu” depending on the classifier it combines with. English number word forms, in contrast, are virtually invariable. “One” is the number word that expresses the cardinal value one in all noun phrases. Russian number word forms are quite variable but for a different reason – they are marked for case and gender (Bailyn, 2014). Therefore, it could be that Japanese children learn the meanings of number words later than English learners because the forms of the number words they hear is more variable, and that they learn them later than Russian learners because the type of variability of Japanese number words makes them more difficult to learn.

Third, Barner et al. (2009) point out that the word order relationship between number words and nouns is more variable in Japanese than in English. In English, number words occur pre-nominally only; e.g., “The two boys went to bed” is grammatical but “The boys two went to bed” is not. In contrast, Japanese number words can move from pre-nominal to post-nominal positions – this is known as “numeral floating” (Kobuchi-Philipp, 2007). Barner et al. reported that number words are frequently floated to a post-nominal position in Japanese child-directed speech. Moreover, Barner et al. remark that Japanese is an argument-dropping language – i.e., it allows speakers to drop both the subjects and the objects of sentences, even if they have not been overtly mentioned in previous sentences (Zushi, 2003). This allows Japanese speakers to use number words without an overt noun. In a corpus analysis, Barner et al. (2009) found that Japanese speakers do this frequently – the Japanese forms for one and two were used without a noun over 80% of the time. However, English speakers can use number words without a noun too – e.g., “Take two stickers and give three to your brother” – but Barner et al. did not estimate how often they do so in speech to young children.

Barner et al. argue that the fact that the ordering of number words relative to nouns is less predictable in Japanese than in English, and that Japanese number words are frequently used without a noun could make number word learning harder in Japanese than in English in several ways. Perhaps the greatest effect of this variability is that it makes it harder to use nouns to determine the units of counting in Japanese than in English. Number words cannot be interpreted unless some unit of counting is provided. To be sure, when nouns are dropped, the units can be inferred from context. But it seems plausible that nouns are more efficient than context at conveying them. The pairing of nouns with number words may also be less variable in Russian than in Japanese. Like Japanese, Russian allows its number words to appear both pre- and post-nominally (Madariaga, 2007; Pereltsvaig, 2007). However, unlike Japanese, Russian only allows for argument dropping in restricted contexts, such as in answers to wh-questions (Gordishevsky

& Avrutin, 2003). This could contribute to making number word learning easier in Russian than in Japanese.

Fourth, based on analyses of transcripts of conversations between children and caregivers in the CHILDES database (MacWhinney, 2000), Sarnecka et al. and Barner et al. both found that Japanese children hear number words less frequently than American children. This could explain why American children learn the meaning of the number word for one earlier than Japanese children. Sarnecka et al. also found that Japanese children hear number words *more* frequently than Russian children. Yet, they found that Japanese children learn the meaning of the number word for one later than Russian children. However, the reliability of Sarnecka et al's comparison of number word frequency is unclear because their Russian corpus contained ten times fewer words than their Japanese and English corpuses. Thus, it remains an open question whether English and Russian learners learn the meaning of the number word for one earlier than Japanese learners because they hear number words more frequently.

Finally, neither of the studies that reported a delay in Japanese number word learning carefully matched their samples on the socioeconomic status (SES) of the families of the children. SES is known to affect the acquisition of numerical knowledge in general, and of number word learning in particular (Fluck & Henderson, 1996; Jordan, Huttenlocher, & Levine, 1992). Thus, an inadvertent difference in the SES of the Japanese and American or Russian children in these studies could have contributed to the difference in the rate of number word learning.

Like the Japanese-English and the Japanese-Russian contrasts, the present study seeks to determine whether singular/plural morphology supports the acquisition of the meaning of the number word for one by asking whether it is learned earlier in a language with obligatory singular/plural morphology than in a language without it. But the present study goes beyond the previous ones by testing whether there remains evidence in favor of this hypothesis, even when the alternative explanations mentioned above are ruled out.

We chose a cross-linguistic contrast that allows us to rule out effects of the variability of number word forms and of the relative order of nouns and number words. That is, we compared number word learning in English to number word learning in Mandarin. Like Japanese, Mandarin is a classifier language. Its speakers cannot combine number words directly with nouns, but must insert a classifier immediately after the number word. For example, to say that the number of chairs in the room is two, speakers of Mandarin Chinese must use the appropriate classifier for chair, “ba”, as in (1). Without it, the sentence is ungrammatical. Moreover, like Japanese, Mandarin does not obligatorily mark singular/plural reference on nouns, verbs or adjectives (see (1) below). Mandarin does have an optional plural morpheme of sorts which indicates reference to a collectivity when it is marked on animate nouns and pronouns. However, it is infrequently used and children learn its meaning many months after English learning children learn the numerical meaning of singular/plural morphology (Li et al., 2009).

(1) 房間裡有兩*(把)椅子。

Fángjīan-lǐ	yǒu	lǐang	*(BǍ)	yǐzi
House-inside	exist	two	CL_{ba}	chair

There are two chairs inside the house.

Crucially, unlike Japanese, Mandarin has only one count list, its number words always have the same form regardless of the classifier that follows them[1], and they do not float – they occur pre-nominally only. Therefore, if Japanese children’s delay, relative to English learners,

[1] The only variability in Mandarin number word forms involves the Mandarin number word for two, which differs in form when used in the count list and when used as number word with a classifier in noun phrases (“er” vs. “liang” respectively.) This difference is irrelevant to our purposes, since our question concerns the acquisition of the number word for one, not two. Furthermore, it does not constitute an exception to the generalization that number words retain the same form when bound to different classifiers in Mandarin.

results from any of these differences, we would not expect Mandarin learners to be similarly delayed.

Part I tests whether Mandarin learners learn the meaning of the number word for one later than English learners and Mandarin learners with a large sample of two- to- four-year-olds (133 for each language), matched closely in age. Unlike previous studies, for a little over one-half of our total sample, we included a rough measure of the socio-economic status of the children's parents. To foreshadow our results, we find robust evidence that Mandarin-learners learn the meaning of the number word for one 3 to 6 months later than English-learners. We also find that the delay is specific to learning the meaning of the number word for one.

Part II addresses whether the Mandarin delay observed in Study 1 is due to cross-linguistic differences in the frequency of number words, in the frequency of nominal ellipsis, and in the types of individuals that are enumerated in child-directed speech. We analyzed CHILDES transcripts of conversations between monolingual Mandarin and English learners and their parents. Unlike the CHILDES analysis in the above mentioned studies, the context of the interaction of the dyads, and the socioeconomic status of the caregivers were highly similar across languages.

Study 1: Comparison of English and Mandarin learners

Methods

Study 1 was conducted in two phases. Phase 1 involved testing American and Chinese 2:6- to 3:8-year-olds on the Give-a-Number task. This age range was chosen because previous studies show that children learning American English typically learn the meaning of the number word for one right around their second birthday, and that most have learned the meaning of the number words for one, two and three by age three-and-a-half (Barner, Chow, & Yang, 2009; Le Corre et al., 2006; Sarnecka et al., 2007; Wynn, 1990, 1992). Chinese children were recruited in

Beijing and in Taiwan, and American children were recruited in Cambridge, MA. American children were tested in English and Chinese children were tested in Mandarin.

Data collection for Phase 2 started after Phase 1 had been completed. Phase 2 also involved testing American and Chinese children, but it differed from Phase 1 in four important ways. First, it also included younger children: the age of the participants ranged from 2:0 to 3:8. Second, the phrasing of the question asked in Give-a-Number isolated the contribution of English learners' knowledge of number word meaning from their knowledge of the numerical meaning of singular-plural morphology (see details below). Third, the parents of the Phase 2 participants were asked to fill out a questionnaire which, among other things, asked them to report their level of education, (see procedure for the complete contents of the questionnaire). Parents' level of education served as index of their socioeconomic status (SES). This allowed us to test whether evidence that English-speaking American children acquire number words earlier than Mandarin-speaking Chinese children could be due to differences in the two populations' SES. Finally, in addition to being tested on the Give-a-Number task, the participants in Phase 2 were also tested on a second task, namely Wynn's (1992) Point-to-X. This allowed us to ensure that evidence that English-speaking American children acquire number words earlier than Mandarin-speaking Chinese children could not be due to idiosyncrasies of the Give-a-Number task.

Participants. Participants in Phase 1 were 63 American children and 64 Chinese children, aged between 30 and 44 months.[2] Mean ages were 37.1 and 38.2 months, respectively. American children were recruited in the New York City area, and in the Greater Boston Metropolitan area. Chinese children were recruited in Beijing and Shanghai, China and in Taipei,

[2] Data collected for 50 of the Phase 1 American children were previously reported in Le Corre, Van de Walle, Brannon, & Carey (2006) and in Le Corre & Carey (2007). All data from the Chinese children, all Phase 2 data, and data from 13 Phase 1 American participants are reported for the first time.

Taiwan. Participants in Phase 2 were 70 American children and 69 Chinese children, aged between 24 and 44 months, with mean ages 34 and 34.1 months, respectively. American children were recruited in Los Angeles, California and Chinese children were recruited in Taipei, Taiwan. Data from a questionnaire distributed to the parents in Phase 2 (see below) showed that one Mandarin-speaking child and one English-speaking child had been diagnosed with a language delay. These children were excluded from our sample.

All of the following were true in both phases. Roughly half of the children were boys. American children were monolingual English-speaking or used English as their dominant language. Chinese children were monolingual Mandarin-speakers or used Mandarin as their dominant language. American children were tested either at a university child development laboratory or at local day care centers or nursery schools. The majority of the American children were from middle-class backgrounds, and most were non-Hispanic Caucasian children although a small number of Asian American, African American, and Hispanic American children participated. Chinese children were all ethnically Chinese and were living in China or Taiwan. They were either tested in their home or in daycares/preschools that were affiliated with universities or that served primarily middle-class communities. Teachers at all Chinese daycares interacted exclusively in Mandarin with their children; teachers at all American daycares interacted exclusively in English with their children.

Stimuli and procedure.

Translation of Phase 1 and Phase 2 tasks and materials from English to Mandarin. All written materials used in Phase 1 and Phase 2 (recruitment letters, parent consent forms, SES questionnaires) and task protocols were translated to Mandarin Chinese by two of the authors (B.H and P.L.). Both authors are native speakers of Mandarin, and fluent English speakers. The materials were checked for accuracy and comparability by native speakers of the target languages and by another bilingual speaker.

Phase 1.

Count list elicitation. The Give-a-Number task (see below) tested children's knowledge of the meaning of the number words for one to six. To ensure that all participants knew the form of each of these number words used in these assessments, all children were asked to count a row of ten identical toys[3]. When children were reluctant to count, they were encouraged to do so by the experimenter. For example, when children who were asked to count a row did not start counting on their own, the experimenter pointed to the leftmost toy in the row, said the number word for one and then pointed to the next toy.

Give-a-Number (GN). This task was used to assess children's knowledge of individual number word meanings. It consisted of asking children to create sets of one to six small toys out of a pile of twelve to fifteen. Each number was requested up to a maximum of three times. The numbers requested depended on children's performance; i.e., when testing, the experimenter sought to determine which numbers children could give correctly twice out of a maximum of three trials. Whenever children gave a number correctly, the experimenter asked for the next highest number. The experimenter stopped when she reached a number that children could not give correctly at least twice out of a maximum of three trials. As in previous studies of number word learning (Le Corre et al., 2006; Wynn, 1990, 1992), children were never asked for numbers higher than six.

The questions in the Mandarin and English versions of the task were written so that children's performance would be minimally affected by aspects of their understanding of

[3] Due to a technical error, the counting data for 28 of the Chinese children who were asked to count a row of objects were lost.

language other than number word meanings. In the Mandarin version of the task, the toys that were used as stimuli all were denoted by Mandarin nouns that combined with the classifier that children were most likely to understand, namely the generic classifier “ge.”

To begin, the experimenter placed a collection of toys (e.g. plastic fruit) in front of the child and said: “Can you give me one strawberry?” After this initial question, the experimenter proceeded to ask for up to six toys. On trials where two or more toys were requested, children were always asked to check whether they had given the correct number of toys by counting the set they had given, unless they had already counted the toys as they gave them to the experimenter. If children counted and the last number of their count did not match the number of toys requested, the experimenter then asked children to fix their answer by saying: ‘‘But I wanted N strawberries— can you fix it so that there are N?’’ Thus, trials could end in three ways: 1) Trials where children counted out the correct number of objects (allowing for one counting error) following the experimenter’s first request ended when children were done giving toys; 2) Trials where children gave the correct number of objects without counting ended when they counted the objects to check their answer, and 3) Trials where children gave an incorrect number of objects ended after they responded to the experimenter’s request to fix their answer.

Phase 2.

Count list elicitation. As in Phase 1, we checked whether children knew the forms of the number words from “one” through “ten” in English and from “一” through “十” in Mandarin. Unlike the children in Phase 1, children in Phase 2 were not asked to count objects. They were simply asked to count out loud until they reached “ten” (“十”). If they stopped counting before they reached the , the experimenter asked “What comes after N” (where N was the last number word the child had said). If the child did not continue counting with the first prompt, the experimenter then repeated the last three number words produced by the child, ending her count with a rising, expecting tone (e.g., in English, "five, six, seven…..?"). If the child still did not continue counting, his or her count list was deemed to end at the last number word he or she had said.

Give a Number. The protocol for Give a Number in Phase 2 was the same as in Phase 2, with one exception: the experimenter first named the toys in the pile – e.g., "Here are some strawberries" – and then never used the noun when requesting numbers – e.g., "Can you give me one/two?" Thus, the English-speaking American children in the Phase 2 version could not use the singular/plural distinction as an additional cue to distinguish requests for one toy from requests for more than one. Rather, they had to rely exclusively on their knowledge of individual number word meanings. The comparison between Give-a-number with nouns (Phase 1) and Give-a-number without nouns (Phase 2) thus allowed us to determine whether English-speaking children's performance in Phase 1 was artificially inflated by their knowledge of the numerical meaning of singular-plural morphology.

Point-to-X. Phase 2 participants were tested on a second assessment of their knowledge of number word meanings – namely, the "Point-to-X" task. In this task, children were presented with two 22 X 28 cm cardboard cards each showing a set of objects, and were asked to point to one of the two sets.

<u>Warm-up trials:</u> Children first completed four warm-up trials where they were presented with a single object on each card. The objects either differed in size (e.g. a small orange and a large orange) or in color (e.g. a small yellow shoe and a small red shoe). On these trials, children were asked to choose one of the two objects on the card on the basis of its color or size (e.g. Experimenter: "Can you point to the picture with the red shoe?"). Children had to answer at least

one of the two warm-up questions to be included in the analyses of the Point-to-X task. Only one child (a 34-month-old American) failed to meet this criterion.

Test trials: On test trials, children saw two sets of objects, one displayed on each card. Children were asked to identify which of the two sets had a given cardinal value. Both in Mandarin and in English, the noun denoting the objects was always dropped and the generic classifier "ge" was used (e.g. Experimenter: "Can you point to the side with two?"; 你指給我看哪邊有兩個？nǐ zhǐ gěi wǒ kàn nǎ biān yǒu liǎng ge?). Thus, when English-learning children were presented with a set of one and a set of more than one, they could not merely rely on their understanding of the singular/plural meaning of singular/plural morphology to choose the correct set. Rather, they had to know the meaning of the target number word.

The test trials assessed children's knowledge of the meaning of the number words for one, two, and three. Knowledge of the meaning of each number word was tested on three trials. On one trial, the target set contained the number of objects denoted by the number word, and the distractor set contained one more object (e.g., for "one", target = 1, distractor = 2). On the other two trials, the distractor set contained two more objects than the target set (e.g., for "one," target = 1, distractor = 3)[4]. The correct answer was on the left side of the card on half of the trials. Three different kinds of items were chosen, one for each of the numerical targets tested (one=cake, two=ball, three=balloon). Again, these items were selected because the Mandarin noun denoting them is associated with the generic classifier "ge." Trials were presented to all children in the same randomized order. All experimental sessions were videotaped.

Demographics questionnaire. A questionnaire was distributed to the parents of all the children who participated in Phase 2. It asked them to report the highest level of education they

[4] The task also included trials with targets = 4, 5, and 6. However, only a subset of the children were tested on these trials (English-learning, N =30; Mandarin-learning, N = 28). Therefore, these trials are not included in the analyses.

had completed. It also asked them to report (1) their child's primary language; (2) whether their child was exposed to languages other than the primary one; (3) whether their child produced two-word sentences; and (4) whether their child had been diagnosed with any developmental-behavioral condition (e.g., developmental delays, mental retardation, autism).

Results

We analyze the results of Study 1 in two steps. First, we combine the Phase 1 and Phase 2 Give-a-Number data to determine whether Mandarin learners start learning the meaning of number words later than English learners. We find that the Mandarin learners start learning number word meanings later. Then, we analyze the results of Phase I and Phase II separately (and compare them) to assess the effect of a few factors other than cross-linguistic differences in singular/plural morphology.

Do Mandarin-speaking Chinese children start learning number word meanings later than English-speaking American children?

Knowledge of number word meanings (from Give-a-Number). As a first step towards determining whether Mandarin learners start learning number word meanings later than English learners, we determined what number word meanings each child had learned based on their performance on the Give-a-Number task. Although this was not the main purpose of this paper, this analysis also allowed us to determine whether the stages of number word learning are the same in two very different languages.

To be considered to know the meaning of a number word "N", children had to:

(1) Give N objects on at least two out of a maximum of three trials when asked for "N" objects.

(2) Give N objects no more than half as often when asked for a different number.

(3) Satisfy conditions 1 and 2 for all numbers less than N.[5]

Children were deemed to have learned the cardinal principle – i.e., that the last number word of a correct count denotes the number of objects in the counted set – if they met the above criteria for all number words up to the number word for six. The same criteria have been used in several previous studies of number word learning (Barner, Chow, & Yang, 2009; Le Corre, Van de Walle, Brannon & Carey, 2006; Lee & Sarnecka, 2011; Sarnecka et al., 2007; Wynn, 1990, 1992). It has been shown that two- to four-year-olds show essentially the same knowledge of number word meanings when their knowledge is assessed with other tasks that make different processing demands (Le Corre et al., 2006; Wynn, 1992). Therefore, the criteria used here are a valid measure of knowledge of number word meanings.

Based on our criterion, we found exactly the same groups of children in the two languages. Some had not learned the meaning of any number word, some had learned the meaning of the number word for one only (a.k.a. "one-knowers"), for one and two only ("two-knowers"), for one, two and three only ("three-knowers"), for one, two, three, and four only ("four-knowers"), and for the cardinal principle ("CP-knowers"). No other stages were detected in either language group. Thus, despite the fact that Mandarin and English are very different languages, learners of both languages learn number word meanings in the same sequence.

Testing whether Mandarin number word learning is delayed. To test whether Mandarin learners reach any of the number word learning stages later than English learners, we compared the proportions of Mandarin and English learners who had not learned the meaning of any number word, and the proportions of who had learned the meaning of number words for all

[5] Six of the 133 Chinese children met criteria 1 and 2 for number words beyond their knower-level. Two failed on the word for one but succeeded on the one for two, one succeeded on the number word for one and on the one for three, one succeeded on the number words for one, two and four, and two succeeded on the number words for one, two, and five.

numbers at least up to one, up to two, up to three, up to four, and up to the cardinal principle (see Figure 1). For example, the proportion of children who had learned the meaning of the number words for numbers at least up to three included all the children who had learned the meaning of the number words for one, two, and three only, those who had learned the meaning of the number words for one, two, three and four only, and all children who had learned the cardinal principle. The proportion of children who had not learned the meaning of any number word (“non-knowers”) was significantly *greater* amongst Mandarin learners than amongst English learners (29% vs. 11%), $\chi^2(1) = 11.4$, $p < .001$. In contrast, all the proportions of children who had learned the meaning of at least some number words were significantly *lower* amongst Mandarin learners than amongst English learners. That is, Mandarin learners’ proportion was lower than English learners’ for number words for numbers at least up to one (71% vs. 89%), $\chi^2(1) = 12.6$, $p < .001$, up to two (47% vs. 71%), $\chi^2(1) = 14.9$, $p < .001$, up to three (26% vs. 46%), $\chi^2(1) = 11.9$, $p < .001$, and up to four, (13% vs. 23%), $\chi^2(1) = 4.4$, $p < .05$. Finally, the proportion of children who had learned the cardinal principle was marginally smaller amongst Chinese children (8% vs. 17%), $\chi^2(1) = 3.5$, $p = .06$. Since the two language groups were closely matched for age, this suggests that the Mandarin number word learning sequence starts later than the English one so that the former reach each of the steps of the sequence later than the latter.

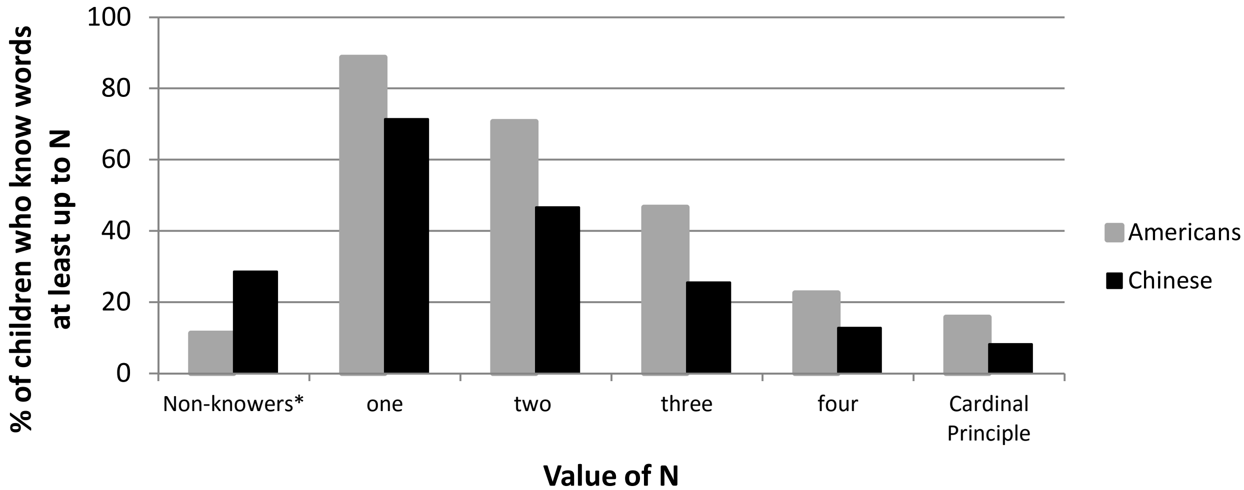

Figure 1. Percentages of Mandarin and English two- to –four year-old learners who knew the meaning of the number words for numbers at least up to one, two, three, four and the cardinal principle as per Give-a-Number. *: The proportion of non-knowers includes non-knowers *only*.

Estimating the extent of the delay. To estimate the extent of Chinese children's delay, we started by dividing each sample into six age groups: 24 to 29 months; 30 to 32 months; 33 to 35 months, 36 to 38 months; 39 to 41 months; and 42 to 44 months. Each age group contained 21 to 24 children of each language group, except for the youngest group (24- to 29 months), which had 10 children from each language. For each age group, we plotted the percentage of children who had learned the number words at least for the numbers up to one, up to two, up to three, and up to the cardinal principle (see Figure 2). Then, we estimated the age group where at least 60% of the children in each language had learned its meaning. The 60% mark is indicated by a dotted line on Figure 2. As can be seen from Figure 2, there was no age group at which 60% of the children had become CP-knowers in either of the language groups. Therefore, we set a criterion of 30% to compare the ages at which children in each language group become CP-knowers. The age groups at which Mandarin and English learners reach the 60% mark for each number word (and the 30% mark for the cardinal principle) are reported in Table 1.

Since the learning curves of each number word for each language group have comparable shapes, the difference between the times when the groups reach the 60% mark (or the 30% for the cardinal principle) gives us at least a rough estimate of the extent of the Mandarin delay at each step of the number word learning sequence. Table 1 suggests that, on average, Mandarin learners start learning number word meanings – i.e., learn the meaning of the number word for one – some six months later than English learners. This six-month delay is preserved through the rest of the sequence, except for the acquisition of the cardinal principle where the Mandarin delay shrinks to three months.

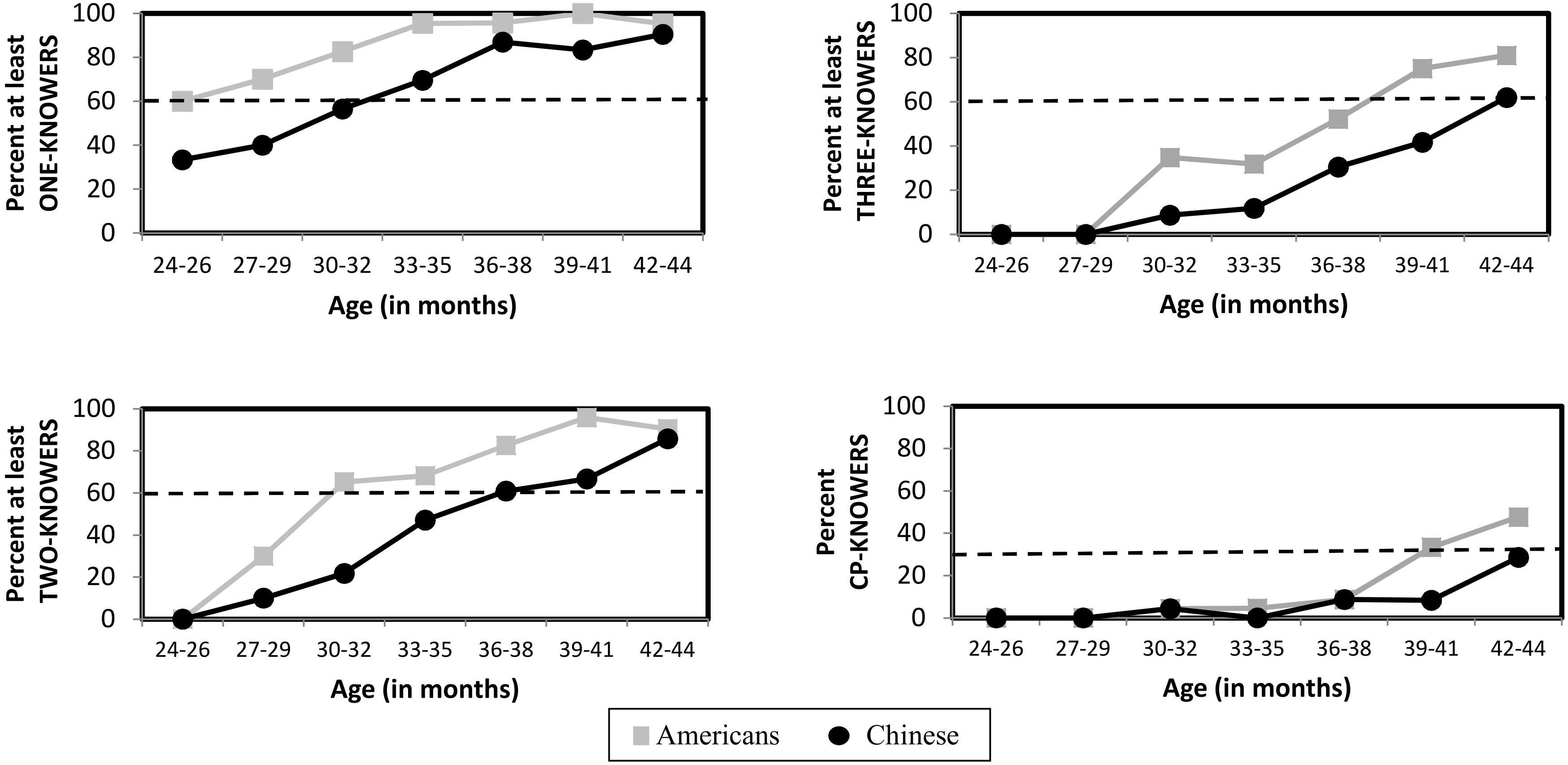

Figure 2. Percentage of children in each language group who had learned the meaning of the number word for one (top left), one and two (bottom left), one, two, and three (top right) or the cardinal principle (bottom right) as a function of age (in months) as per Give-a-Number. American data are plotted as light grey squares and Chinese data are plotted as black circles

Table 1.

Age group (in months) at which 60% of Mandarin and English learners have learned the meaning of the number word for one, for two, or for three and age group at which 30% have learned the cardinal principle.

	Approximate age group when criterion is met (in months)	
Number word	Mandarin	English
For one	30-32	24-26
For two	36-38	30-32
For three	42-44	36-38
Cardinal principle	42-44	39-41

Was the delay specific to the acquisition of the meaning of the number word for one?

If the only difference between Mandarin and English number word learning is that the latter is supported by singular/plural morphology, then the Mandarin number word learning delay should be specific to the acquisition of the meaning of the number word for one. The previous results suggest that Mandarin learners reach each stage of the number word learning sequence later than English learners. This need not mean that every number word is harder to learn in Mandarin than in English. Rather, it may be that the Mandarin number word learning sequence *starts* later than the English one, but that, they have started learning number word meanings, Mandarin learners move from one stage to the next at the same rate as English learners, so that Mandarin learners consistently reach each stage later than English learners.

Table 1 suggests that the Mandarin number word learning delay is indeed specific to the acquisition of the meaning of the number word for one. Mandarin and English learners both make the transition from knowing the meaning of the number word for one to knowing the meaning of the number words for one and two in about six months. The transition from knowing the meaning of the number words for one and two to knowing the meaning of the number words for one, two and three also takes about six months in both languages. However, Table 1 suggests that Mandarin learners go through the entire sequence – from knowing the meaning of the number word for one to knowing the cardinal principle – a little faster than English learners; i.e., the former take about 12 months whereas the latter take about 15.

In sum, we find that, while Mandarin learners learn the meaning of the number word for one later than English learners, they then proceed through the rest of the sequence as fast as and perhaps even faster than English learners, exactly as predicted by the hypothesis that the only difference between English and Mandarin number word learning is that the former benefits from the numerical information conveyed by singular/plural morphology.

Phase 1 vs. Phase 2

Was the Mandarin delay due to differences in the level of education of children's parents? We first analyzed the questionnaire given to American and Chinese Phase 2 participants. Seventy-four percent of the parents surveyed in Phase 2 completed the questionnaire. All respondents in each language group were part of two-parent families where at least one parent had obtained at least a college degree. All Chinese parents reported that Mandarin was their child's primary language. All American parents reported that English was their child's primary language. Thirty-seven percent of Chinese parents and forty-two percent of American parents reported that their child was exposed to other languages. The daily exposure to other languages ranged from "minimal" to "three hours per day" for the Chinese children, and from "minimal" to "four hours per day" for the American children. All children had at least reached the "two-word" stage in language development. In sum, these reports suggest that the linguistic and socioeconomic backgrounds of the children in the two Phase 2 groups were comparable, and that there were no gross differences in their overall linguistic and cognitive development.

We next analyzed whether the Mandarin delay in learning the meaning of the number word for one reported above for the whole sample held for the Phase 2 sample alone. The proportions of Phase 2 English learners who had learned the number word for one, or for one and two, were both significantly greater than the corresponding proportions of Phase 2 Mandarin learners. That is, 86% (60/70) of the Phase 2 English learners had learned the meaning of the number word for one compared to 68% (46/69) of the Mandarin learners, $\chi^2(1) = 5.95$, $p < .05$, and 59% (41/70) of the English learners had learned the meaning of the number words for one and two, compared to 39% (27/69) of the Mandarin learners, $\chi^2(1) = 4.5$, $p < .05$.[6] This analysis suggests that differences in the level of education of children's parents or in the amount of the children's exposure to languages other than the ones targeted here are not sufficient to explain the Mandarin-learners' delay in learning the meaning of the word for one. Other factors are involved.

Was English learners' performance on Give-a-Number inflated by their knowledge of the numerical distinction between singular and plural morphology? In Phase 1, the experimenter's requests in the English version of Give-a-Number included nouns marked for number. Thus, English learners could have correctly differentiated requests for one toy from requests for other numbers of toys without having to know the meaning of any number word. Instead, they could have distinguished requests for one from requests for more than one by drawing on knowledge of the meaning of numerical morphology. Like Sarnecka et al., (20060), we find no evidence to that effect. First, we asked whether more English learners distinguished requests for one toy from requests for more than one toy in the Phase 1 version of Give-a-number where the requests included nouns marked for singular/plural than in the Phase 2 version where the requests did not include nouns, and therefore did not include singular/plural marking. We matched the participants of the two phases for age: we only included children who were 30 months of age or older because Phase 1 did not include any include any children under 30 months. The proportion of children who distinguished requests for one from requests for greater numbers was equal (94%) in both conditions. This suggests that American children succeeded on requests for one toy because they had learned the meaning of the number word for one, not because they were merely responding on the basis of their knowledge of the numerical meaning of the singular-plural distinction.

Second, the number word knowledge comparison that was restricted to our SES-matched participants – i.e., the Phase 2 participants – also showed that fewer young Mandarin learners know the meaning of the number word for one than young English learners (see above). In Phase 2, the English version of Give-a-Number did not include any nouns marked for number. Thus, this provides further evidence that the Mandarin delay is genuinely due to cross-linguistic differences in children's knowledge of the meaning of the number word for one, and not to the fact that English learners relied on their knowledge of the numerical meaning of singular/plural morphology to succeed on requests for one.

Was the Chinese delay caused by factors that are specific to the Give-a-Number task? We sought to determine whether English learners outperformed Mandarin learners on the Give-a-Number because of factors that are specific to the Give-a-Number task, or because they genuinely started learning number word meanings earlier. To do so, we analyzed children's performance on a second measure of knowledge of number word meanings, namely Wynn's

Point-to-X task (included in Phase 2 only).

The number of correct answers on each of the number words for one to three (maximum = 3 for each target) was calculated for each child. These scores were averaged for each of the seven age groups that were used in our analyses of Give-a-Number, for each language group. Then, for Mandarin and English learners, we determined the youngest age group where (1) children were significantly more accurate than predicted by chance; and (2) all older groups also were significantly more accurate than predicted by chance. Comparisons to chance were carried out with one-tailed, one-sample t-tests, with $\alpha = 0.05$.[7,8]

The results of the Point-to-X task paint the same picture as the results of the Give-a-Number task. They provide evidence that Mandarin learners reach each step in the number word learning sequence three (for the number words for one and three) to six months (for the number word for two) later than English learners. Moreover, they also confirm that, although Mandarin learners started learning number words later than their English learners, both groups went through the sequence at the same rate: both took about twelve months to go from knowing the meaning of the number word for one only to knowing the meanings of the number words for one, two, and three.

[7] We also tested whether English learners learn the meaning of the number word for one earlier than Mandarin learning by using independent samples t-tests and Mann-Whitney U-tests to compare the mean number of correct answers (out of a maximum of 3) on trials where the target was one object for the youngest children in each sample (i.e., children who were less than 30 months old; n = 19 in each group). English learners made more correct answers ($M = 1.9$) than Mandarin learners ($M = 1.4$), but the difference was not significant (t-test: $p = .10$; Mann-Whitney U-test, $p = .11$). It may be that the narrow range of possible scores – i.e., perfect performance would yield a mean of 3, and failure to perform the task would yield a mean of 1.5 – partially explains why the tests did not detect a significant difference.

[8] Since we required that all age groups above the youngest one where children performed significantly above chance also perform significantly above chance, our estimate of the youngest age group where children knew the meaning of a number word is highly unlikely to be the result of a Type 1 error. Therefore, although we carried out multiple t-tests, we did not correct their alpha level for multiple comparisons.

Table 2.

Youngest age (in months) of knowledge of meaning of number words for one, two and three respectively on the Point-to-X task.

	Youngest age (in months)	
Number Word	Chinese	American
For One	31	28
For Two	37	31
For Three	43	40

Did Chinese and American children have equal knowledge of number word forms and equal counting skills? Chinese children could start learning number word meanings later than American children because they first memorize the *forms* (as opposed to the meaning) of the number words later than American children or because they have poorer counting skills. To determine whether this explained the Chinese delay observed here, we determined the length of the count list of each child in each language group. Count list length was defined as the highest number word children counted to in any of the tasks they participated in. The highest number word of a count was defined as the last word of a counting sequence with no more than one error. For example, a child whose longest count was "one, two, three, four, six" would have a list length of 6 because he only made one error in counting to "six."

Our analyses of children's counting suggest that the Mandarin learners knew as many number word forms and had the same counting skills as the English learners. That is, on average, Mandarin (mean count list length = 10.1; range 3 to 20) and English (mean count list length = 9.8; range 5 to 18) learners counted equally far. Moreover, aside from a few rare exceptions, all children in our sample knew the forms of all the number words that were used in the Give-a-Number task (up to “six”/ “六”) and in the Point-to-X task (up to “three”/ “三”): i.e., they could recite their language’s count list at least up to “six”/ “六” (94% of Mandarin and 98% of English learners, $p = 0.1$). Therefore, evidence that Chinese children start learning number word meanings later than American children cannot be attributed to their having weaker counting skills or to their knowing fewer of the forms of the number words that were used in our tasks.

Discussion

Study 1 yielded two important results. First, the sequence of number word acquisition in Mandarin is the same as that observed in all languages studied thus far (Almoammer et al., 2013; Barner et al. 2009; Piantadosi et al, 2014; Sarnecka et al. 2007; Villaroel, Miñon, & Nuño, 2011) – i.e., Mandarin-learning children first learn the meaning of the number words for one, two, three and sometimes four one at a time, and then learn the cardinal principle. Thus the differences between Mandarin and English that account for the delay in learning the meaning of the number word for one do not change the sequence of acquisition of number word meanings, as far as these measures are concerned.

Second, we find that Mandarin-learning children learn the meaning of the number word for one some three to six months later than English-learning children. This is consistent with the hypothesis that knowledge of the numerical meaning of singular/plural morphology supports the acquisition of the meaning of the word for one, and it converges with previous evidence from comparisons of number word learning in English and Russian to Japanese (Sarnecka et al., 2007; Barner et al., 2009). Importantly, except for the presence of classifiers, the factors other than the absence of consistent, obligatory, singular/plural marking that might have accounted for the delay in Japanese children are not present in Mandarin. It thus follows that these alternative factors cannot explain the present result, and that they are probably not sufficient to explain the Japanese delay either.

Study 1 goes beyond the previous Japanese-English comparisons in other ways as well. It tested a much larger sample, allowing us to obtain a more fine-grained description of the time course of number word learning in each language. These descriptions suggest that Mandarin learners learn the meaning of the number word for one later than English learners but then proceed through the sequence at the same rate as English learners. In other words, they suggest that the Mandarin number word learning delay is specific to the number word for one. In turn, this strongly suggests that the difference in number word learning is caused by cross-linguistic differences in singular/plural morphology, rather than by more general factors such as differences in learning abilities.

Also, the Japanese-English (and Japanese-Russian) comparisons only included one assessment of children's knowledge of number word meanings – i.e., Wynn's Give-a-Number task. The present study used two tasks – Give-a-Number and Point-to-X. Both tasks provided evidence that number word learning is delayed in children learning Mandarin relative to children learning English. Finally, unlike the studies that compared Japanese and English learners, Study 1 provides evidence that differences in SES (as indexed by parent level of education) are not sufficient to explain why children learning a language without obligatory numerical morphology start learning number words later than children learning a language with obligatory numerical morphology.

We turn now to alternative accounts of the delay now found both for Japanese learners and Mandarin learners, relative to English learners—alternatives to the hypothesis that the delay reflects the absence of consistent number morphology on nouns and verbs in Mandarin and

Japanese. Both Sarnecka et al. (2007) and Barner, Libenson, et al. (2009) found that number words were more frequent in English than in Japanese speech to children. Thus frequency could have accounted for earlier acquisition of number words by English-learning American children relative to Japanese children.

Two previous studies (Chang & Sandhofer, 2009; Chang et al., 2011) suggest that this explanation probably does not apply to the Mandarin-English comparison. These studies reported that number words (occurring with or without an overt noun) are more frequent in Mandarin than in English child-directed speech. Chang and colleagues observed this difference in two different contexts. Chang and Sandhofer (2009) observed the Mandarin advantage in the context of bilingual Mandarin-English parents reading the same picture book to their child once in Mandarin and once in English. Chang et al. (2011) observed it in the context of everyday conversations between monolingual children and adults.

Chang and colleagues' results strongly suggest that Mandarin learners do not learn the meaning of the number word for one later than English learners because they hear number words less frequently. However, their studies have some limitations. The bilingual parents in Chang and Sandhofer (2009) were native Mandarin speakers. Thus, they might have used more number words in Mandarin because they were more fluent in that language. In their study of monolinguals, Chang et al. (2011) did not match the contexts of the conversations they analyzed. Therefore, it could be that, by coincidence, number words were more frequent in Mandarin because the contexts of the Mandarin conversations were more conducive to number talk. To be sure, it is unlikely that these limitations can account for the result because each study addresses the limitation of the other one – i.e., the study of monolingual dyads (Chang et al., 2011) deals with the problem of bilingual mothers being more fluent in Mandarin than in English, and the study of bilingual mothers (Chang and Sandhofer, 2009) deals with the problem that the conversations between monolinguals dyads were not matched for context. However, it would be ideal to analyze the frequency of number words in caregiver-child conversations that are matched for both caregivers' fluency and for context. We carry out this analysis in Experiment 2. Our analysis also explicitly matches caregivers' socioeconomic status. Replicating Chang and colleagues' findings would provide strong support for the conclusion that Mandarin learners do not learn the meaning of the number word for one later than English learners because they hear number words less frequently.

Barner et al. (2009) offered an additional alternative account of the delay in Japanese learners relative to English learners. They suggested that, because Japanese permits argument dropping, Japanese adults use number words in phrases with nouns less frequently than English speaking adults. The absence of nouns means that children have less information for inferring the meanings of number words, and thus could explain the delay.

Mandarin also allows argument dropping (Cheng, 2011; Huang, 1984). However, both of the studies by Chang and colleagues cited above found that number words are combined with an overt noun more frequently in Mandarin than in English. This suggests that it is not the case that Mandarin learners learn the meaning of the number word for one later than English learners because they are less likely to hear them in phrases that contain an overt noun. Experiment 2 asks whether the same finding emerges with our transcripts matched for caregivers' fluency, SES, and context.

Part 2: The CHILDES Analyses

Methods

Participants. In Experiment 2, we analyzed the utterances produced by the parents in the conversations of the 52 parent-child dyads of the CHILDES New England corpus (Ninio, Snow, Pan, & Rollins, 1994) and in the conversations of the 46 parent-child dyads of the Zhou corpus (MacWhinney, 2000; Zhou & Zhang, 2008). The ages of the children in the dyads ranged from 14 to 32 months, covering the period that extends from the very beginning of language learning to the age when children begin to learn the meanings of number words. Collection of the Zhou corpus followed the design of the New England corpus, with the exception that the Zhou corpus was cross-sectional and the New England corpus was longitudinal. Children in the New England corpus were sampled three times, at 14 months, 20 months, and again between 27 and 32 months. To match the New England corpus, the Zhou corpus included a sample of 14 month-olds (n = 11), a sample of 20 month-olds (n = 16), and a sample of 26- (n = 11) and 32 month-olds (n = 11). The parents in both corpora were from lower-middle to upper-middle class backgrounds, and all dyads were instructed to engage in free play with similar sets of toys. All interactions lasted approximately twenty minutes.

Chang et al. (2011)'s study drew upon some entries of the Zhou corpus, so there was overlap between our choice of Chinese transcripts and theirs. However, there was no overlap between our American transcripts and theirs.

Results

Since our interest is in the number word forms that are acquired in early childhood, we searched the transcripts for the number words "one"/"一" through "nine"/"九" only, analyzing "one" ("一") separately from "two" ("二/两") through "nine" ("九"). Most of the parents (86% of the American parents and 90% of the Chinese parents) used number words to refer to the number of things in a set at least once during the course of these 20 minute conversations.

We calculated frequency as the number of occurrences of each target word per 1000 utterances of parents over all transcripts for each child-parent dyad. Then, we averaged this number over all dyads in each language; i.e., over 52 dyads for English, and over 46 for Mandarin. Figure 3 presents the average frequency for each word form in parental speech in the two languages.

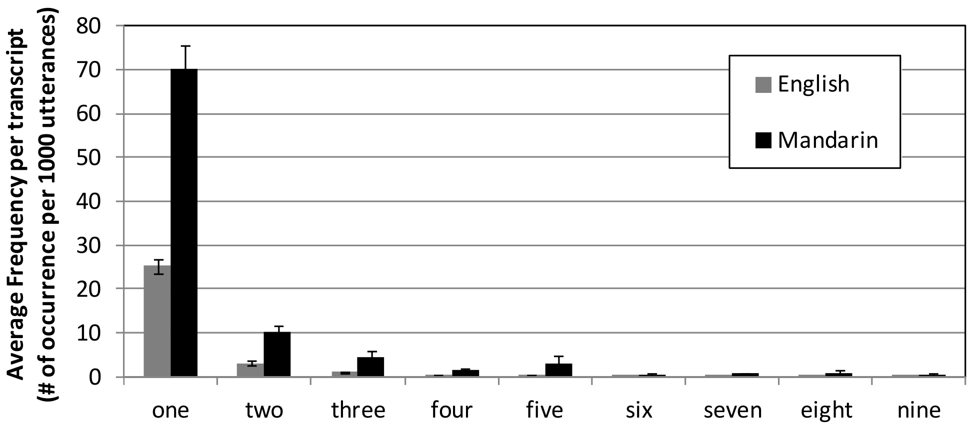

Figure 3. Frequency of word forms for numbers between one and nine in English and Mandarin child-directed speech.

Replicating Chang et al.'s findings, our word counts show that Mandarin-speaking parents used number words significantly more often than English-speaking parents—roughly three times more for the number word for one (Mandarin: 70 uses per 1000 utterances; English: 25 uses per 1000 utterances, $t(185) = 10.694$, $p < .001$) and five times more often for the number word for two through nine (24 vs 5 uses per 1000 utterances, respectively, $t(1, 185) = 52.6$, $p < .001$). Averaging over all nine number words, we found that this difference held in each of our three age groups (14-months: 81 vs. 21 per 1000 utterances; $t(61) = 9.06$, $p < .001$; 20 months:

65 vs. 29 per 1000 utterances, $t(62) = 3.44$, $p < .001$; 27 to 32 months[9]: 114 vs. 44 per 1000 utterances, $t(57) = 8.45$, $p < .001$).

Because some uses are more helpful than others for identifying number word meanings, our next analyses examined how Mandarin- and English-speaking parents use number words in conversation with their young children. We first tested whether Mandarin parents use number word to denote a cardinal number (henceforth, "cardinal uses") less frequently than English parents. To carry out this analysis, all utterances containing one or more number words were singled out from the transcripts. Then, a coder examined each number word one by one and judged whether it could have been used to refer to a cardinal value. When the type of use of a number word could not be determined on the basis of the utterance alone, the coder consulted its transcript of origin to see the context in which it was produced. All number word uses were analyzed by the same Mandarin-English bilingual coder.

Clear examples of cardinal uses were number words followed by an overt noun such as "three ducks" in English and "三個小碗" (san1 ge xiao3 wan3/three CL_{indiv} small bowls, 'three small bowls') in Mandarin. Many uses of number words without an overt noun were also counted as cardinal uses. Examples from our transcripts include the English "you have four" in reference to four crayons and the Mandarin "有四個" (you3 si4 ge/exist four $CL_{individual}$; 'there are four') in reference to four toy blocks.[10] Examples of non-cardinal uses are reference to an

[9] The Mandarin mean for this age group was obtained by combining the group of 26 month-olds with the group of 32 month-olds.

[10] On some analyses, some uses of "one" without an overt noun in English are taken to be pronouns rather than nominal ellipsis (e.g., "I'll take the orange one," in the context of a choice between an orange and a yellow candy, Jackendoff, 1977). However, Llombart Huesca (2002) convincingly argues that even in these uses, "one" is a number word in a nominal ellipsis. Specifically, she shows that "one" anaphora is best analyzed as "one" being inserted into the empty head of a number phrase, when NP ellipsis prevents the head from being licensed. Therefore, we took all uses of "one" without an overt noun to be instances of a number word in nominal ellipsis. The use of "one" as a generic pronoun (e.g., "One must not lie.") is the only use that is not a number word. Such uses did not appear in our transcripts.

Arabic digit (“this is an eight,” while pointing to the number “8”) and reference to dates (“八月一號,” eight-month-one-number, ‘August first’; see below for a complete analysis of non-cardinal uses).

Summing across uses with and without an overt noun, we find that cardinal uses of the number word for one are almost two times more frequent in Mandarin (41.97/1000 utterances) than in English (24.01/1000 utterances) child-directed speech, $t(185) = 5.20$, $p < .01$, (see Table 3). The difference is even more pronounced for the words for two through nine; cardinal uses are approximately four times more frequent in Mandarin (13.89/1000 utterances) than in English (3.56/1000 utterances), $t(185) = 6.7$, $p < .001$, (see Table 3). Cardinal uses make up a similar proportion of the sum of cardinal and non-cardinal uses in both languages (Mandarin: 95%; English: 97%).

Table 3

Frequency (per thousand utterances) of cardinal and non-cardinal uses of number words and of non-numerical compounds.

	Number words			
	For one Frequency per 1000 utterances		For two through nine Frequency per 1000 utterances	
Types of uses	Mandarin	English	Mandarin	English
Cardinal with overt noun	21.37	3.48	12.03	2.56
Cardinal with ellipsis	20.60	20.53	3.59	1.00
Total Cardinal	41.97	24.01	15.61	3.56
Count Routine/Count Chants	1.71	0.57	4.23	1.08
Ordinals	0.09	0.00	0.05	0.00
Arabic Numerals	0.63	0.15	2.77	0.41
Names	0.00	0.00	1.61	0.10
Total Non-Cardinal	2.43	0.72	8.66	1.59
Non-numerical compounds	25.66	0.57	---	---

Thus far, our analyses suggest that the frequency of number words in child-directed input cannot explain why Mandarin learners learn the meaning of the number word for one later than English learners. In fact, our analyses suggest that Mandarin learners have a considerable advantage in this respect. However, it still possible that Mandarin input is not ideal because it might also include more number words used in *non*-cardinal contexts. Clear examples of non-cardinal uses are number words used to name Arabic numerals (e.g., “number two box”, for a box labeled with “2”; “是八”, saying ‘is eight’ while pointing to the Arabic numeral “8”), addresses, phone numbers, dates or time (e.g., 八月一號, eight-month-one-number, ‘August first’). In Mandarin, speakers can use the very number word forms that denote cardinalities to denote ordinals by combining them with the prefix “$\mathrm{di}_{\mathrm{ordinal}}$” (e.g., 第二天, $\mathrm{di}_{\mathrm{ordinal}}$-two-day, ‘second day’). These were also counted as non-cardinal uses. Finally, number words are also used in counting routines or rhythm chants (e.g., “one, two, three, four”; “one-two-one-two”). In cases such as “one, two, three, four ducks”, “four ducks” was counted as a cardinal use of a number word (because the last word of a count denotes the cardinality of the counted set), whereas “one,” “two” and “three” were not.

Non-cardinal uses were more frequent overall in Mandarin than in English (number word for one: 2.43/1000 utterances vs. 0.72/1000 utterances, respectively; words for two to nine: 8.66/1000 utterances vs. 1.49/1000 utterances, respectively). However, relative to cardinal uses, the frequency of non-cardinal uses was negligible in both languages: they made up 5% of the sum of cardinal and non-cardinal uses in Mandarin and 3% in English (see Table 3). Moreover, the bulk of the non-cardinal uses occurred in what is arguably the non-cardinal context that is least likely to interfere with learning the cardinal meaning of number words, namely counting routines or chants (Mandarin: 70%; English: 79%). Therefore, it seems unlikely that differences in the amount of noise created by non-cardinal uses can explain why Mandarin learners learn the meaning of the number word for one later than English learners.

However, as we searched the transcripts for non-cardinal uses of the Mandarin number word for one, we found that it is also used in other non-numerical structures, namely a verb reduplication structure and various compound words. The verb reduplication (V-yi-V) construction means “to perform a little of the action denoted by the verb” (e.g., kan-yi-kan; look-one-look – have a look). The compound words include adverbials (e.g., “yíxìa” and “yīhŭir” – awhile; “yīdĭanr” – a little; “yīqĭ”, “yídào”, “yigòng” – (al)together), a modal (“yídìng” – must), and an adjectival (“yíyàng” – same, of one kind). Possible English compounds are the quantifiers “no one,” “someone,” “anyone” and “everyone.” We refer to the verb reduplication structure and to the compound words as “non-numerical compounds.”

Our searches suggest that the non-numerical compounds considered here are used very frequently in Mandarin child-directed speech – we observed an average of 25.66 tokens per 1,000 utterances – but are almost never used in English child-directed speech– we observed an average of 0.72 tokens per 1,000 utterances (see Table 3). Could this explain why Mandarin learners learn the meaning of the number word for one later than English learners? While we cannot answer this question definitively, we think that it does not. In short, the main reason is that the non-numerical compounds and the number words occur in very different syntactic contexts. A few studies suggest that children do not take word forms used in different syntactic contexts to be tokens of the same word or morpheme (e.g., Hall, Lee & Bélanger, 2001; Katz, Baker & Macnamara, 1974). Therefore, the uses of “yi” in non-numerical compounds are unlikely to interfere with the acquisition of the meaning of the number word “yi.” We address this issue in greater detail in the general discussion.

Following Barner et al’s suggestion that the meaning of a number word is easier to infer when it occurs with an overt noun, our next analysis asked whether English learners hear number words with an overt noun more frequently than Mandarin learners. As can be seen from Table 3, Mandarin children hear the number word for one, as well as the number words for two through nine, with overt nouns far more often than do English learners (Mandarin “yi”: 21.37 occurrences/1000 utterances; English “one”: 3.48/1000, $t(185) = 11.18$, $p <.001$; words for two through nine, Mandarin: 10.30/1000; English: 2.56/1000, $t(185) = 5.71$, $p < .001$).

We also asked whether uses of number words *without* an overt noun are more frequent in Mandarin than in English. For number words “yi”/“one” heard in cardinal contexts, nominal ellipsis is not more common in Mandarin than in English (20.6 occurrences/1000 utterances vs. 20.5/1000, $t(185) = .02$, n.s.). For number words for two through nine, nominal ellipsis is statistically more common in Mandarin than in English (3.6/1000 utterances vs. 1.0/1000, $t(185)=3.54$, $p < .01$), but such ellipsis is relatively infrequent.

Finally, when one considers the relative proportions, cardinal uses with an overt noun actually make up a greater proportion of the cardinal uses in the Mandarin input than in the English input. Over half of Chinese parents’ cardinal uses of “yi” occurred in full noun phrases with an overt noun (50.9%), whereas such usages comprised only 14.5% of American parents’ cardinal uses of “one.” Number words for two through nine mostly occurred with overt nouns, both in Mandarin input (74%) and English input (72%).

Our last analysis examined whether the relative ease of identification of the units of counting denoted by the nouns that are combined with number words can explain this delay. To learn the cardinality denoted by number words from their use in the utterances of other speakers, children must be able to determine what units are being counted. Past research indicates that, while three- and four-year-olds easily determine the units of counting when they are discrete objects or temporal intervals (e.g., dogs, jumps, claps; Shipley & Shepperson, 1990; Wagner & Carey, 2003; Giralt & Bloom, 2000; Brooks, Pogue, & Barner, 2010; Cheung, Barner, & Li, 2010), they find it difficult to do so when they are collections (e.g., families or armies) or kinds (e.g., kinds of animals; Bloom & Kelemen, 1995; Huntley-Fenner, 1995). That is, when they are asked to count collections or kinds, three- and four-year-olds tend to count the discrete objects that are elements of the collections or kinds, rather than the collections or kinds themselves. For example, they count individual members of a family instead of families or individual cats and dogs instead of kinds of animals (Huntley-Fenner, 1995). Preschoolers also have difficulties determining the units of counting when number words are used in attributives (e.g., "two three-bedroom cottages"; Foushee, Falkou, & Li, Nov. 2014), when they are used in partitives that count parts of objects (e.g., "two pieces of fork"; Srivinisan et al. 2013; Li, Huang, & Hsiao, 2010), and when they are used with units of measurement (e.g., "two cups of sand" or "two liters of milk"; Gal'perin & Georgiev, 1969; Li, Huang, Hsiao, 2010; Li, Barner, & Huang, 2008; Wang, Li, & Carey, 2013).

To assess whether cross-linguistic differences in the frequency of use of difficult units of counting in child-directed speech can explain why number word learning starts later in Mandarin, we counted how frequently number words occurred with a noun that denotes a difficult unit of counting – i.e., a collection, a kind, an attributive, or a partitive that contains a word for a part, or for a unit of measurement – in child-directed input in each language. Every noun in a number word-noun pair was classified as denoting an easy or a difficult unit of counting. No nouns were unclassifiable.

Table 4

Frequency (per thousand utterances) of use of number words with nouns denoting easy units of counting and with nouns denoting difficult units of counting.

	Number words			
	For one Frequency per 1000 Utterances		For two through nine Frequency per 1000 Utterances	
Type of unit of counting	Mandarin	English	Mandarin	English
Easy	19.44	3.29	7.59	2.19
Difficult	1.93	0.19	2.64	0.37

Table 4 shows the frequency of number words combined with nouns that denote easy or difficult units of counting in Mandarin and English input to young children. The tables show that Mandarin learners hear number words with overt nouns that designate easy units of counting three to eight times more frequently than American English learners. They also show that, proportionally speaking, Mandarin and English child-directed input contain similar amounts of number words combined with overt nouns that designate easy units of counting, especially for the number word for one (91.0% vs. 94.5% of number word for one and 74.2% vs. 85.3% of the number words for two through nine). Therefore, differences in the frequency or proportion of number words used with easy units of counting cannot explain why Mandarin learners learn the meaning of the number word for one later than English learners.

Discussion

We compared the use of the number words for one to nine in Mandarin Chinese and American English child-directed input. Specifically, we compared the inputs in terms of the frequency of all tokens of these number words, of uses meant to denote a cardinality, of uses with and without an overt noun, and of uses with units of counting that are easy to identify for three- and four-year-olds. We found that all of these uses are more frequent, sometimes considerably so, in Mandarin than in English input. We also found that the proportions of number word uses that are most helpful for learning the cardinalities denoted by number words – i.e., cardinal uses, uses with an overt noun, and uses with easy units of counting – are either greater in Mandarin (uses of the number word for one with an overt noun) or very similar in both languages (cardinal uses, uses with easy units of counting). Therefore, none of these features of number word input can explain the Mandarin delay. If anything, they predict a result opposite to what we found – i.e., that Mandarin children should learn number words faster than English learners. The only exception is the fact that the uses we referred to as non-cardinal compounds could cause greater interference in Mandarin than in English because they are considerably more frequent in Mandarin input. However, in what follows, we argue that this fact does not explain the delay because there are good reasons to think that non-cardinal compounds do not actually interfere with the acquisition of the cardinal meaning of number words.

General Discussion

The present study yielded two theoretically important results. First, despite marked linguistic differences between Mandarin and English, we found that Mandarin and English learners learn number word meanings in the same stages. They start by memorizing part of their language's count list. Then, they learn the meaning of the number word for one, two, and three (sometimes four) one at a time in that order. Finally, they acquire the cardinal principle – they learn that the last number word of a correct count denotes the number of objects in the counted set. Thus the presence or absence of morphological number marking in noun phrases and on verbs does not affect the sequence of acquisition of number word meanings and of the cardinal principle. Given evidence of the same sequence in many other languages (Almoammer et al., 2013; Barner et al. 2009; Piantadosi et al, 2014; Sarnecka et al. 2007; Villaroel, Miñon, & Nuño, 2011), this suggests that the hypothesis space that constrains number word learning is cross-linguistically universal.

Second, we found that Mandarin learners learned the meaning of the number word for one some three to six months later than English learners. Importantly, our data suggest that the delay was specific to the acquisition of the meaning of the number word for one. That is, although Mandarin learners learned the meaning of the number word for one later than English learners, they proceeded through the number word learning sequence at the same rate as the English learners – i.e., on average, all children took about a year to go from learning the meaning of the number word for one to learning the cardinal principle.

That Mandarin learners learn the meaning of the number word for one later than English learners converges with previous evidence that children learning Japanese -- another language that does not have obligatory singular/plural morphology – also learn the meaning of the number word for one later than English and Russian learners (Sarnecka et al. 2007). However, Miller and colleagues (1995) obtained evidence which seems conflict to with ours. They found that young Mandarin learners knew the cardinal meaning of as many number words as English learners of the same age. Closer inspection of Miller et al's data shows that this is not a genuine conflict. Their youngest participants were 38 months old – a full fourteen months older than the youngest participants in our study. Moreover, compared to ours, the number of participants Miller et al's youngest group (38 to 48 month-olds) was very small – summing across Chinese and American participants, Miiler et al's youngest group only included 29 participants. When we take these differences into account, we see that our results actually converge with Miller et al's. For example, extrapolation from Figure 2 suggests that average number word knowledge in the age range of Miller et al's youngest group is probably very similar in Mandarin and English learners, or at least too similar for a difference to be detected with a sample as small as Miller et al's.

The convergence with the English/Japanese contrast strengthens the case in favor of the hypothesis that singular/plural morphology supports the acquisition of the meaning of the number word for one. In particular, it shows that the acquisition of the meaning of the number word for one is delayed even when many of the alternative factors that have been proposed to explain the Japanese delay are absent, including the fact that Japanese has more than one count list, the fact that the form of each number word is highly variable because it changes depending on the classifier following it, and the fact that the relative order of nouns and number words is less predictable than in English because number words can float to post-nominal positions. None of these differences can account for the delay observed here because Mandarin does not differ from English in any of these ways.

Another alternative explanation (i.e., other than lack of informative singular/plural morphology in Japanese) of Japanese children's delay, relative to English-learners, is that number word usage is less frequent in Japanese parental input than in English parental input (Sarnecka et al. 2007; Barner et al. 2009). Our analyses of number word usage in child-directed speech converge with those of Chang and colleagues (Chang et al., 2011; Chang and Sandhofer, 2009) in suggesting that this alternative does not apply to the Mandarin-English comparison. Rather, unlike what has been reported for Japanese children, Mandarin learners hear number words more frequently than American English learners. This is true whether we look at all uses of number word forms, or whether we specifically look at cardinal uses of number words, at uses with an overt noun, or at uses with nouns that denote easy units of counting. Moreover, cardinal uses, uses with an overt noun, and uses of with easy units of counting make up similar proportions of total number usage in both Mandarin and English. Thus, none of these features of number word input can explain the Mandarin delay.

Further observations suggest that the delay in Mandarin children's learning of the meaning of the word for one, relative to American children, is not due to differences in factors that affect learning in general. First, the parents of the children recruited in Phase 2 of Study 1 all had the same level of education. Yet, we found that Mandarin learners learn the meaning of the number word for one later than English learners when we restricted our analyses to that phase only. On their own, parental level of education and the factors that correlate with it – e.g., SES – are not sufficient to explain why Chinese children learned the meaning of the number word for one later than their American counterparts.

Second, because the delay is specific to the acquisition of the meaning of the number word for one, it is highly unlikely that Mandarin learners are delayed because they were slower at learning language in general, or because they had weaker processing skills. Indeed, other studies establish that one- and two-year-old Mandarin learners have larger vocabularies than American English learners of the same age (e.g., Tardif, Gelman and Xu (1999), and Sabbagh and colleagues (2006) suggest that middle-class Chinese three-year-olds have stronger executive function than middle-class American three-year-olds (Sabbagh et al. 2006). Thus, Chinese children seem to be overall *more* efficient learners than American children at the ages studied here, and yet they still are 3 to 6 months delayed in figuring out the meaning of the number word for one.

In our view, there remain only four factors that could explain the Mandarin delay: 1) the fact that Mandarin number words are always followed by a classifier, 2) the high frequency of uses of the Mandarin word form for one ("yi") in what we referred to as non-cardinal compounds, 3) better distributional overlap between number words and quantifiers in English than in Mandarin, and 4) the lack of obligatory singular/plural morphology on nouns and verbs in Mandarin. We now consider each of these in turn. To foreshadow, we argue that the lack of singular/plural number morphology is the most likely explanation.

Classifiers. Relative to English, Mandarin phrases that contain number words are more complex at least in the simple sense of being composed of an additional overt element on the surface – i.e., a classifier. For example, the Mandarin equivalent of the English noun phrase "two big brown bears" is "兩隻大棕熊" (liǎng ZHĪ dà zōng xióng or "Two CLASSIFIER big brown bear"). Moreover, different nouns require different classifiers. Mandarin has more than a hundred different classifiers, 30 of which are commonly used in everyday speech (Chao, 1968). The pairing between nouns and classifiers is determined by conceptual and/or perceptual features of the referents of the nouns. The process of learning these pairings is a protracted one (Li, Barner, & Huang, 2008; Wang, Li, & Carey, 2013). Thus, it could be that Mandarin number word learning is delayed with respect to English because it involves one more problem, namely learning classifiers.

Our data suggest that this is not the right explanation. In Mandarin, all number words must be followed by a classifier. Thus, one might think that, if the problem of learning classifiers delays number word learning at all, it should delay all Mandarin number word learning relative to English – i.e., the entire number word learning sequence should take longer in Mandarin than in English. But this is not what we found. Rather, we found that the delay is specific to learning the meaning of the number word for one. Therefore, we conclude that it is unlikely that the Mandarin learners were delayed relative to English learners because they had to learn classifiers.

Uses of "yi" in non-cardinal constructions. Our CHILDES analyses showed that the Mandarin number word for one ("yi") is also used in what we have called "non-numerical compounds," namely, the V-yi-V verb reduplication construction and in compound words such as the adverbials "yíxìa" and "yīhǔir." The English word form "one" is also used in what could be called be compounds, namely quantifiers such as "everyone" and "anyone." But, proportionally speaking, the number word for one is used in non-numerical compounds some twenty times more frequently in Mandarin than in English.

In principle, this difference could explain the Mandarin delay. However, on closer inspection, it seems unlikely. The occurrences of "yi" in non-numerical compounds pose a problem for the acquisition of the meaning of the number word "yi" only if children take the non-numerical compounds and the number word to be tokens of a single word and try to find a meaning that fits all of its uses. This probably does not happen because the non-numerical compounds and the number word are used in very different syntactic contexts. One of the non-numerical compounds is a verb, one is a modal, one is an adjectival, and the others are adverbials. Many studies have shown that, at least by 24 months of age, the meaning children assign to a word form depends on its syntactic context. For example, they take the word form "zav" to refer to a particular individual if they hear it being used as an NP ("This is Zav") but not if they hear it as a noun preceded by a determiner ("This is a zav"; Hall, Lee & Bélanger, 2001; Katz, Baker & Macnamara, 1974). This suggests that Mandarin children probably take the use of "yi" in non-numerical compounds and as a number word as tokens of *different words* (or morphemes) with *different meanings.* Thus, it is quite possible that the uses of "yi" in non-numerical compounds do not interfere with the acquisition of the meaning of the number word "yi."

Our claim is further supported by evidence that the meanings of English morphemes that are used in multiple syntactic contexts are not harder to learn than the meanings of morphemes that are used in fewer syntactic contexts. The English suffix "-s" can be added to a noun to denote plurality, to an NP to denote possession, or to a verb to mark third person agreement (e.g., "cars," "John's," and "dares"). Yet, Brown's (1973) seminal study of the order of acquisition of fourteen different English morphemes showed that children consistently acquire the plural "-s" before other morphemes that do not show the same variability (e.g., the determiners "a" and "the", and the regular past tense marker "-ed"; see also de Villiers & de Villiers, 1973). Brown (1973) and de Villiers and de Villiers (1973) also showed that the earlier acquisition of the plural "-s" cannot be explained by differences in the frequency of the different morphemes in child-directed input. By analogy, it seems unlikely that Mandarin learners learn the meaning of the word for one later than English learners because the Mandarin form for one is used in more syntactic contexts than the English form for one.

Distributional overlap between number words and quantifiers. Following a hypothesis first put forth by Bloom and Wynn (1997; see also Wynn, 1992), Barner et al. (2009) proposed that "a frequent distributional overlap of quantifiers and [number words] might allow children to infer that [number words] denote the properties of sets, like quantifiers, thereby initiating their acquisition." (p. 434). On Barner et al.'s definition of distributional overlap, a number word overlaps with a quantifier if it can be replaced by the quantifier without making the sentence ungrammatical. For example, in "I ate two apples", "two" overlaps with "some" and "many" but not with "each" or "all."

On this view, the more number words overlap with quantifiers, the easier it is to learn their meaning. There are theoretical problems with this proposal. First, number words and quantifiers do not have the same syntax. For example, number words can be used as modifiers ("I gave water to these three boys") but quantifiers cannot (*"I gave water to these some/each/all boy(s)"; Giusti, 1991). Therefore, from the point of view of syntax, analyzing number words as quantifiers might hinder learning instead of helping it. The same is true of semantics. To our knowledge, no formal analysis of the semantics of number words takes them to have the same semantics as all quantifiers, and indeed, quantifiers differ semantically in deep ways among themselves. On some analyses, number words have the same semantics as quantifiers such as "many" and "some" but do not have the same semantics as universal quantifiers such as "each" and "all," or as proportional quantifiers such as "most" (e.g., Keenan, 1996). On other analyses, number words are not quantifiers at all (e.g., Heim, 1988; Ionin & Matushansky, 2006). Therefore, at best, overlap between number words and quantifiers might help children learn their meaning but only if the overlap is restricted to some quantifiers. It is also possible that it does not help at all.

Second, suppose that we disregard the aforementioned problems and assume that number words are quantifiers. Then, overlap with quantifiers will help children discover that number words are quantifiers only if it is greater for quantifiers than for other lexical categories. For example, if number words overlap more with adjectives than with quantifiers, then overlap is not helpful, at least not on the view that number words are quantifiers. Barner et al. did not analyze how much number words overlap with words from lexical categories other than quantifiers. Therefore, their analysis cannot tell us whether overlap actually supports number word learning in English to a greater extent than in Japanese.

Building on Barner et al.'s overlap analysis, we conducted more complete analyses for English and Mandarin. Using the CHILDES New England corpus for English child-directed speech and the Zhou corpus for Mandarin (see Study 2), we determined how frequently number words in input to children could be replaced with any of five frequent quantifiers (every/měi, some/xiē, all/suǒyǒu, several/jǐ, and many/duō), but could not be replaced with an adjective (big/dà). Since it is not clear that the linguistic assumptions of this analysis are valid, we do not report it here, but have placed it online (https://software.rc.fas.harvard.edu/lds/wp-content/uploads/2015/07/Le-Corre-et-al-supp-materials-July-2015.pdf). In short, we found no overlap advantage for English. We find the opposite: the number word for one overlaps with quantifiers but not adjectives a bit more in Mandarin than in English, and the number words for two to nine overlap with quantifiers but not adjectives about four times more often in Mandarin than in English. This analysis provides empirical evidence against the hypothesis that distributional overlap between number words and quantifiers can explain why Mandarin learners learn the meaning of the number word for one later than English learners, supplementing the theoretical problems summarized above.

Cross-linguistic differences in numerical morphology. We propose that the most likely explanation of the fact that English learners learn the meaning of the number word for one earlier than Mandarin learners is that English learners have access to an additional clue to its meaning, namely the numerical information provided by numerical morphology. In English, overt nouns that are directly quantified by the number word "one" are always in singular form, whereas nouns that are directly quantified by the number words "two" or more are in plural form. In many contexts, the singular and plural forms provide information about whether one or more individuals are being referred to or have been introduced in discourse. English learners are sensitive to the numerical information provided by singular/plural morphology prior to learning the meaning of the number word "one" (Kouider et al., 2006; Mervis & Johnson, 1991; Zapf & Smith, 2007, 2008). In contrast, the form of Mandarin nouns rarely provides numerical information. In addition to the fact that none of the many alternatives considered above provide satisfactory explanations of the Mandarin delay, we see two reasons to favor the singular/plural hypothesis. First, Almoammer et al. (2013) find that children learning a language with obligatory dual morphology (Slovenian or the Najdi dialect of Saudi Arabic) learn the meaning of the number word for two earlier than children learning a language with no dual morphology (English). They provide strong evidence that the number word learning difference is due to the cross-linguistic difference in numerical morphology. This provides an existence proof that cross-linguistic differences in numerical morphology can cause cross-linguistic differences in number word learning.

Second, the acquisition of the meaning of the number word for one has also been found to be delayed in Japanese relative to English (Barner et al., 2009; Sarnecka et al. 2007) and to Russian (Sarnecka et al. 2007). The Japanese word form for one does not participate productively in verb reduplication constructions, unlike Mandarin "yi." The presence or absence of a distinction between singular and plural nouns is one of the only cross-linguistic differences that the English-Mandarin contrast shares with the Russian-Japanese and the English-Japanese contrasts. The only other difference is whether the language has classifiers (Japanese and Mandarin have them, but Russian and English do not). However, the fact that the Mandarin delay is specific to the acquisition of the meaning of the number word for one poses problems for the hypothesis that the complexity of the classifier system is the sole explanation of the delay. Also, classifiers are not implicated in the Slovenian/English or Arabic/English contrasts. It could be, of course, that the delay in learning the meaning of the number word for one in Mandarin and Japanese, relative to English, and of the number word for two in English, relative to languages with dual markers, is caused by factors unique to each case, and that numerical morphology is not one of them. But it is more likely that these patterns of relative rates of learning the meanings of number words are at least partly explained by a factor common across all them — namely, details of obligatory numerical morphology.

To be sure, it may be that the factors other than numerical morphology add to the delay in each case. Indeed, Japanese children's delay is greater than Mandarin children's. Sarnecka et al. (2007) found that 100% of English 33- to 40-month-olds had learned the meaning of the number word for numbers equal to or greater than one, whereas only 54% of Japanese learners had done so. The corresponding proportions in the present data were 98% for English learning 33- to 40-month olds and 84% for Mandarin learners of the same age. Similarly, Barner et al. found that 74% of their English-learning 2-year-olds had learned the meaning of the number word for numbers equal to or greater than one, compared to 22% of their Japanese learning 2-year-olds. The corresponding proportions in the present data were 80% for English learning 2-year-olds and 55% for Mandarin-learning 2-year-olds. Thus, relative to English learners, Japanese learners are significantly more delayed in learning the meaning of the number word for one than Mandarin learners. This cannot be due to methodological differences between the studies because the proportions of English learners who had learned the meaning of the number word for one were remarkably similar across them. It is thus likely that, relative to English, there are more factors that hinder the acquisition of the meaning of the number word for one in Japanese than in Mandarin, namely the very factors that have been controlled for in the present study (e.g., the greater variability of the position of Japanese number words relative to nouns, the fact that

Japanese has two distinct count lists, and the lower frequency of number words in Japanese child-directed speech).

Conclusion. The morphology of many human languages encodes numerical information (Corbett, 2000). A few studies have provided evidence that the numerical information encoded in numerical morphology supports the acquisition of number word meanings (Almoammer et al. 2013; Barner et al. 2009; Sarnecka et al. 2007). The present study extends this body of evidence by providing the strongest evidence thus far that prior knowledge of the numerical meaning of the morphological distinction between singular and plural nouns (and perhaps other parts of speech such as verbs) helps children learn the meaning of the number word for one. It seems likely that this occurs because some number words and numerical morphology share common meanings. As suggested by Carey and her colleagues (Carey, 2004, 2009; Carey & Sarnecka, 2006), it thus may be that some of the conceptual roots of our representations of the natural numbers are found in the meanings expressed by linguistic distinctions as widespread and basic as the one between singular and plural.

Acknowledgements

Thanks are due to David Barner and Pierina Cheung for answering all our questions on their analyses of Japanese input, to Barbara Sarnecka, Moriko Moher, and Yoko Futagi for help with Japanese syntax, and to Sarah Turner for help with Russian syntax. Thanks also to Rende Shui, Marvin Li, and Wen-shong Li for help with data collection and/or analysis, and to Jody Tomchishen, and Samantha Shortall for their grammaticality judgments. Finally, we thank the many parents, children, and day care personnel who generously contributed to this project. This research was supported by NIH Grant # RO1-HD038338 and NSF ROLE Grant #REC-0196471 to S.C. and by NSERC Discovery grant 371718-2009 and a PRODEP grant to M.L.C.

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