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Running Head: JAPANESE QUANTIFIER AND NUMERAL ACQUISITION

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Cross-linguistic relations between quantifiers and numerals in language acquisition:

Evidence from Japanese

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Abstract

A study of 104 Japanese-speaking 2- to 5-year-olds tested the relation between numeral and quantifier acquisition. Experiment 1 assessed Japanese children's comprehension of quantifiers, numerals, and classifiers. Relative to English-speaking counterparts, Japanese children were delayed in numeral comprehension at 2 years old, but showed no difference at 3 and 4. Also, Japanese 2-year-olds had better comprehension of quantifiers, indicating that their delay was specific to numerals. A second study examined the speech of Japanese and English caregivers, to explore the syntactic cues that might affect integer acquisition. In English, quantifiers and numerals occurred in similar syntactic positions, and overlapped to a greater degree than in Japanese. Also, Japanese nouns were often dropped, and both quantifiers and numerals exhibited variable positions relative to the nouns they modified. We conclude that syntactic cues in English facilitate bootstrapping numeral meanings from quantifier meanings, and that such cues are weaker in classifier languages like Japanese.

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Early in language development, children acquire words rapidly, learning up to ten words a day from the age of 18 months (Bates & Goodman, 1997; Caselli, Casadio, & Bates, 1999; Fenson et al., 1994; Goldfield & Resnick, 1990). Children's early vocabularies are filled with names for things, and even include a sprinkling of words that denote actions and events (Nelson, Hampson, & Shaw, 1993). However, before the age of two most children lack words that denote the properties of sets. For example, quantifiers and number morphology like singular-plural marking are largely absent from children's language production before 24-months of age (Dale & Fenson, 1996; Fenson et al., 1994). Also, children's comprehension of quantifiers develops gradually between 2 and 5 years of age. The relative absence of number marking and set-relational quantifiers in early language suggests that these words pose a special challenge in acquisition (Barner, Chow, & Yang, 2009; Bloom & Wynn, 1997; Wynn, 1992).

Like quantifiers, numerals such as *one*, *two*, and *three* typically emerge in children's speech at around 2 years of age. Also, children's emerging comprehension of numerals in English is significantly correlated with their developing comprehension of quantifiers (Barner et al., 2009). Although many children can recite numerals in the count list by the age of two, learning their meanings normally takes an additional 18 to 24 months (Fuson, 1988; Le Corre & Carey, 2007; LeCorre, Van de Walle, Brannon, & Carey, 2006; Sarnecka, Kamenskaya, Yamana, Ogura, & Yudovina, 2007; Schaeffer, Eggleston, & Scott, 1974; Wynn, 1990, 1992). By 2-and-a-half, many English-speaking children have acquired the meaning of the word *one*. These "one-knowers" give one object when asked for one, but give more than one for all other numbers. Children often spend a number of months as one-knowers before they acquire the meaning of *two* (becoming two-knowers), and then *three* (becoming three-knowers). By the time children understand *four*, they often demonstrate an understanding of all numerals in the count sequence

that they can recite. These children have transitioned from naming sets on the basis of associations between words and set sizes to inferring their cardinality based on their understanding of the cardinal principle – i.e., that the last number recited in the counting routine refers to the cardinality of the set (see Carey, 2004, for review).

As English-speaking children learn the meaning of each numeral, their knowledge of quantifiers also grows. For 2- to 5-year-olds, knowledge of quantifiers and determiners like *a*, *some*, *most*, *all*, *none*, etc., predicts greater comprehension of numerals (number knower level), independent of effects due to age (Barner et al., 2009). Further, this correlation between number knowledge and quantifier comprehension is true of almost all quantifiers and determiners individually (i.e., it is not driven by one or two quantifiers). Thus, English children who show delayed numeral comprehension also tend to show delayed quantifier comprehension, whereas children who are advanced in one domain are also advanced in the other.

Why does knowledge of integers and quantifiers emerge so late in language development, relative to other words, and why are the two types of word so tightly yoked in acquisition? Wynn (1992) notes that to learn integers, children must discover: (1) that numerals denote the properties of *sets*; (2) that they denote the cardinalities of sets; and (3) that *two* denotes ‘two’, *three* denotes ‘three’, etc. – i.e., *which* specific cardinality each numeral denotes. Quantifiers pose a similar learning problem. As with numerals, children must first discover that quantifiers denote properties of sets, rather than properties of individual things. Second, they must discover that they denote set relations (e.g., *all*, *every*, *some*), or in certain cases proportions of sets (e.g., *most*, *many*, *few*). Finally, they must discover which specific relations or proportions they denote.

As Wynn (1992) observes, the first step in this process poses a significant problem. By denoting the properties of *sets* rather than of individual things, quantifiers and numerals differ

from almost all other words that children learn in their first two years of life. Words like *five* and *many* (unlike nouns such as *cat*) can be applied to a set of things without being true of any single individual in isolation (e.g., in a set of five cats, no single cat has the property of “fiveness”). As Bloom and Wynn (1997) note, “sets are notoriously abstract entities. One can see and hear cats, but nobody has ever been wakened in the middle of the night by the yowling of a set.” (p. 512)

Figuring out that a word denotes the property of a set is surely hard. Harder still, however, would be to learn this separately for each quantifier and numeral that is confronted in acquisition. To ease this burden, Bloom and Wynn suggest that children might use cues from both the syntax and semantics of known words to bootstrap the meanings of unknown quantifiers and numerals. Bootstrapping mechanisms can take multiple forms, involving semantic inferences based on syntactic facts (Gleitman, 1990), syntactic inferences based on semantics (Grimshaw, 1981; Macnamara, 1982; Pinker, 1984), or inferences within a domain. Three variations on these bootstrapping mechanisms are relevant to the problem of acquiring quantifiers and numerals.

First, as noted by Bloom and Wynn, the syntax and semantics of English noun phrases (NPs) might signal that both quantifiers and numerals denote the properties of sets. In English, both can be used to modify count nouns, which denote kinds of individuals (see Barner & Snedeker, 2005). Also, both can occur in partitive constructions, which denote part-whole relations – e.g., *six of the dogs* / *some of the dogs*, and neither can occur between an adjective and a head noun, although other adjectives – which denote the properties of individuals – can (e.g., *the big smelly dogs*; **the big some dogs*; **the big five dogs*). Finally, certain NP sub-distinctions might provide cues to meaning. For example, both the words *a* and *one* can be used in singular noun phrases (e.g., *a / one cat* vs. *some / two cats*), which might lead children to conclude that both words denote sets of one, whereas other quantifiers and numerals denote sets of “more than one”

(Carey, 2004; Sarnecka et al., 2007; Li et al., 2003). For the purposes of the current discussion, we will call this first class of possible mechanisms, by which quantifier and numerals meanings are bootstrapped via NP syntax and semantics, “NP bootstrapping”.

In addition to NP bootstrapping, children might also exploit direct syntactic relations *between* quantifiers and numerals to discover their meanings. By learning their common distributional profiles, children could use knowledge of one set of words (e.g., quantifiers) to inform their hypotheses about the other set (e.g., numerals). For example, having learned that *all* refers to the property of a set, children could infer that other words used in similar syntactic contexts, like *three* or *four*, also do. In this way, learning a small set of quantifiers might permit children to begin the process of integer acquisition, beginning with the inference that numerals, like quantifiers, represent sets. Since this mechanism involves inferences about numeral meanings based on their distributional overlap with quantifiers, we will call it “quantifier bootstrapping”.

Finally, relations between quantifier and integer acquisition might be mediated *conceptually*. During their first 2 years of life, children have not yet had the occasion to explicitly represent set relations in language, and may lack the representational resources to do so. Many early utterances may well require only a basic predicate logic that lacks logical quantifiers. To explicitly express set relations like *some* and *all*, however, demands more sophisticated representational resources, and minimally a first order predicate logic that supplies variables and logical quantifiers (e.g., $\forall x$ = “for all x ”; $\exists x$ = “there exists an x , such that...”). Without such variables and logical quantifiers, children could perhaps talk about things and sets of things, but would be unable to explicitly represent set relations or their properties. However, having acquired operators that express existential quantification, for example, children would have the

resources needed to represent not only quantifiers, but also numeral meanings.¹ By this account, which we will call “conceptual bootstrapping”, acquiring one or two quantifiers might require children to undergo a conceptual change, thereby setting the stage for acquiring other set relational quantifiers and numerals (for discussion of conceptual bootstrapping in this and other domains, see Carey, 2004; Gentner, 1989; Perkins & Unger, 1994).

Within a particular language like English, it is difficult to distinguish the relative role of these three possible bootstrapping mechanisms. Although we know that quantifier and numeral comprehension are significantly correlated within English, it is difficult to say *why*. The two types of words could be acquired in parallel, each separately facilitated by the presence of count syntax, as with NP bootstrapping, or could interact directly, either via quantifier or conceptual bootstrapping. Also possible is that all three mechanisms play a role.

As Bloom and Wynn suggest, our best chance to distinguish the roles of particular cues is to compare acquisition cross-linguistically (see also Dowker, Bala & Lloyd, 2008). In particular, Bloom and Wynn propose comparing languages like English and Japanese, which differ in several ways that speak to the hypotheses at hand. In Japanese, the syntactic relations between quantifiers, numerals, and nouns may be less consistent and informative than in English. For one, Japanese lacks count syntax at the level of the noun, and thus does not obligatorily mark individuation syntactically. As a result, words that denote objects, like *ball*, can be used in many of the same syntactic frames as words that denote non-solid substances, like *water*. Also, as a classifier language, Japanese requires the use of classifiers whenever numerals are used. Somewhat like English measure words, which are often used with mass nouns to permit counting (e.g., six *piles* of dust), Japanese classifiers intervene between numerals and nouns, and encode

¹ For example, $\exists x(Px \ \& \ (\exists y)(Py \ \& \ \neg(x=y)))$ means “there are at least two”; $\exists x(Px \ \& \ (\exists y)(Py \ \& \ \neg(x=y))) \ \& \ \neg(\exists z)(Pz \ \& \ \neg(z=x) \ \& \ \neg(z=y))$ means “there are exactly two”.

semantic properties of the noun such as shape information. For example, the classifier *-nin* is used when counting people, as in (1), but is not used with quantifiers like *both*, as shown in (2):

1. [*san-nin-no gakusei*]-ga aruita
 3-CL-GEN student-NOM walked
 ‘Three students walked’
2. [*ryoohoo-no gakusei*]-ga aruita
 both-GEN student-NOM walked
 ‘Both students walked’

Because they intervene between numerals and nouns, classifiers prevent the two types of word from appearing adjacently. Also, in Japanese, classifiers cause important phonological changes in numerals. For example, the word *one* takes the forms *ippiki*, *ichimai*, *hitotsu*, and *ikko* when used with classifiers for naming animals, flat sheets, generic objects, and small objects, respectively. This can hardly help children converge on a meaning for *one*, especially since there are over 100 classifiers in Japanese, 30 of which are used frequently (Downing, 1996). Children learning Japanese and Chinese acquire classifier meanings very gradually, and even some very common classifiers are not fully understood by the age of 6 (see Sumiya & Colunga, 2006; Uchida & Imai, 1999; Yamamoto & Keil, 2000; for evidence from Mandarin Chinese, see Chien, Lust & Chiang, 2003; Li, Barner, & Huang, 2008). Thus, the use of numerals in children’s language input is highly variable and different in many respects from the use of quantifiers.

One final cross-linguistic difference that might cause differences in how quantifiers and numerals interact in Japanese is “floating”. In Japanese, both numerals and quantifiers can “float” to post-nominal positions, as in (3) and (4):

3. a. [*san-nin-no gakusei*]-ga aruita

3-CL-GEN student-NOM walked

‘Three students walked’

b. *gakusei-ga [san-nin aruita]*

student-NOM 3-CL walked

‘Three students walked’

4. a. *[ryohoo-no gakusei]-ga aruita*

both-GEN student-NOM walked

‘Both students walked’

b. *gakusei-ga [ryohoo aruita]*

student-NOM both walked

‘Both students walked’

In contrast, English numerals and quantifiers normally precede the noun, though quantifiers can float to post-nominal positions, as in (5). English numerals never float, as in (6):²

5. a. All the students walked to the store.

b. The students all walked to the store.

6. a. Four of the students walked to the store.

b. *The students four walked to the store.

As noted by Mintz (2003), detecting distributional relations between words should be easiest in languages with stable word order, and harder in languages that permit relatively freer ordering of constituents. In the present context, freer word order due to floating could have two primary effects. First, relevant to NP bootstrapping, floating could obscure the relationship between

¹ Barbara Sarnecka (personal communication) notes that such uses are possible in English, though they are not productive, and are idiomatic in character: “Old King Cole was a merry old soul, and a merry old soul was he; he called for his pipe, and he called for his bowl, and he called for his fiddlers *three*.”

quantifiers, numerals, and the nouns they modify, making it harder for children to recognize that numerals and quantifiers denote properties of sets. Second, in the event that quantifiers and numerals float with different frequencies in the input, the distributional overlap between quantifiers and numerals would be reduced, thereby weakening the signal to distributional learning and thus to quantifier bootstrapping.

In support of Bloom and Wynn's prediction that cross-linguistic differences should affect integer acquisition, recent studies have found delayed integer acquisition in both Japanese and Mandarin Chinese (two classifier languages), relative to English and Russian (two languages with richer number marking; Sarnecka et al., 2007; Li et al., 2003). For example, Sarnecka et al. (2007) found that children learning Russian and English began to comprehend numeral meanings earlier than children learning Japanese. In their study, almost half of the Japanese children (aged 2;9 to 3;6) had not yet acquired the meaning of *one* whereas over 90% of English and Russian children knew at least *one*. Strikingly, these results were found even though Japanese children typically receive equal exposure to numerals and counting routines, and even though Japanese and Chinese children acquire the count list with greater ease than English-speaking children (see Miller & Stigler, 1987; Miller, Smith, Zhu, & Zhang, 1995).

This delay of integer acquisition in Japanese provides a case in which it is possible to tease apart the bootstrapping mechanisms that might be used to discover numeral meanings. For example, if, as described in the NP bootstrapping hypothesis, both quantifier and numeral meanings are bootstrapped in parallel from NP syntax and semantics, then both should be equally delayed in Japanese, since both should be equally affected by the relative lack of number marking on nouns. Similarly, if acquiring quantifiers bootstraps integer acquisition *conceptually* (driving the correlation in English development), then Japanese children's delay in integer

acquisition should correspond to a similar delay in quantifier development. However, if integer acquisition in English is facilitated by the distributional overlap between quantifiers and integers, as suggested by the quantifier bootstrapping hypothesis, then weaker syntactic relations between quantifiers and numerals in Japanese would predict a delay that is specific to integer acquisition without a corresponding delay in quantifier acquisition.

We performed two studies to (1) assess cross-linguistic differences in the acquisition of set representations, and (2) test the possible mechanisms of integer bootstrapping. The first study tested the comprehension of numerals, quantifiers, and classifiers in Japanese 2- to 5-year-old children, to determine whether their development is yoked, as in English, or whether Japanese children's difficulty is specific to acquiring the meanings of numerals. In the second study, we examined caregiver speech in both Japanese and English, to determine whether the syntactic relations between quantifiers and numerals are in fact stronger in English than in Japanese.

Experiment

The first study tested the course of quantifier and integer acquisition in Japanese children, to determine whether quantifiers emerge earlier than numerals, or are also delayed relative to English. We also tested comprehension of classifiers, to evaluate their role in integer acquisition.

Method

Participants

Participants were 104 Japanese-speaking children (55 girls) aged between 23.8 and 59.0 months ($M = 48.1$), recruited at five childcare centers and preschools in Fukuoka, Japan. Children were divided into three groups: 2-year-olds ($N = 32$; $M = 29.7$; range = 23.8-35.7), 3-year-olds ($N = 37$; $M = 42.33$ months; range = 36.5 – 47.7 months), and 4-year-olds ($N = 35$; $M = 54.3$ months; range = 49.1 - 59.0 months). Additional pilot subjects, used to develop the

methods, were tested in a childcare centre in Toronto, Canada. Sixteen Japanese-speaking college students were recruited and tested at Sapporo University, in Japan.

For a subset of analyses, Japanese children were compared to 72 English-speaking children (38 girls) from Barner et al. (2009), who were also divided into three closely age-matched groups: 2-year-olds ($N = 44$; $M = 29.3$ months; range = 22.8 - 35.0 months), 3-year-olds ($N = 12$; $M = 41.4$ months; range = 38.4 - 45.9 months) and 4-year-olds ($N = 16$; $M = 54.3$ months; range = 48.5 - 60.4 months). These children were tested in Boston, MA, and in Toronto, Canada.

Stimuli and Procedure

Each child was tested individually in a classroom environment in a single session lasting between 15 and 20 minutes. Children sat at a child-sized table across from the experimenter, who was a native speaker of Japanese (author M.T.). A second experimenter sat next to the table to record responses and to videotape sessions. All children were tested in Japanese. Three tasks were used: (1) the Give-Quantifier task, (2) the Give-a-Number task, and (3) the Classifier Matching task. The tasks were always presented in the above order. Adult controls were tested only with the Give-Quantifier task.

The Give-Quantifier Task. This task was adapted from Barner et al. (2009). Stimuli consisted of a red plastic circle and three sets of small plastic fruit (i.e., 8 oranges, 8 bananas, and 8 strawberries) that were presented in separate piles organized by kind. The experimenter first introduced the child to the fruits to ensure that she could distinguish them: “*Kore wa nani?*” (“What is this called?”), “*Kore shitteru?*” (“Do you know what this is?”). The experimenter was careful not to use the target quantifiers when introducing the items. The experimenter then showed the child the red circle and asked her to put a quantity of a specific kind of fruit into it, using a quantifier (e.g., “*Maru no naka ni mikan wo zenbu iretekureru?*”; “Could you put *all* of

the oranges into the red circle?"). The following quantifiers were tested: *chotto* (a few), *takusan* (many), *nokotteiru* (the other Xs), *ikutsuka* (some), *hotondo* (most), *zenbu* (all), *hitotsumo* (none), and *ryoho* (both). These quantifiers were selected based on previous studies of quantifier development (e.g., Hanlon, 1987) due to their relatively early acquisition and to focus on words that were likely to exhibit variability in young children. Examples of how each quantifier was used are presented in Table 1. For *ryoho* (both), we presented children with one token of each fruit type (1 orange, 1 strawberry, and 1 banana), and asked in Japanese: "Can you find both of the fruits that you like and put them into the red circle?" ("Maru no naka ni suki na kudamono wo ryoho iretekureru?"). For *nokotteiru X* (the other Xs), the experimenter said the following to the child: "I will move four of them here" ("Mazu yonko ugokasu ne"). She then moved four of the objects into a separate pile and asked the child to put "the other" things (e.g., strawberries) into the circle ("Nokotteru ichigo wo maru no naka ni irete"; *nokotteru* may also be translated as "the remaining" or "the rest"). Thus, a correct response required selecting the remaining objects, but not those moved by the experimenter.

----- Insert Table 1 about here -----

After each trial, the experimenter thanked the child and returned all fruit objects to their original piles before the next request. The quantifiers were presented in two different orders across participants, and pairings of quantifiers and fruit kinds were quasi-randomized. Each word was tested twice within subjects.

The Give-Number Task. This task was adapted from Wynn (1992) to test numeral comprehension. Stimuli were the same red plastic circle and a set of eight plastic strawberries. To begin, the experimenter presented the strawberries to the child and asked, "Oh, there are strawberries. How many do you think there are? Could you count them for me?" Then, the

experimenter showed the child the red circle and asked them to put a certain number of strawberries into it: “Maru no naka ni ichigo wo rokko irete?” (“Could you put six strawberries into the red circle?”). Following Wynn (1992) we used a titration method. When children successfully gave N strawberries (e.g., 3) they were then asked to give N+1 strawberries (e.g., 4). When they failed with N, they were tested on N-1 (e.g., 2). When they initially failed to give a correct amount, they were asked, “Are you sure there are N strawberries?” and then, following their response, “Can you count to make sure?” If children counted and the last number of their count did not match the number requested, they were asked again, “Is that N strawberries? Can you fix it to make it N strawberries?” If they failed to correctly fix the set, they were then tested with N-1. If they succeeded, they were tested with N again.

Children were called N-knowers (e.g., two-knowers) if they correctly gave N strawberries 2 out of 3 times when they were asked for N, but failed to give the correct number 2 out of 3 times for N+1. Children were credited as CP-knowers (Cardinal Principle knowers) if they could correctly give six and seven strawberries at least two out of three times for each.

The Classifier Match Task. This task tested Japanese children’s comprehension of frequently used classifiers. In Japanese, classifiers typically select for nouns with certain semantic properties. For example, when counting animals the classifier *-hiki* is used, such that the numeral *one* becomes *ippiki*. We tested children with four highly frequent classifiers³, used with the numeral *one*: *ippiki* (“one animal”), *ichimai* (“one flat sheet”), *hitotsu* (“one object”) and *ikko* (“one small object”). Using a two-item forced-choice paradigm, a distractor stimulus was always paired with a target object for each classifier (see Chien, Lust, & Chang, 2003). The

² According to Tamiko Ogura (personal communication), data from the Japanese Communicative Development Inventory (a parental report measure) indicate that *-tsu*, *-ko*, *-mai*, and *-hiki* are the most frequent classifiers in the speech of Japanese children at 30 months of age (*tsu* is used by 72% of children, *ko* by 62.2%, *mai* by 23.2%, and *hiki* by 13.3%; see also Naka, 1999).

experimenter then asked the following question: “‘*One-classifier*’ *ha docchi?*” (Which is the ‘classifier-one’?). Based on the classifier used, the child had to choose one of the two objects. The target objects and distractors for each classifier were as follows: *ippiki* (a small toy frog vs. a small box-shaped present), *hitotsu* (a small box-shaped present vs. a small toy frog), *ichimai* (a flat card vs. a small box-shaped present), and *ikko* (a small box-shaped present vs. a flat card). The child received a score of one for each correct choice, for a maximum of four.

Results

For quantifiers and numerals we performed three analyses. First, we examined Japanese children’s comprehension of numerals, to determine whether they were delayed relative to children acquiring English, as previously reported by Sarnecka et al. (2007). Second, we compared quantifier comprehension in Japanese and English. Third, we analyzed the relation between quantifier comprehension and number knower level, to determine whether quantifier and integer acquisition are correlated in Japanese, as in English. In each analysis, Japanese children were compared to English-speaking children from Barner et al. (2009), who were tested using exactly the procedures and materials described above, but in English, and with the words: *a, some, all, most, most, both, none, another, the others*. English sentences are shown in Table 1.

For classifiers, we determined the number of trials on which children matched classifiers to their appropriate objects, and compared behavior between 2-, 3-, and 4-year-olds.

Numeral comprehension

We assigned each child a number-knower level using the criteria described above. To compare the knower levels of Japanese and English-speaking children, number knower level was entered into an analysis of variance (ANOVA) with two between-subjects factors: Age (2-year-olds vs. 3-year-olds vs. 4-year-olds) and Language (Japanese vs. English). The analysis found a

main effect of age ($F(2,166) = 108.09, p < .001$), but no main effect of language ($F(1,166) = .18, p > .5$), indicating that there was no overall difference in knower level between children acquiring the two languages. However, crucially, there was a significant interaction between age and language ($F(2,166) = 5.47, p < .01$).

To investigate this interaction, we compared the average number knower levels of English and Japanese children at ages 2, 3, and 4 (see Figure 1). At age 2, Japanese children had a significantly lower knower level ($M=0.44$) than English-speaking children ($M=1.14$; $t(75) = 3.11, p < .003$). However, there was no effect of language at age 3 (Japanese= 2.62; English=2.25), or at age 4 (Japanese= 3.89; English= 3.38; both p 's $> .05$).

----- Insert Figure 1 about here -----

The cross-linguistic difference for 2-year-olds reflected the fact that significantly more Japanese 2-year-olds were non-knowers (25 out of 32) relative to English (11 out of 42; $\chi(1) = 17.6, p < .001$). There were more one-knowers in the English sample (19 out of 42) than in the Japanese sample (2 out of 32; $\chi(1) = 11.23, p < .001$), but no difference in the proportion of two-knowers, three-knowers, or CP knowers (all p 's $> .05$).⁴ Thus, following Sarnecka et al., we found a significant difference in the development of numeral meanings across Japanese and English. Whereas almost no Japanese children had acquired the meaning of *one* before their third birthday, almost half of English-speaking children had.

----- Insert Figure 2 about here -----

At later ages there were no cross-linguistic differences in the proportion of children at each number knower level (all p 's $> .05$; See Figure 2). Thus, Japanese children quickly caught up to their English counterparts, and acquired numeral meanings quickly after having acquired *one*.

⁴ There was one 4-knower. To simplify analysis this child was classified as a CP-knower.

This suggests that the delay in Japanese is not attributable to a difficulty acquiring specific numeral meanings, since they acquire the meanings of *two*, *three*, and beyond as early as children learning English. Instead, the result suggests a more general delay, consistent with a failure to recognize that numerals denote the cardinalities of sets.

Quantifier comprehension

To evaluate Japanese children's comprehension of quantifiers we defined "correct" responses for each quantifier as in Table 2. These criteria were based on the judgments of adult speakers of Japanese (N = 16). For each word, 100% of adult participants gave a quantity objects that was consistent with these criteria on 2/2 trials.

----- Insert Table 2 about here-----

Japanese children's comprehension of the quantifiers and determiners was analyzed based on the number of correct responses that they provided over two test trials for each word (resulting in scores of 0, 1, or 2). For each quantifier, we determined whether the rate of correct responses differed from chance using one-sample t-tests. We defined chance based on the assumption that there were nine possible responses: giving 0, 1, 2, 3 ... 8 objects on each trial. For a word like *all*, for which there was only one correct response (i.e., 8 objects), the number of correct responses expected by chance over two trials would be 2/9 (i.e., $1/9 + 1/9 = .222$).

----- Insert Figure 3 about here -----

Figure 3 presents data for each age group (2-year-olds, 3-year-olds, and 4-year-olds) for each quantifier. Items are presented according to the average percentage of trials that children responded correctly for each, thus providing an estimate of their order of acquisition: *hitotsumo* (none), *zenbu* (all), *takusan* (many), *chotto* (a few), *ikutsuka* (some), *nokotteiru* (the other Xs), *ryoho* (both), and *hotondo* (most). Combined, the performance of 2- to 5-year-old Japanese

children was significantly better than chance for all words (all p 's < .001), except for *ikutsuka* (some), and *chotto* (a few) which did not differ from chance ($p > .05$), and *hotondo* (most), which was below chance ($p > .001$). The Japanese 2-year-olds, who were delayed in integer acquisition, exhibited better than chance comprehension of *zenbu* (all), *hitotsumo* (none), and *nokotteiru* (the others; p 's < .001).⁵ Comprehension was at chance for *takusan* (many), *chotto* (a few), *ryoho* (both), and *ikutsuka* (some; $p > .1$), and below chance for *hotondo* (most; $p < .001$).

--Insert Figure 4 here--

To compare quantifier comprehension between Japanese and English, each child was assigned a quantifier score, which was defined as the average number of correct responses (out of 2) for each child across all quantifiers. An ANOVA assessed the effects of Age (2-year-olds vs. 3-year-olds vs. 4-year-olds) and Language (Japanese vs. English) on quantifier score. There was a significant effect of Age ($F(2,169) = 120.1, p < .001$) driven by an overall increase in scores with age. Also, Japanese children had higher quantifier scores, on average, than English-speaking children, resulting in a main effect of Language ($F(1,169) = 9.4, p < .005$). Finally, there was a significant interaction between Age and Language ($F(2, 169) = 11.3, p < .001$), which was due to a difference between English and Japanese children at age two ($E=0.48$; $J=0.93$; $t(73) = 7.27, p < .05$), but not at ages three ($E=1.19$; $J=1.33$) or four ($E=1.63$; $J=1.53$; both p 's > .05). Thus, Japanese children had a slightly greater comprehension of quantifiers at age two, but did not differ at ages three and four. Whereas the Japanese children were initially delayed in acquiring numeral meanings relative to English children, they were relatively

⁵ Interestingly, children succeeded at *hitotsumo* (none) though few were yet one knowers. This suggests that knowing *hitotsu* (one) did not likely contribute to understanding *hitotsumo*, and that *hitotsumo* may be acquired as a frozen phrase.

advanced in quantifier acquisition, suggesting that for them quantifier and numeral comprehension were not yoked in early acquisition.⁶

Correlations between quantifier and numeral comprehension in Japanese and English

For English-speaking children, Barner et al. (2009) reported significant age-independent correlations between quantifier comprehension and number knower level for both older 3- and 4-year-olds and younger 2-year-olds. To explore these relations in Japanese, we also calculated correlations between quantifier score, number-knower level (0,1, 2, 3 or CP), and age.

----- Insert Figure 5 about here -----

Figure 5 presents average quantifier scores for each number knower level. Among older Japanese children (3- and 4-year-olds), there were significant correlations between quantifier and number knower levels ($r(72) = .471, p < .001$), quantifier score and age ($r(72) = .302, p < .01$), and between number knower-level and age ($r(72) = .585, p < .001$). Also, after controlling for age, the relationship between quantifier score and number knower-level remained significant ($r(72) = .381, p < .005$). However, the relationship between quantifier score and age was no longer significant when controlling for number knower-level ($r(72) = .036, p > .5$). This suggests that the relation between quantifier score and age was mediated by children's comprehension of integers. In contrast, when controlling for quantifier score, the relationship between number knower-level and age remained significant ($r(72) = .527, p < .001$), suggesting that quantifier score did not mediate this relationship. This is the opposite of what Barner et al. found with

⁴ Unlike Japanese 2-year-olds, who were tested on all quantifiers used for older groups, English 2-year-olds were only tested on *a*, *some*, *all* and *none*. To verify that this did not drive the difference between groups, we did two analyses. First, a comparison of only overlapping items (*some*, *all*, *none*) found the same significant difference ($E=0.91$; $J=1.27$; $t(74) = 3.33, p < .001$). Second, Japanese children's comprehension of non-overlapping words ($M=0.7$) was significantly worse than their comprehension of overlapping words ($M=1.27$; $t(31) = 6.85, p < .001$), suggesting that the added words did not drive the cross-linguistic difference.

English children for whom quantifier scores mediated the relationship between number-knower level and age. In English, but not in Japanese, knowledge of quantifiers mediates age-related growth in numeral comprehension.

Among younger 2-year-olds, there was also an important difference between Japanese and English-speaking children. Although Barner et al. reported a significant, age-independent, correlation between quantifier and numeral comprehension in English-speaking 2-year-olds, there was no significant correlation for Japanese 2-year-olds ($r(32) = .283, p > .05$). This effect remained non-significant when controlling for effects due to age ($r(32) = .183, p > .1$). Thus, in Japanese, unlike in English, the development of quantifier and numeral meanings was not significantly correlated in 2-year-olds.

A better predictor of numeral comprehension in Japanese 2-year-olds was age. There was a significant correlation between age and number knower level ($r(32) = .550, p < .001$), which remained significant when controlling for quantifier score ($r(32) = .517, p < .005$). In contrast quantifier comprehension was not predicted by age within 2-year-olds; there was no significant correlation between quantifier score and age ($r(32) = .245, p > .05$), including when effects due to number knower-level were controlled ($r(32) = .111, p > .5$).

Classifier comprehension

Japanese children's responses on the Classifier Match task are reported in Figure 6. Overall, children's performance was near chance levels for all classifiers ($M=53\%$; range = 38-62%). A repeated measures ANOVA with Age as a between subjects factor and Classifier as a within subjects factor found a significant effect of classifier ($F(3, 89) = 3.25, p < .05$), but no effect of Age ($F(2, 91) = .001, p > .9$) or interaction between Age and Classifier ($F(6, 180) = .54, p > .7$). The main effect of Classifier was driven by significantly poorer performance on *hitotsu* relative

to the other classifiers (all p 's $< .05$). Sign tests found that overall only children's interpretation of *ippiki* exceeded chance levels ($p < .05$). This effect was driven mainly by the 3-year-olds (68% correct; $p < .05$) and 4-year-olds (63% correct; $p = .08$), whereas the behavior of 2-year-olds did not differ from chance (53% correct; $p > .8$).

-----Insert Figure 6 about here-----

Emerging comprehension of *ippiki* was uncorrelated with number knower level at any age (all p 's $> .4$), as was knowledge of all other classifiers, at all ages (all p 's $> .2$). Overall, there was no significant correlation between children's classifier comprehension (i.e., average percent correct) and number knower level ($r(69) = .152$, $p > .2$). Thus, Japanese children showed little understanding of basic classifier meanings. Also, emerging knowledge at around 3 years of age failed to predict increased number knower level.

Discussion

As reported by Sarnecka et al. (2007), Japanese children were significantly delayed in the onset of integer acquisition. Far fewer Japanese children had acquired the meaning of *one* or of higher numerals, relative to children learning English. However, by testing a broader age range than previous studies, we also found that Japanese children quickly caught up to English-speaking children, resulting in no effect of language for 3- and 4-year-olds. Once Japanese children begin to acquire numeral meanings, they appear to do so quickly, and perhaps more quickly than their English-speaking counterparts. This suggests that Japanese children do not have trouble discovering particular numeral meanings, but instead that they may be delayed in realizing that numerals are, in fact, numerals, and denote sets of things.

In contrast, Japanese children acquired quantifier meanings as quickly as children learning English, and at 2 years of age actually had higher quantifier scores overall. This indicates that

Japanese children did not have a general difficulty acquiring words that denote the properties of sets. Instead, their difficulty was specific to numerals meanings.

One factor that might explain Japanese children's delay in integer acquisition is that integers require the use of classifiers. According to previous studies, classifier acquisition is difficult and protracted, and may be mastered well after children figure out counting (Uchida & Imai, 1999; Matsumoto, 1987). By the most optimistic accounts, children begin to figure out some classifier meanings by three and a half (Yamamoto & Keil, 2000), well after the problem of acquiring *one* has been solved. Classifiers may not only impede integer acquisition, but also cause difficulty when interpreting particular uses of numerals in caregiver speech, and when being tested in tasks like Give-Number. Consistent with previous reports, we found that children failed to show adult-like preferences for how they extended classifiers to objects. Though it is possible that children have assigned tentative non-adult meanings that encode individuation (e.g., assigning all classifiers a general interpretation), the current study found no evidence of early knowledge.

CHILDES Analysis

The data described thus far speak to the three possible mechanisms by which children might initially bootstrap numeral meanings from the syntax and semantics of previously acquired words and structures. According to NP bootstrapping (Bloom & Wynn, 1997), children might use the morphology, syntax, and semantics of nouns to infer the semantics of numerals and quantifiers. For example, in English but not in Japanese, the use of numerals with count nouns might signal to English-speaking children that these words denote the properties of sets. Experiment 1 indicates that the lack of count syntax in Japanese cannot alone explain differences in Japanese and English integer acquisition. If this were the sole reason for Japanese children's delay, we might also expect delays in other set representations, like quantifiers.

Second, we considered the possibility that quantifier acquisition facilitates integer acquisition *conceptually*, by introducing a semantic hypothesis space of sets. Acquiring quantifiers might involve constructing new semantic representations, or might simply make the hypothesis space of set relations more salient, thereby facilitating an earlier acquisition of numeral meanings. Against this hypothesis, we found that Japanese children's delay was specific to integers, indicating that it cannot be attributed to a lack of pre-existing set-relational representations.

Third, we considered the hypothesis that integer acquisition is facilitated via a form of syntactic bootstrapping that we called "quantifier bootstrapping". Having acquired a small set of quantifiers, children might exploit this knowledge to make inferences about words used in similar syntactic frames. In English, a frequent distributional overlap of quantifiers and numerals might allow children to infer that numerals denote the properties of sets, like quantifiers, thereby initiating their acquisition. By this account, Japanese children might acquire quantifiers at the same rate as children learning English, but be less able to exploit this knowledge for the purposes of integer acquisition due to weaker syntactic relations between quantifiers and numerals.

This third hypothesis remains a possible explanation for cross-linguistic differences in integer acquisition. However, it is not clear whether the syntactic relations between quantifiers and numerals are in fact stronger in English than in Japanese. To explore this, the second study investigated the distributional relations between quantifiers and numerals in the speech of Japanese and English children and caregivers.

Methods

Participants

We analyzed child and caregiver speech from six CHILDES corpora (MacWhinney, 2000), including three English and three Japanese children. The three Japanese corpora were Jun (0;6 to

3;8; Ishii, 1999), Taro (2;2 to 3;7; Hamasaki, 2002; Oshima-Takane et al., 1998), and Ryo (1;4 to 3;0; Miyata 1992), for a total of 214 transcripts. The transcripts of three English-speaking children were selected from the Manchester database (Theakston, Lieven, Pine, & Rowland, 2000) to match the Japanese children in age. These children were Carl (1;8 to 2;8), Nic (2.0 to 2.11), and Ruth (1;11 to 2.11), for a total of 97 transcripts.

Analysis

We performed five main analyses. First, we calculated the overall frequency of numerals and quantifiers in the speech of Japanese and English children and caregivers. Second, we assessed the frequency with which numerals were used with classifiers. Third, we determined the frequency with which Japanese caregivers omitted nominal arguments when quantifiers and numerals were used. Fourth, we examined how frequently tokens from each class of words were subject to “floating” (i.e., movement to a post-nominal position – e.g., *the boys all ate lunch*). Finally, we analyzed how frequently numerals could be directly replaced by quantifiers (e.g., *a, some, many, all*, etc.) to determine their distributional overlap.

Two native speakers of Japanese coded the Japanese transcripts and two native speakers of English coded the English transcripts (in each case, the second coder performed analyses for 20% of the transcripts). For Japanese, inter-coder reliability across the five analyses ranged from 93% to 100%. For English, reliability ranged between 93% and 96%.

Frequency of numerals and quantifiers in caregiver speech

The frequencies of *one*, *two*, and *three* were considerably lower in Japanese caregiver speech than in the speech of English caregivers, as previously reported by Sarnecka et al. (2007). In Japanese, caregivers produced *one* 5.2 times on average per 1000 utterances, *two* 2.1 times per 1000, and *three* 0.6 times per 1000. In English, numerals were used more frequently: caregivers

produced *one* 34.8 times on average per 1000 utterances, *two* 13.1 times per 1000, and *three* 5.0 times per 1000. Due to the relative infrequency of “three” in the Japanese transcripts, we restricted the remaining analyses to *one* and *two*.

The overall frequency of quantifiers in caregiver speech was also lower in Japanese than in English. For all quantifiers tested in the Give-Quantifier task, Japanese caregivers used 10.7 tokens per 1000 utterances, compared to 35.5 tokens per 1000 in English. The most frequently used quantifiers in Japanese were *chotto* / *few* (n = 672 overall), *takusan* / *many* (n = 215), and *zenbu* / *all* (n = 133). In contrast, English-speaking parents and children used quantifiers much more frequently. The most frequently used quantifiers in English were *all* (n = 1526), followed by *some* (n = 1201), and *many* (n = 209).

These data suggest that although numeral frequencies were low in the Japanese transcripts, the frequencies of quantifiers were also low relative to English. Sarnecka et al. (2007) argued that the low frequency of numerals in Japanese caregiver speech could not alone explain Japanese children’s delay in integer acquisition; Russian children showed no such delay relative to English, despite the fact that Russian CHILDES transcripts also revealed relatively low numeral frequencies. Our data support this argument by providing language-internal evidence. Since both quantifiers and numerals appeared infrequently in Japanese transcripts, but frequently in English, cross-linguistic differences in frequency cannot likely explain why Japanese children are delayed specifically with numerals, but not quantifiers.

Use of classifiers in Japanese

Japanese caregivers frequently used numerals with classifiers. Overall caregivers used *one* with a classifier 94% of the time (range: 91% to 98%), and *two* 98% of the time (range: 92.6% to

100%). Children used *one* with a classifier 84.4% of the time (range: 69.2% to 100%) and *two* 72.8% of the time (range: 45.6% to 100%).

Children used the numerals *one* and *two* most frequently with the classifiers *-tsu*, *-nin*, and *-ko* (for *-nin*, the forms for one and two are irregular - i.e., *hitori* and *futari*). We coded how often classifiers were paired with nouns in an adult-like fashion (i.e., how often *-nin* was used correctly with animates, and how often *-tsu* and *-ko* were used with inanimates). We found that children used *-nin* correctly 70% of the time, *-tsu* 93.1% of the time, and *-ko* 100% of the time. This pattern of results replicates that reported in previous studies (Sanches, 1977; Matsumoto, 1987; Uchida & Imai, 1996; Yamamoto & Keil, 2000).

Previous studies find that Japanese children exhibit knowledge of classifier meanings starting from the age of 3 or older (e.g., Uchida & Imai, 1999; Yamamoto & Keil, 2000). Consistent with this, results from the Classifier Match Task showed that 3-year-olds were just beginning to comprehend the words. However, like previous studies, the current analysis shows that children frequently produced classifiers with numerals at a young age. This suggests that children use classifiers correctly well before they fully understand their meanings. One possibility is that children view classifiers as being part of the numeral they modify, thereby creating many different instances of each numeral that children somehow have to integrate later in acquisition, when acquiring numeral meanings. If so, children's early acquisition could be delayed by confusion over the identity of numerals across different classifier usages.

----- Insert Figure 7 about here -----

Argument omission and quantifier / numeral floating

To determine the frequency of numeral and quantifier floating in Japanese, we calculated the frequency with which each quantifier or numeral “floated” to post-nominal positions in caregiver

speech. Also, we determined the frequency of quantifier and numeral uses in which nouns were omitted entirely, a common phenomenon in argument-dropping languages like Japanese (Guerriero, Oshima-Takane, & Kuriyama, 2006; Nakayama, 1994).

----- Insert Figure 8 about here -----

Strikingly, a large proportion of quantifiers and numerals were produced with a dropped nominal argument in Japanese (see Guerriero et al., 2006; for a similar result). The numeral *one* was used without a nominal argument 81% of the time, and *two* 82% of the time. Similarly, quantifiers were used with a dropped argument 62% of the time. Thus, the majority of the time, Japanese children could not use information about the syntax and semantics of the head noun to guide inferences about quantifier meaning. Although it is possible that in some cases numerals like *hitotsu* were syntactically NPs (e.g., *I want one!*), such uses could not help children to determine the relation between quantifiers and numerals for quantifier bootstrapping (since in these cases the numeral would occupy an NP position, unlike the quantifier). Also, in absence of a content bearing head noun, children could not use such instances for NP bootstrapping – i.e., to infer the how the numeral relates to sets in the world (e.g., *dogs, tables, cups, etc.*).

The remaining analyses were restricted to quantifier and numeral uses that included an overt nominal argument. In English, this included only quantifier floating, since numeral floating is not possible. Data are presented in Figure 8. For numeral and quantifier uses that included an overt nominal argument (N = 42), Japanese numerals floated to post-nominal positions 57% of the time. Quantifiers used with over arguments (N=126) floated 37% of the time to post-nominal positions. A different pattern was found for the English caregivers. English quantifiers used in noun phrases (N=9305) floated only 4% of the time. Moreover, of all the English quantifiers

analyzed, only *all* and *both* floated. In Japanese, floating was found for a broader range of quantifiers including *takusan* (many), *zenbu* (all), *ryoho* (both), and *chotto* (a few).

Frequency of numerals in quantifier positions

To determine the frequency of numerals used in quantifier positions (i.e., positions in which quantifiers would be considered grammatical), we coded whether numerals that occurred in an NP could be replaced by a quantifier (e.g., *a*, *some*, *many*, *all*). In English, numerals occurred frequently in quantifier positions (Figure 7). On average, English caregivers used *one* in quantifier positions 94% of the time (range: 92% to 97%) and *two* 98% of the time (range: 97% to 100%). In contrast, numerals occurred less frequently in quantifier positions in Japanese caregiver speech. On average, *one* occurred in quantifier positions 67% of the time (range: 56% to 82%) and *two* 55% of the time, with a wide range across the three corpora (range: 23% to 100%). These data indicate that numerals and quantifiers overlap more consistently in English than in Japanese, potentially making distributional analysis, and thus syntactic bootstrapping, more difficult in Japanese (see Mintz, 2003).

Discussion

An analysis of Japanese and English caregiver speech found several important differences between the two languages. First, both numerals and quantifiers occurred less frequently in Japanese than in English, suggesting that the low frequency of numerals in Japanese caregiver speech cannot explain their late mastery. Second, Japanese caregivers and children almost always used numerals with classifiers when they were used in noun phrases. Third, nominal arguments were dropped most of the time when quantifiers and numerals were used. Fourth, unlike in English, Japanese quantifiers and numerals frequently floated to post-nominal positions, causing distributional variability in their relation to nouns. Finally, numerals were used

in quantifier positions more frequently in English than in Japanese. Each of these factors may contribute to the relatively late acquisition of numeral meanings by Japanese children by (1) making the relationship between nouns, quantifiers, and numerals more obscure, and (2) weakening the distributional relationship between quantifiers numerals in Japanese. Below, each possibility is discussed in relation to the experimental data.

GENERAL DISCUSSION

Early in language development, Japanese children exhibit knowledge of quantifier meanings that equals or exceeds that of English-speaking children, yet are delayed in their comprehension of numerals. At 2 years of age, most Japanese children have begun to acquire words that denote set-relational properties, but do not yet know the meaning of the word *one*. However, Japanese 3- and 4-year-olds quickly catch up to their English-speaking counterparts, and exhibit equal numeral comprehension. These results indicate that Japanese children do not have difficulty acquiring set-relational meanings, since they acquire quantifiers as easily as children learning English. Also, they suggest that Japanese children do not have trouble distinguishing particular numeral meanings (i.e., *two* vs. *three*). Instead, the results support the hypothesis that their difficulty lies in determining that numerals, like quantifiers, denote the properties of sets.

These experimental results allow us to address the possible bootstrapping mechanisms that might relate quantifiers and numerals in language acquisition. In the Introduction, we presented three such mechanisms. By one account, which we called NP bootstrapping (see Bloom and Wynn, 1997), children might use the syntax and semantics of nouns (and related bound morphology, like plural marking) to infer the semantics of quantifiers and numerals in parallel (Carey, 2004; LeCorre & Carey, 2007; Sarnecka et al., 2007). By this account, cross-linguistic differences in the syntax or semantics of noun phrases might affect both quantifiers and

numerals, and thus predict an equal delay in both domains. For example, one possibility is that count syntax, which is marked on nouns only in English, might signal to English-speaking children that numerals denote the properties of sets. This syntactic difference would therefore predict a faster acquisition of both numeral meanings and quantifiers.

In its simplest form, this hypothesis is not supported, since Japanese children's comprehension of quantifiers was equal to or better than that of English-speaking children. Still, there are ways in which NP bootstrapping might selectively affect numerals. For example, as reported in our analysis of Japanese child-directed speech, numerals are frequently used with classifiers, which intervene between the numeral and the head noun. As shown here, and by previous studies of classifier acquisition, children only begin to acquire adult-like classifier meanings at around the age of 3 (Chien, Lust & Chang, 2003; Li, Barner, & Huang, 2008; Sumiya & Colunga, 2006; Yamamoto & Keil, 2000), despite using them frequently in spontaneous speech. As a result, hearing an NP that contains a numeral confronts Japanese children with two difficult problems simultaneously, equivalent to hearing an English sentence like "*toma-blicket* cat" (assuming that the noun is not dropped, and they know its meaning). Since there are more than 100 classifiers in Japanese and around 30 that are used regularly in everyday speech (Downing, 1996), particular numerals like *one* can take on many distinct forms. For example, in the Classifier Match Task presented here, the word *one* took on four forms: *ippiki* ("one animal"), *ichimai* ("one flat sheet"), *hitotsu* ("one inanimate"), and *ikko* ("one small object"). Thus, NP bootstrapping may selectively facilitate quantifier acquisition if classifiers obscure the semantic relation between numerals and nouns.

Another version of NP bootstrapping, presented by Carey (2004), LeCorre & Carey (2007), and Sarnecka et al. (2007), is that the syntax and semantics of nouns in English could speed

integer acquisition, and in particular the acquisition of *one*, by marking a distinction between singular and plural nouns (e.g., *This is one cat* vs. *These are two / three cats*). By noting that only *one* occurs with singular morphology, English children could infer that only *one* denotes singleton sets. Such a mechanism would affect all integers (by helping children get counting off the ground), and would predict, as we find, a difference in the onset of integer acquisition. While this possibility is plausible on its face, there is currently no evidence that singular-plural morphology does, in fact, help English-speaking children. There is, however, evidence that singular-plural morphology probably does not help distinguish *one* from other numerals.

By hypothesis, to speed children's learning of *one* the singular-plural distinction would need to mark an exact boundary between sets of "one" and sets of "more than one". However, Barner et al. (2009) found that among 2-year-olds who have acquired the meaning of *one*, children assigned qualitatively different meanings to *one* and to singular nouns, treating only *one* as exact. Children judged that singular nouns were consistent with sets of two and that plurals were consistent with sets of one, but judged that *one* could only refer to sets of one object. Also, although the comprehension of several quantifiers was correlated with number knower level among 2-year-olds, assigning the singular-plural distinction a "one" vs. "more than one" interpretation was not. Thus, children appear to mark an exact boundary between singular and plural nouns only *after* they've acquired the meaning of *one*, not before, suggesting that number morphology does not play a role in specifying specific numeral meanings like "exactly *one*".

According to a second account, which we labeled "conceptual bootstrapping", quantifier acquisition might facilitate the development of numeral meanings *conceptually*, by making a semantic hypothesis space of sets available to children (for related mechanisms, see Gentner, 1989; Smith & Unger, 1997). This facilitation could take several forms. For example, acquiring

quantifier meanings might require constructing new semantic representations (e.g., logical quantifiers that range over variables), or might simply make the hypothesis space of sets, cardinalities, and set relations more salient to language learning, by making them explicit. In either case, English-speaking children might acquire numeral meanings earlier because they are also earlier to acquire quantifier meanings. To explain why English children learn numeral meanings earlier, this hypothesis would need to predict that quantifiers are also acquired earlier in English. Contrary to this prediction, we found no difference in quantifier comprehension between groups, despite finding a difference in numeral comprehension.

According to the third hypothesis, a form of syntactic bootstrapping that we called “quantifier bootstrapping”, quantifier and integer development might interact causally, via their shared distributional profiles. Having established, for instance, that words used in partitive constructions denote set relations (e.g., *x of the dogs*), children could infer that other words used in such constructions also denote some quantity of individuals. Crucially, this view predicts that integer acquisition should be delayed in languages in which the distributional profiles of quantifiers and numerals are only weakly related, even if quantifiers are acquired rapidly (as reported here). Insofar as the distributional link between quantifiers and numerals is weaker in Japanese than in English, Japanese integer acquisition should be delayed relative to English.

Our analysis of Japanese and English caregiver speech confirmed that the distributional link between quantifiers and numerals differed across languages. First, we found that in Japanese classifiers were used frequently with numerals but never (of course) with quantifiers, potentially obscuring the relation between the two types of word (in addition to obscuring how each relates independently to the head noun). Second, we found that in English, a much higher proportion of numerals used in noun phrases could be replaced by quantifiers like *some* or *all*. Whereas

numerals could be replaced by quantifiers over 90% of the time in English child-directed speech, the proportion was much lower in Japanese. Clearly, if children are sensitive to the syntactic relations between quantifiers and numerals when formulating hypotheses about numeral meanings, then they should have a distinct advantage in acquiring English, relative to Japanese.

Finally, we found that the opportunity for observing syntactic similarities between quantifiers and numerals were quite few, owing to the frequent omission of nominal arguments in Japanese. Japanese caregivers omitted nominal arguments over 60% of the time when using quantifiers in noun phrases, and over 80% of the time when using numerals in NPs (see also Guerriero et al., 2006). Even when nouns were present, their relation to quantifiers and numerals was highly variable, owing to quantifier “floating” in Japanese (see Kobuchi-Philip, 2007). Whereas quantifiers almost never floated in English (and numerals cannot), both types of word frequently floated to post-nominal positions in Japanese caregiver speech. As noted by Mintz (2003), detecting distributional relations between words should be easiest in languages with stable word order, and harder in languages that permit freer ordering of constituents. In the present context, argument omission and freer word order could diminish the strength of the relationship between quantifiers, numerals, and the nouns they modify, thereby making it harder for children to recognize that numerals and quantifiers denote properties of sets.

The current study found that although numeral acquisition is affected by cross-linguistic differences in syntactic structure, quantifier development may be more robust. Future studies should test relations between quantifier and numeral development in other classifier and mass-count languages, to test the mechanisms that children use to bootstrap numeral meanings.

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Table 1. Experimenter requests in the Give-Quantifier Task.

Quantifier	Example in Japanese and English translation
<i>some / ikutsuka</i>	<p>“Maru no naka ni mikan wo ikutsuka iretekureru?”</p> <p>“Could you put <i>some</i> of the oranges into the red circle?”</p>
<i>the other / nokotteiru</i>	<p>“Maru no naka ni nokotteru mikan wo iretekureru?”</p> <p>“Could you put <i>the other</i> oranges into the red circle?”</p>
<i>a few / chotto</i>	<p>“Maru no naka ni mikan wo chotto iretekureru?”</p> <p>“Could you put <i>a few</i> of the oranges into the red circle?”</p>
<i>most / hotondo</i>	<p>“Maru no naka ni mikan wo hotondo iretekureru?”</p> <p>“Could you put <i>most</i> of the oranges into the red circle?”</p>
<i>all / zenbu</i>	<p>“Maru no naka ni mikan wo zenbu iretekureru?”</p> <p>“Could you put <i>all</i> of the oranges into the red circle?”</p>
<i>none / hitotsumo</i>	<p>“Maru no naka ni mikan wo hitotsumo irenaide.”</p> <p>“Could you put <i>none</i> of the oranges into the red circle?”</p>
<i>both / ryoho</i>	<p>“Maru no naka ni suki na kudamono wo ryoho iretekureru?”</p> <p>“Could you put <i>both</i> of the fruits you like into the red circle?”</p>
<i>many / takusan</i>	<p>“Maru no naka ni mikan wo takusan iretekureru?”</p> <p>“Could you put <i>many</i> of the oranges into the red circle?”</p>

Table 2. “Correct” (adult) responses for each Japanese quantifier (total number of objects: 8 for some, the other, a few, most, all, none, many; 3 for both).

Quantifier	Correct response
<i>some / ikutsuka</i>	1-7
<i>the other / nokotteiru</i>	4 objects not moved by experimenter
<i>a few / chotto</i>	1-7
<i>most / hotondo</i>	5-7
<i>all / zenbu</i>	8
<i>none / hitotsumo</i>	0
<i>both / ryoho</i>	2
<i>many / takusan</i>	5-8

Figure Captions

Figure 1. Average number knower level for Japanese and English children at ages 2, 3, and 4.

Figure 2. The distribution of non-knowers, subset knowers and CP-knowers in English and Japanese children at ages 2, 3 and 4.

Figure 3. The average percentage of trials on which Japanese children gave adult-like responses for the quantifiers *hitotsumo* (none), *zenbu* (all), *takusan* (many), *chotto* (a few), *ikutsuka* (some), *nokotteiru* (the other Xs), *ryoho* (both), and *hotondo* (most).

Figure 4. Average quantifier score for Japanese and English children at ages 2, 3 and 4.

Figure 5. Average quantifier score by number knower level for both English and Japanese children.

Figure 6. Percentage of trials on which Japanese 2-year-olds, 3-year-olds, and 4-year-olds correctly matched classifier usages to corresponding objects (*ippiki* / *animal*, *ichimai* / *flat sheet*, *hitotsu* / *objects*, *ikko* / *small objects*).

Figure 7. Percentage of noun phrases in which the numerals *one* and *two* could be replaced by a quantifier for Japanese and English caregivers.

Figure 8. Percentage of numeral and quantifier tokens that were used in either pre- or post-nominal positions, for numeral floating and quantifier floating in Japanese and quantifier floating in English.

Figure1

Figure 1. Average number knower level for Japanese and English children at ages 2, 3, and 4

Figure2

Figure 2. The distribution of non-knowers, subset knowers and CP-knowers in English and Japanese children at ages 2, 3 and 4.

Figure3

Figure 3. The average percentage of trials on which Japanese children gave adult-like responses for the quantifiers *hitosumo* (none), *zenbu* (all), *takusan* (many), *chotto* (a few), *ikutsuka* (some), *nokotteiru* (the other Xs), *ryoho* (both), and *hotondo* (most).

Figure4

Figure 4. Average quantifier score for Japanese and English children at ages 2, 3 and 4.

Figure5

Figure 5. Average quantifier score by number knower level for both English and Japanese children.

Figure6

Figure 6. Percentage of trials on which Japanese 2-year-olds, 3-year-olds, and 4-year-olds correctly matched classifier usages to corresponding objects (*ippiki* / *animal*, *ichimai* / *flat sheet*, *hitotsu* / *objects*, *ikko* / *small objects*).

Figure 7. Percentage of noun phrases in which the numerals *one* and *two* could be replaced by a quantifier for Japanese and English caregivers.

Figure8

Figure 8. Percentage of numeral and quantifier tokens that were used in either pre- or post-nominal positions, for numeral floating and quantifier floating in Japanese and quantifier floating in English.