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Finding one's meaning: A test of the relation between quantifiers and integers in language
development

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Abstract

We explored children's early interpretation of numerals and linguistic number marking, in order to test the hypothesis (e.g., Carey, 2004) that children's initial distinction between *one* and other numerals (i.e., *two*, *three*, etc.) is bootstrapped from a prior distinction between singular and plural nouns. Previous studies have presented evidence that in languages without singular-plural morphology, like Japanese and Chinese, children acquire the meaning of the word *one* later than in singular-plural languages like English and Russian. In two experiments, we sought to corroborate this relation between grammatical number and integer acquisition within English. We found a significant correlation between children's comprehension of numerals and a large set of natural language quantifiers and determiners, even when controlling for effects due to age. However, we also found that 2-year-old children, who are just acquiring singular-plural morphology and the word *one*, fail to assign an exact interpretation to singular noun phrases (e.g., *a banana*), despite interpreting *one* as exact. For example, in a truth value judgment task, most children judged that *a banana* was consistent with a set of two objects, despite rejecting sets of two for the numeral *one*. Also, children who gave exactly one object for singular nouns did not have a better comprehension of numerals relative to children who did not give exactly one. Thus, we conclude that the correlation between quantifier comprehension and numeral comprehension in children of this age is not attributable to the singular-plural distinction facilitating the acquisition of the word *one*. We argue that quantifiers play a more general role in highlighting the semantic function of numerals, and that children distinguish between numerals and other quantifiers from the beginning, assigning exact interpretations only to numerals.

According to an old Harry Nilsson song, “one is the loneliest number that you’ll ever do, whoa, worse than two.”¹ Nowhere is *one* lonelier than in the vocabularies of young children learning language. Sometime after their second birthday, most children learning English distinguish the meaning of *one* from that of all other numerals (e.g., *two*, *three*, *four*), and interpret it as referring to sets of exactly one individual, while failing to distinguish the meanings of all numerals greater than one (e.g., labeling sets as *two* regardless of their cardinality, and giving random sets greater than one when asked for *two*, *three*, *four*, etc.). After figuring out *one*, children spend anywhere between 6 to 12 months as “one-knowers”, with *one* being the only numeral that they reliably interpret in an adult fashion (Le Corre & Carey, 2007; LeCorre, Van de Walle, Brannon, & Carey, 2006; Fuson, 1988; Sarnecka, Kamenskaya, Yamana, Ogura, & Yudovina, 2007; Schaeffer, Eggleston, & Scott, 1974; Wynn, 1990, 1992).

After spending months as one-knowers, children eventually acquire the meaning of two (whose loneliness, according to Nilsson’s song, “can be as bad as one”). At this point, children are two-knowers, since they can reliably give a correct amount only when asked to give either one or two objects. For *three* and above, they give random amounts. After a slightly shorter delay, children acquire the meaning of *three* and are known as three-knowers. By the time they acquire the meaning of *four* most children can also correctly interpret all other numerals in the count sequence that they can recite (though some four-knowers who cannot interpret higher numerals are sometimes reported in the literature; see references above). Apparently, children make a conceptual leap from naming sets on the basis of associations between numerals and cardinalities to *inferring* the cardinality of sets on the basis of a counting procedure; they have

¹ The song “One” was made popular by the American rock ensemble, Three Dog Night, on their 1969 album “Three Dog Night”, and written by the lesser known Harry Nilsson, who recorded it first in 1968 on his album “Aerial Ballet”.

discovered the “cardinality principle” – that the last numeral uttered in the counting procedure represents the cardinality of the last set named (Gelman & Gallistel, 1978). At this point, children have discovered the role of the numerals in the integer system. However, children’s understanding of the numerals *one*, *two*, and *three* prior to making this leap remains somewhat mysterious. How is their knowledge of these words organized prior to mastering the counting principles? Do the words exhibit the signatures of integers from the beginning, or does their logic change as they become integrated to a larger integer system? What is the initial hypothesis space by which children formulate early numeral meanings? One possibility, recently proposed by Sarnecka et al. (2007), Carey (2004), and LeCorre and Carey (2007) is that children’s first representations of *one* (and possibly *two* and *three*) are embedded in a system of natural language quantifiers and determiners that includes words such as *all*, *some*, *a*, *many* and *most*. By this view, *one* may not be so lonely after all.

During the protracted period in which they are one-knowers, children exhibit a remarkable failure to distinguish the meanings of higher numerals such as *two*, *three*, and *four*. When asked to label a set of two or more things, one-knowers frequently default to the word *two*, even for large sets (e.g., Wynn, 1990, 1992), perhaps due to its high frequency relative to other numerals (Dehaene & Mehler, 1992). Similarly, when asked to give the experimenter (or a puppet) two things (e.g., fish) these same children give a random quantity that is greater than one (Le Corre & Carey, 2007; LeCorre et al., 2006; Fuson, 1988; Sarnecka & Gelman, 2004; Sarnecka et al., 2007; Schaeffer et al., 1974; Wynn, 1990, 1992). As noted by Carey (2004), children’s initial distinction between *one* and other numerals resembles the distinction made by singular-plural morphology in language. *One*, similar to the singular form in English, appears to specify reference to singleton sets, whereas *two*, *three*, and above appear to specify reference to

pluralities of unspecified magnitude, like plural nouns. Carey notes that since only *one* and no other numeral can occur with singular agreement (e.g., *one cat, two cats, three cats... ten cats*) children might use singular-plural morphology to acquire the meaning of *one* early in acquisition. For example, upon hearing “That is one cat” a child could conclude that a single cat is being referred to based on the singular morphology, and thereby infer that *one* is used to refer to singleton sets. Typically, children acquiring English begin to produce and comprehend singular-plural morphology at around 24-months of age (Barner, Thalwitz, Wood, Yang, & Carey, 2007; Brown, 1973; Cazden, 1968; Clark & Nikitina, in press; Fenson, Dale, Reznick, Bates, Thal & Pethick, 1994; Kouider, Halberda, Wood, & Carey, 2006; Mervis & Johnson, 1991). Thus, by this age, English-speaking children might use the contrast between singular and plural nouns to infer the meaning of *one* and distinguish it from *two* and all other numerals.

In support of this, Sarnecka et al. (2007) presented evidence that children learning English and Russian, both of which have singular-plural morphology, become one-knowers and distinguish *one* from other numerals earlier than children learning Japanese, which lacks obligatory singular-plural marking on nouns. Similarly, Li et al. (2003) found a relative delay in the onset of numeral comprehension in children learning Mandarin Chinese, which also lacks obligatory singular-plural morpho-syntax. Strikingly, these results were found even though Japanese children receive equal amounts of exposure to numerals and counting routines, and even though Japanese and Chinese children reportedly acquire the count list with greater ease than English-speaking children (see Miller & Stigler, 1987; Miller, Smith, Zhu, & Zhang, 1995).

The results of these cross-linguistic studies are consistent with two hypotheses previously discussed in the literature, one put forward by Carey (2004) and LeCorre and Carey (2007) and the other by Sarnecka et al. (2007). First, Carey and LeCorre propose that the meanings of

children's early numerals may be supplied by representations normally deployed for interpreting the morphology and syntax of natural language (e.g., singular-plural morphology and lexical quantifiers). According to this view, not only does singular-plural morphology narrow the hypothesis space regarding the meaning of *one*, but the meanings that are encoded by this distinction are exactly the same meanings that are deployed by early numerals; early in acquisition, the meaning for *one* "would be the same as the meaning of the singular determiner *a*" (LeCorre & Carey, 2007, p. 6). Sarnecka et al., take this hypothesis a step further, and suggest that early numerals may not only be acquired based on the same underlying meanings as singular-plural morpho-syntax, but may actually be interpreted by children as identical to natural language number marking. According to their hypothesis, children may initially interpret *one* as a form of singular morphology, and the words *two*, *three*, *four*, etc., as markers of plurality.²

One recent study supports the idea that children may initially interpret numerals and singular-plural morpho-syntax identically. In a study of children acquiring English, Clark and Nikitina (in press) presented both naturalistic speech samples and experimental evidence suggesting that children use numerals in place of plural morphology early in acquisition. For example, Clark and Nikitina report that in normal conversation, children in their study initially used numerals in conjunction with bare nouns (e.g., *two blanket*) to mark plurality, and used numerals in this role more frequently than actual plural morphology. At a later stage, these children began using plural morphology in a piecemeal fashion with nouns, now in absence of numerals (e.g., *blankets*; see also Mervis & Johnson, 1991; Zapf & Smith, 2003; Zapf, 2004). Finally, sometime after this, the children finally combined the two types of number marking, and produced noun phrases with both numerals and plural morphology (e.g., *two blankets*). Consistent with these naturalistic

² The basis for this hypothesis comes from the observation that some languages have specialized morphology for sets of two and three, called "dual" and "trial" morphology (see Corbett, 2000).

observations, Clark and Nikitina also reported a study of elicited singular-plural production, in which they found that many 2- and 3-year-olds in their study (12 out of 25) relied on the combination of numerals and bare nouns to express plurality. These results are consistent with the idea that, for many children, plural morphology and numerals greater than one serve a similar function, and thus do not initially co-occur within noun phrases. In some early vocabularies, *two*, and sometimes *three* may function as forms of plural morphology.

The present study engaged the question of how early number morpho-syntax is related to children's understanding of numerals in two steps. Following the logic of Sarnecka and colleagues, we reasoned that if children's acquisition and interpretation of numerals depends in some way on their prior mastery of grammatical number marking, then we should find strong age-independent correlations between the two types of knowledge, not only across languages (as Sarnecka et al. found), but also within groups of children acquiring a particular language. Further, if numerals are initially part of a broader system of natural language quantification, then we should expect their development to be correlated not only with singular-plural morphology, but also with other expressions of set-relational quantification in early language, such as lexical quantifiers. Therefore, we performed a study of children's comprehension of numerals and a large set of quantifiers (i.e., *a*, *some*, *all*, *most*, *another*, *the others*, *both*).

If the two systems support one another in acquisition or are initially part of the same system, then they should emerge in close relation early in development. Further, we should expect the interpretation of closely related members of each system, such as *one* and *a*, to reflect this relationship directly. This is a strong prediction, since previous studies have noted signature differences between quantifiers and numerals early in acquisition. According to several reports (Hurewitz, Papafragou, Gleitman, & Gelman, 2006; Noveck, 2001; Papafragou & Musolino,

2003; Huang & Snedeker, in prep.) young children assign exact, mutually exclusive, interpretations to numerals, while failing to do so for quantifiers like *some* and *all*. For example, 3-year-old children reject that an alligator who is holding four cookies has *two cookies* while accepting that he has *some of the cookies* despite having all of them (Hurewitz et al., 2006). They assign an “upper bound” to *two* (limiting it to sets of at most two individuals), but do not assign an upper bound to *some* (allowing it to refer to whole sets). According to such studies, children are unable to make the pragmatic inference that *some* entails *not all*, but do not require pragmatics to distinguish the exact meanings of numerals (since exactness is part of the meaning of these words). If children distinguish quantifiers and numerals from the beginning, then we would expect a similar result for *a* and *one* – i.e., only *one* should be treated as exact. However, if the hypotheses of Sarnecka et al., (2007), Carey (2004), and Le Corre and Carey (2007) are correct, then the two words should be interpreted identically when first acquired, and we should find either (1) a stage at which both *one* and *a* have identical, non-exact meanings (with no upper bound), or (2) a stage at which both *one* and *a* means exactly one.

In addition to examining the basic relation between quantifiers and numerals in development and testing the specific distinction between *a* and *one*, the present study also provides a detailed characterization of early quantifier development in English-speaking children. Previous studies of quantifier development have focused mainly on the specific challenges posed later in acquisition by certain quantifiers. For example, a large literature has investigated children’s capacity to distinguish the pragmatics of quantifiers like *some* and *all* and other subtle semantic and pragmatic distinctions that are mastered later in acquisition (see Brooks & Braine, 1996; Crain & Thornton, 1998; Drozd & van Loosbroek, 1998; Ferenz & Prasada, 2002; Gualmini, 2003; Inhelder & Piaget, 1964; Meroni, Gualmini, & Crain, 2000; Neimark & Chapman, 1975;

Papafragou & Schwarz, 2006; Philip, 1996; Stickney, 2007). Also, numerous studies have investigated children's understanding of distinctions like that between *more* and *less* (Donaldson & Balfour, 1968; Donaldson & Wales, 1970; Gathercole, 1985; Palermo, 1973; Wannemacher & Ryan, 1978; Weiner, 1974). Relatively little attention has been paid to children's earliest comprehension of quantifiers as a class. One study, by Hanlon (1987), studied a broad range of quantifiers (*all, none, some, any, other, another, each, both, either, neither*) using a comprehension task. In this task, which we label below the *Give-Quantifier* task, children were asked to give a set or subset of cookies to a Cookie Monster puppet (e.g., *Give him some of / all of the cookies*). However, Hanlon's study (and a similar study by Badzinski, Cantor, & Hoffner, 1989) only reported data for children aged 4 and older, and provided only a very general analysis of children's relative success in interpreting the quantifiers within this wide age range. A study by Ferenz and Prasada (2002) tested younger children and assessed both quantifiers and numerals, but asked children to give subsets of only three objects, making it difficult to assess certain key results.³ Here, we adopted the *Give-Quantifier* method, and tested children from 2 years of age, before most children have begun producing quantifiers in spoken language (see Dale & Fenson, 1996). We coupled this with the *Give-Number* task, used by Wynn (1992) and

³ For example, on singular trials – e.g., “...put the (object) in the tray” - children were presented with one object, and therefore could not easily respond incorrectly, whereas on plural trials “put the (objects) in the tray” they were presented with three. In each case, a bias to select all objects would result in adult-like behaviors. F&P report that all children aged 1;8 to 2;7 gave three objects when asked for three. This is surprising, since in many studies children do not understand even *one* until after their second birthday. Again, this result could be due to a bias to give all the objects in a set by default, since children were only presented with three objects from which to choose. Consistent with this possibility, children did not perform as well for the numeral *two*. If children used their knowledge of *one* to infer that *two* does not mean one, then by chance they would be expected to choose correctly 50% of the time between sets of two and three, which is exactly what they did (20/32 gave 2, which is not different from the chance level of 50%).

others to study numeral acquisition, and a *Truth-Value Judgment* task, used here to assess whether children assigned exact meanings the words *one* and *a*.

Experiment 1

The goals of the first experiment were (1) to test the relation between quantifier and numeral comprehension across a broad age range in children acquiring English, and (2) to test children's comprehension of noun phrases (NPs) containing *one* and *a*. If quantifier and numeral development are tightly yoked early in acquisition (Sarnecka et al., 2007; Carey, 2004) then we should expect a strong, age independent, correlation in the development of the two systems. Also, if Sarnecka et al. (2007), Carey (2004), and Le Corre and Carey (2007) are correct, then children should assign similar meanings to NPs containing *a* and *one*, and should have higher knower levels when they show adult-like interpretation of the singular-plural distinction.

Quantifier and numeral comprehension were tested with three tasks: the Give-Quantifier, Give-Number, and Truth-Value Judgment tasks. The first two asked children to give quantities specified by either quantifiers or numerals, respectively. Thus, they examined the quantities that children spontaneously associate with each word. The third task asked participants to judge whether quantifiers and numerals were consistent with specific quantities. This allowed us to test children's judgments for quantities that they did not spontaneously select in the other tasks.

Methods

Participants

Participants were 58 English-speaking children aged 28- to 67-months ($M = 45.27$ months), recruited from the greater Boston area, and 16 English-speaking adults, recruited on the University of Toronto campus. Children were tested at local childcare centers or were recruited to visit the laboratory via a database created from mailed invitations and follow-up phone calls.

Six additional children were excluded, one due to failure to follow instructions and five due to failure to complete the task. Additional pilot subjects, used to develop the methods, were tested in childcare centers in Comox, British Columbia.

Stimuli and Procedure

Each child was tested in a session that lasted between 15 and 20 minutes, and sat across from the experimenter at a child-sized table. Three tasks were used: (1) the *Give-Quantifier* task, (2) the *Give-Number* task, and (3) the *Truth-Value Judgment* task. Each child received the tasks in the above order. Adults were tested with the Give-Quantifier and Truth-Value Judgment tasks.

The Give-Quantifier Task. This task was adapted from Hanlon (1987; see also Badzinski, Cantor, & Hoffner, 1989, and Ferenz & Prasada, 2002). Stimuli consisted of a red plastic circle and three sets of small plastic fruits (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 make sure that she could distinguish the different kinds: “What is this called?”, “Do you know what this is?”, “Can you say *orange*?” The experimenter was careful not to use the target quantifiers when introducing the items. When the child demonstrated that she knew the names of each fruit, the experimenter showed her the red circle and asked her to put a quantity of a specific kind of fruit into it, by using a target word (e.g., “Could you put *all* of the oranges into the red circle?”). Here, and in all tasks, care was taken to insure that prosody was equated across quantifier and numeral trials (i.e., by adding stress to the target word). The following quantifiers/determiners were tested using this procedure: *a, another, the other Xs, some, most, all, none* and *both*. For all words, the partitive construction was used where possible (e.g., *some of the Xs*, instead of *some Xs*), to make clear that a subset of all items presented was being requested. Examples of how these words were used are presented in Table 1.

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

For the word *both*, we presented children with one token of each fruit type (1 orange, 1 strawberry, and 1 banana), and asked: “*Can you find both of the fruits that you like the best and put them into the red circle?*” By presenting children with three fruits and implicitly requesting two, we avoided a problem encountered by Hanlon (1987) who presented children with only two objects and asked them to give *both*. Using Hanlon’s method, children might succeed at the task, as she found, without knowing the meaning of *both* by using plural agreement or a bias to give all of a set when they do not know the meaning of a quantifier.

After each trial, the experimenter returned all fruits to their original piles before the next request. The quantifiers were presented in four different orders between participants, and pairings of quantifiers and fruit kinds was quasi-randomized so that a particular fruit+quantifier combination was not repeated within a session. The order of quantifiers was also quasi-random, with the constraint that *another* and *the other x’s* were tested directly after either *a* and *some*, such that their interpretation was supported by a plausible pragmatic context (i.e., there were *others* or *another* that had not been given on the previous trial). However, to make these trials equivalent to other trials, the fruits given on previous *a* and *some* trials were nonetheless returned to their original piles before testing *another* and *the other x’s*. Each participant was tested twice with each quantifier.

The Give-Number Task. This task was adapted from Wynn (1992) and used for evaluating children’s numeral comprehension. Stimuli consisted of the same red plastic circle and a set of eight plastic fish. To begin, the experimenter presented the fish to the child and asked, “Do you like to count? Could you count the fish for me?” Then, the experimenter showed the child the red plastic circle and asked the child to put a certain number of fish onto the circle (e.g., “Could you

put six fish into the red circle?”). Following Wynn (1992) we used a titration method. When children successfully gave N fish (e.g., 3) they were then asked to give N+1 fish (e.g., 4). When they failed, they were given a chance to count and correct their response. If they continued to provide an incorrect response, they were then tested with N-1 (e.g., 2). There was one exception to this: testing began with the experimenter asking for 6 fish. If the child failed to give six, they were next tested on 1 (and next 2, if they succeeded with 1). Testing ended when children had given the incorrect number 2 out of 3 times for a given number.

Children were called N-knowers (e.g., two-knowers) if they correctly gave N fish 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 fish at least two out of three times for each. Otherwise, their knower level was identified only up to the number that they could give correctly at least two out of three times (e.g., one-knower, two-knower, etc.).

The Truth-Value Judgment Task. This task used the same red circle and toy fruits as the *Give-Quantifier* task. The fruits were presented in three separate piles of eight next to the red circle, as before. For each trial, the experimenter moved a certain number of one kind of fruit into the circle and asked the child a Yes/No question using either a numeral or a quantifier. For example, after moving three bananas into the red circle, the experimenter asked, "*Are all of the bananas in the red circle?*". Thus, questions marked number not only via the quantifier and singular-plural marking on the noun, but also on the main verb (e.g., *Is there a banana?* vs. *Are there some bananas?*). The fruits were returned to their original piles after each trial. In addition to the quantifier judgments, the number words *one* and *two* were each tested in two trials. Figure

1 shows the complete list of conditions, including the number of objects presented on each trial and the question asked. The order of conditions was varied between subjects.

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

Results

Give-Quantifier

For the *Give-Quantifier* task we performed three analyses. First, we determined whether children in our study, as a group, demonstrated adult-like comprehension of each quantifier. Second, we examined how children's comprehension of quantifiers as a class was related to their understanding of numerals as a class. Finally, we examined how knowledge of specific quantifiers and determiners was related to knowledge of specific numerals (e.g., *one, two, three*).

We defined correct responses for each quantifier as in Table 2. These criteria were verified with adult speakers of English ($N = 16$). For each quantifier, 100% of adult participants gave the correct number of fruit objects (based on the criteria in Table 2) on two out of two trials. The decision to categorize responses as "correct" or "incorrect" was used in order to simplify the description of the results. We did not intend the prescriptive connotations of the labels.

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

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 would be $2/9$ (i.e., $1/9 + 1/9 = .222$).

Figure 2 shows the number of subjects who gave a correct amount on 0, 1, or 2 trials for each quantifier. Children's performance was significantly better than chance levels for *a*, *another*, *none*, *all*, and *both* (all p 's < .001). Behavior did not differ from chance for *some* and *the others* (both p 's > .7), and was below chance for *most* (p < .005).

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

The relation between quantifier and numeral comprehension (Give-Quantifier vs. Give-Number)

We assigned each child a number-knower level, using the criteria described above. There were six non-knowers (i.e., children who failed to give correct amounts for any numeral), seven one-knowers, sixteen two-knowers, four three-knowers, and twenty-five CP-knowers (i.e., children who understood counting). Each child was also assigned a quantifier score from 0 to 2, which was defined as the average number of correct responses (out of 2) that a child made for each quantifier. Figure 3 shows the average percent by knower level. Figure 4 presents overall performance for each quantifier individually, order from highest overall percent correct (on the left) to lowest (on the right), as follows: *all*, *a*, *another*, *the others*, *none*, *some*, *both*, *most*.

-----Insert Figures 3 and 4 about here -----

The correlation between quantifier score, number-knower level (1, 2, 3 or CP), and age was calculated. The analysis revealed a significant correlation between quantifier and number knower levels ($r(56) = .716$, $p < .001$), indicating that children who had a greater comprehension of quantifiers also had a higher number knower level. There were also significant correlations between quantifier score and age ($r(56) = .693$, $p < .001$), and between number knower-level and age ($r(56) = .594$, $p < .001$). After controlling for age, the relationship between quantifier score and number knower-level remained significant ($r(55) = .525$, $p < .001$). Thus, there was an age-independent correlation between quantifier and numeral comprehension. However, when

controlling for quantifier score, the relationship between number-knower level and age was no longer significant ($r(55) = .195, p > .1$). This suggests that the relation between number knower level and age was mediated by children's comprehension of quantifiers. In contrast, when controlling for number knower-level, the relationship between quantifier score and age remained significant ($r(55) = .476, p < .001$), suggesting that number-knower level did not mediate this relationship. Thus, crucial to the hypothesis that quantifier and numeral development are tightly linked, we find a significant correlation between quantifier and numeral comprehension that is independent of effects due to age, and that children's understanding of quantifiers mediates a correlation between age and numeral comprehension. This result is consistent with the idea that quantifier acquisition may support numeral acquisition in development.

We next examined the relationship between number-knower level and quantifier comprehension for each quantifier individually. Figure 5 shows children's average number knower level as a function of their performance for each quantifier. Children were divided into two groups: those who gave correct responses on both trials and those who did not. For all items except *the others*, the average number knower-level of children was higher if they gave correct responses on both trials than if they did not (all p 's $< .03$; t-tests; for *the others* $p > .3$).

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

The fact that quantifier and numeral comprehension are related in almost all quantifiers is of crucial importance. Although Sarnecka et al. (2007) investigated the effect of singular-plural morphology on integer development, they did not show that their effects were specific to this distinction, or whether Japanese children are also delayed in acquiring quantifiers as a class. The data presented here suggest that many set-relational distinctions, and not only the singular-plural distinction, may be correlated with numeral comprehension in development.

Truth-Value Judgment Task

Figure 6 shows the percentage of “yes” responses for each quantifier. Of primary interest were children’s judgments for *a* and *one*. Children showed a distinct difference in their truth-value judgments for the two words. Though almost all children responded “yes” for both *a* and *one* when one object was presented in the circle (30/32 for *a* and 25/26 for *one*), there was a large difference between the words when children were presented with sets of two (5/32 for *one* and 25/32 for *a*; $\chi(1) = 17.7$, $p < .001$). Thus, although *a* and *one* were both judged to be consistent with sets of one, children were much more likely to reject sets of two as consistent with the numeral *one* relative to the determiner *a*. This result provides strong evidence that children in this experiment, aged 3- to 5-years of age, did not interpret the two words identically.

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

One reason why children might show this difference between *a* and *one* is that the meaning of *a*, unlike *one*, may not specify an “upper bound” of one, and thus may permit reference to larger sets, short of some additional pragmatic inference. Previous studies have argued that for adults, the use of quantifiers is limited not only by their meanings, but also by the meanings of other quantifiers. For example, adults frequently deny that the quantifier *some* can be applied to whole sets, since it is more informative to label them with *all*. By using the word *some*, the speaker implies that they intend to refer to a subset rather than a whole set, since they did not use the stronger, more informative, term *all* (e.g., Grice, 1989). Following this, young children, who are less adept at calculating these pragmatic implicatures than adults, should be less likely to assign an upper bounded interpretation to quantifiers like *some* and *a*, a prediction which has been confirmed by numerous studies (e.g., Papafragou & Mussolino, 2003). These same studies show that children do assign exact interpretations to numerals, suggesting that numerals encode

an upper bound as part of their core meanings, independent of pragmatics. This conclusion is consistent with our current results, which find an exact interpretation of *one*, but not *a*.

We performed two additional analyses to test whether *a* exhibits the same signatures as *some*, for which an upper bounded interpretation depends on an emerging capacity to make pragmatic inferences. First, we compared children's interpretation of *a* and *one* to that of adults. Second, we compared children's and adults' interpretation of *some* and *all* to determine whether children in our study failed to assign an upper bounded interpretation to *some*.

Consistent with the hypothesis that adults narrow the application of quantifiers and determiners like *a* via pragmatic implicature, we found that adults never accepted sets of two objects as consistent with *a*. Though 100% of adults accepted one object for both *a* and *one*, 0% accepted two objects for each of the two words. Thus, adults assigned upper bounded interpretations to both *a* and *one* in contrast to children, who did so only for *one*.

Second, we also found evidence that children were less likely to assign upper bounded interpretations to *some* than were adults. More children accepted *some* as consistent with 8/8 objects (17/32) relative to adults (3/16; $\chi(1) = 3.87, p < .05$). Still, children did distinguish *some* and *all*. Significantly more children accepted 2 objects as consistent with *some* (29/32) than 3 as consistent with *all* (9/32; $\chi(1) = 23.39, p < .001$). This indicates that most children required all 8 objects to be in the circle for *all* but not for *some*. Also, for *some*, children were more likely to accept 2 objects (29/32) than 8 objects (17/32; $\chi(1) = 9.35, p < .002$). Finally, significantly more children accepted 8 objects as consistent with *all* (29/32) compared to *some* (17/32; $\chi(1) = 9.35, p < .002$). In sum, children were less likely than adults to assign an upper bounded interpretation to *some*, though they did show evidence of distinguishing *some* from *all*.

One final piece of evidence suggests that children do not treat the singular-plural distinction as a distinction between “one” and “more than one”. We have already shown that children accept sets of more than one for singular noun phrases, like *a banana*. In addition, children frequently accepted sets of one as consistent with plural noun phrases. When making truth value judgments, 21/32 children judged that there were *some* in the circle when there was only one. Although they accepted *a* for sets of one more frequently ($\chi(1) = 4.48, p < .05$), their failure to reject sets of one for *some* was no different from their failure to reject sets of eight for *some* ($\chi(1) = .58, p > .4$). Thus, children were no better at recognizing that *some* excludes sets of one than they were at recognizing that *some* excludes whole sets. As shown by the Give-Quantifier task and many previous studies (see introduction for review), this does not mean that children don’t understand the singular-plural distinction. Instead, the results indicate that for young children the words *a* and *some* do not specify a sharp boundary between “one” and “more than one”. This sharp distinction may not be encoded in the meaning of the distinction, even for adults, but may be a product of both semantic and pragmatic factors combined. In the discussion, we examine further what singular and plural nouns might denote, if not sets of “one” and “more than one”.

Summary

Experiment 1 found a significant, age-independent, correlation between children’s comprehension of numerals and a large set of natural language quantifiers and determiners. Further, we found that knowledge of numerals is partially mediated by children’s comprehension of quantifiers, but not vice versa. Although it is impossible to rule out alternative sources of this correlation (e.g., vocabulary size, mental age), its presence and nature do speak strongly to the hypothesis at hand. First, a failure to find such a correlation would be strong evidence against the idea that quantifier acquisition supports numeral acquisition in development (whether within or

across languages). Second, the specificity of the correlation can be used to test the bootstrapping hypothesis. Our data show that the correlation was not specific to singular-plural morphology, but was found across almost all quantifiers tested. This raises the possibility that cross-linguistic differences may be related to differences in quantifier acquisition as a whole, and not specific to singular-plural morphology (in Experiment 2, we demonstrate that the correlation breaks down in crucial ways that allow us to differentiate between these two possibilities).

Experiment 1 also found that *one* and *a* have distinct meanings for young children, and that only *one* is assigned an exact interpretation. Children also accepted whole sets for the quantifier *some*, suggesting that their divergence from adult behavior was due to a lack of pragmatic understanding. Children have learned the core meanings of *a* and *some*, which are not exact, but have not learned the pragmatics of how these words contrast with other words.

In sum, these results suggest that although English-speaking 3- to 5-year-olds exhibit a strong correlation between quantifier and integer comprehension akin to the cross-linguistic correlation reported by Sarnecka et al. (2007), the correlation is not specifically attributable to the development of singular-plural morphology. The comprehension of several quantifiers is correlated with integer development, and children do not assign identical meanings to *a* and *one*. However, this first experiment leaves open the possibility that *a* and *one* do have the same meaning for younger children, when the words are first being acquired. To examine this possibility, Experiment 2 tested younger 2-year-old children.

Experiment 2

The first experiment established that, in English-speaking children, the development of numerals and quantifiers is highly correlated in language development. This result is consistent with the cross-linguistic correlation reported by Sarnecka et al. (2007). A correlation between

knowledge of quantifiers and numerals could reflect specific processes of bootstrapping (e.g., singular-plural morphology highlighting the meaning of *one*), or could reflect a more general relation, such as the fact that both systems rely on a common capacity for representing sets. For example, acquiring number morphology in English might speed numeral acquisition because it makes the general hypothesis space of set relations more salient to children, and not because it makes *specific* relations or concepts more salient (see Bloom & Wynn, 1997).

The purpose of Experiment 2 was to test whether a general correlation between systems can be explained as stemming from specific relations between early quantifier and numeral meanings. Using the tasks of Experiment 1, we tested younger children who were just acquiring both *a* and *one* to determine if these words ever share a meaning in acquisition, and if acquiring one of the words predicts a more rapid acquisition of the other.

Methods

Participants

Two groups of participants were tested. The first group was tested with only the Give-Quantifier and Give-Number tasks. Having determined that most 2-year-olds were capable of performing several tasks in a single session, a second group was tested with these tasks plus the Truth-Value Judgment task. Group 1 included 29 English-speaking children aged 24- to 35-months ($M = 29.02$ months). Group 2 consisted of 15 English-speaking children aged 23- to 35-months ($M = 30.02$ months). These children were recruited from the greater Boston and Toronto areas. Four additional children were excluded from analyses due to failure to complete the tasks.

Stimuli and Procedure

The procedures were identical to those used in Experiment 1, except that only a subset of the quantifiers was tested. For Group 1, the Give-Quantifier task included: *a*, *some*, *none*, and *all*.

For Group 2, the words were: *a*, *some*, *all*. We were interested in how *a* contrasts with *some*, and how *some* contrasts with *all*. We were also interested in whether children are initially able to correctly interpret *none* as applying to sets of zero individuals, even though it occurs with plural morphology. The Truth-Value Judgment task tested children with: *a*, *some*, *all*, *one*, *two*.⁴

Results

We analyzed: (1) children's understanding of each quantifier, (2) the relationship between children's comprehension of quantifiers and their understanding of number words and counting, and (3) how the meanings of the words *one* and *a* were related across the tasks.

Give-Quantifier

Correct responses for quantifiers and determiners were defined as in Experiment 1 (Table 1). For each quantifier, we analyzed whether the rates of correct responses from children differed from chance using one-sample t-tests. We found no difference in the pattern of responses between the two groups of children, and thus we combined their results for *a*, *some*, *all*, and *none*. Figure 7 shows the number of children who gave correct responses on 0, 1, or 2 trials for each quantifier. The number of children who selected a correct set size on both trials was greater than chance for *all* (34 out of 44 children; $t(43) = 15.16, p < .001$), for *a* (17 out of 44; $t(43) = 6.94, p < .001$), and below chance for *some* (6 out of 44; $t(43) = -7.36, p < .001$). Behavior did not differ from chance for *none* (1 out of 29; $t(28) = -0.17, p > .8$).

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

The relation between quantifier and numeral comprehension (Give-Quantifier vs. Give-Number)

⁴ We excluded *none* from the Truth-Value Judgment task based on the observation that even older children found it difficult to answer “yes” when there were no things in the circle, and “no” when there were some things. We doubt that this result reflects children's understanding of the quantifiers so much as the difficulty of pairing a positive “yes” response with the negative outcome “none” (try it at home!).

As in Experiment 1, we calculated the correlation between children's quantifier score (0 to 2, representing the average number of trials correct), number-knower level (0, 1, 2, 3, and CP), and age. In all, there were eleven non-knowers, nineteen one-knowers, ten two-knowers, two three-knowers and one CP-knower. Between the two groups of children tested there was no difference in average quantifier score (Gp.1 = 1.00, Gp.2 = 1.43; $p > .1$) or number-knower level (Gp.1 = 0.81, Gp.2 = 0.67; $p > .1$) and thus they were combined for this analysis. In Figure 8, quantifier score is converted to average percent correct (by dividing individual quantifier knower level scores by 2), and the percent correct is presented for children at each number-knower level.

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

The relationship between quantifier and numeral comprehension was similar to that found in Experiment 1. There was a significant correlation between quantifier score and number knower level ($r(43) = .495, p < .001$). However, there was no significant correlation between number-knower level and age ($r(42) = .286, p > .06$) or between quantifier knower level and age ($r(43) = .077, p > .6$). The absence of age effects, unlike in Experiment 1, was probably due to the restricted range of ages, spanning only 12 months. As with older children, the correlation between quantifier knower level and number knower level remained significant when controlling for age ($r(43) = .506, p < .001$). Thus, we again find an age-independent correlation between quantifier and numeral comprehension.

-----Insert Figure 9 about here -----

We next examined the relationship between number-knower level and quantifier comprehension for each quantifier individually, to determine whether the correlation reported above was driven by particular items or was characteristic of all quantifiers tested. Figure 9 shows children's average number knower level as a function of their performance for each

quantifier. As in Experiment 1, children were divided into two groups: those who gave correct responses on both trials and those who did not. In general, children's number knower levels were higher when they exhibited adult-like comprehension of quantifiers, though only the differences for *all* and *some* were significant (*all*: $t(41) = 3.12, p < .005$; *some*: $t(41) = 2.57, p < .01$).

-----Insert Figure 10 about here -----

It is of particular interest that children who gave one object for *a* did not have higher number knower levels than children who did not. This result clearly fails to support the hypothesis that singular-plural morphology drives the acquisition of numerals. By this hypothesis we would expect children who treat *a* and *one* identically to have a higher number-knower level (since for these children *a* could potentially provide the meaning of *one*). Perhaps even more significant is the number of one-knowers who failed to give exactly one object for the word *a* in the Give-Quantifier task. Overall, 12 of the 19 one-knowers gave more than one object when asked for *a* thing (see Figure 10). Clearly, if the acquisition of *one* depends on singular-plural morphology this result would not be expected. The very same children who assign exact interpretations to *one* failed to do so for *a* at an age when they are first acquiring both.

Truth-Value Judgment Task

For children who performed the Truth-Value Judgment task, there were two non-knowers, six one-knowers, five two-knowers, and one CP-knower. For one child it was impossible to determine a knower level. Children showed a distinct difference in their truth-value judgments for *a* and *one* (see Figure 11). Although almost all children responded “yes” for both *a* and *one* when one object was presented in the circle (14/14⁵ for *a* and 14/15 for *one*; $\chi(1) = .97, p > .3$), there was a large difference between the words when children were presented with sets of two

⁵ One child failed to provide a yes/no response for *a* with one object.

(11/15 for *a* and 5/15 for *one*; $\chi(1) = 3.35, p < .05$). Thus, although *a* and *one* were both judged to be consistent with sets of one, children were much more likely to accept sets of two as consistent with *a* relative to *one*. This provides strong evidence that 2-year-old children who are just acquiring *one* and singular-plural morphology did not interpret *a* and *one* identically.

-----Insert Figure 11 about here-----

As in Experiment 1, children often judged sets of one individual to be consistent with *some*. When asked if there were *some* things in the circle, 10 out of 15 children said yes when there was only one. This did differ from their higher rate of acceptance for *a* (with one object; $\chi(1) = 3.55, p < .05$), but not from their tendency to accept *some* for whole sets (11/15; $\chi(1) = .16, p > .6$).

In Experiment 1, we hypothesized that children differ from adults due to a failure to make pragmatic inferences. For example, children may fail to recognize that singular nouns, despite being logically consistent with plural sets, are not a maximally informative way to describe sets of more than one. To verify that the 2-year-olds in our study failed to make pragmatic inferences, we examined their judgments for *some* and *all* as in Experiment 1. Significantly more children (11/15) accepted 8/8 objects as consistent with *some*, relative to adults (3/16; $\chi(1) = 7.24, p < .008$). Also, children were equally likely to agree that there were *some* objects in the circle when there were 2 objects (14/15) relative to when there were 8 objects (11/15; $\chi(1) = .96, p > .3$). Children distinguished between *some* and *all* in only one context: they accepted eight objects as consistent with *all* (14/14) significantly more often than for *some* (11/15), $\chi(1) = 2.38, p > .1$. Thus, our results are consistent with the idea that 2-year-olds fail to use pragmatic information to distinguish *some* from *all*, a finding which we now extend to the indefinite article *a*.

Summary

We again found a significant age-independent correlation between quantifier and numeral comprehension, indicating a tight relationship in their development. Such a correlation is expected if numeral development depends on quantifier acquisition. Although many factors may drive such a correlation, its specificity can nonetheless speak strongly to the hypothesis at hand. The correlation reported here was driven by children's comprehension of the quantifiers *all*, *some*, and *none*, but broke down in exactly the place where it is predicted to exist according to theories such as Carey (2004), Le Corre and Carey (2007) and Sarnecka et al. (2007). There was no difference in the knower levels of children who gave exactly one for *a* relative to children who gave more than one. Further, we found that more than half of the one-knowers gave more than one object when asked to give *a* thing, and that most children judged *a* to be consistent with sets of two objects, despite rejecting sets of two for the numeral *one*. Thus, we conclude that any correlation between quantifier and numeral comprehension cannot be explained by the hypothesis that singular-plural morphology facilitates the acquisition of the word *one*.

General Discussion

This study explored early quantifier acquisition and how it is related to the development of numeral comprehension. In both 2-year-olds and 3- to 5-year-olds, we found significant age-independent correlations between children's comprehension of quantifiers and numerals. This result is consistent with the hypothesis that quantifier acquisition and numeral acquisition are in some way related developmentally. However, we did not find evidence that acquiring singular-plural morphology is specifically responsible for this correlation. Instead, we found that acquiring the singular-plural distinction fails to predict speeded integer acquisition, and that early numerals were interpreted as exact, unlike early quantifiers and determiners. From these results, we conclude that the acquisition of singular-plural morpho-syntax cannot alone explain the

cross-cultural finding that Japanese and Mandarin-speaking children acquire the meaning of *one* later than English and Russian-speaking children (Li et al., 2003; Sarnecka et al., 2007).

LeCorre and Carey (2007), and Sarnecka et al. (2007), each suggest that the distinction between *one* and higher numerals is either identical to or based on the morphological distinction between singular and plural nouns. This view predicts that expressions like *a banana* should initially mean the same thing as *one banana*. However, three key findings fail to support this prediction. First, in the Truth-Value Judgment task, most children judged that singular nouns were consistent with sets of two objects, but rejected sets of two for the numeral *one*. Thus, children assigned an exact meaning only to *one*. Second, the majority of one-knowers in Experiment 2 gave more than one object when asked for *a* thing (e.g., *a banana*). Therefore, even children who had recently acquired the meaning of *one* did not assign an exact meaning to *a*. Third, children who did give one object for *a* did not have a better mastery of numerals than children who gave two or more objects. These results clearly indicate that children assigned different meanings to *a* and *one*, and that acquiring *a* does not facilitate acquiring *one*.

At 2 years of age, children distinguish numeral meanings from those of quantifiers, suggesting that *one* really is a lonely number after all. Unlike adults, children have not yet acquired the full inferential system in which numerals are embedded. Similarly, it is possible that they have not learned the inferential relations that support the use of quantifiers, which might explain the differences between children and adults in our study. Previous studies have argued that children fail to make pragmatic inferences when interpreting semantically “weak” quantifiers like *some* (and thus fail to consider whether words are maximally informative in a given context). Whereas adults can use pragmatics to infer that *some bananas* entails “not all bananas” and that “a banana” entails “not some bananas”, children cannot (Grice, 1989;

Papafragou & Musolino, 2003). On this view, children, like adults, may have inexact meanings for *some* and *a*, but fail to make pragmatic inferences to limit their use.

It remains possible, however, that other contexts, and perhaps other tasks, could elicit adult-like responses in children's interpretation of singular nouns. For example, Papafragou and Musolino (2003) showed that children's interpretation of *some* becomes more adult-like when they are first trained to "strengthen" the informativeness of other utterances (e.g., replacing the expression "a small four-legged animal" with "a dog"). Similarly, Musolino (2004) presents evidence that 5-year-old children can access non-exact interpretations of numerals in certain contexts (e.g., "at least" and "at most" interpretations). Such studies raise a potential problem for evaluating early semantic competence. If it is true that children can access multiple interpretations for both quantifiers and numerals, then it may be difficult to distinguish the specific contributions of "pragmatics" and "semantics" in these tasks (or in other tasks in the quantifier and counting literatures). To the extent that semantics cannot be isolated from pragmatics, it becomes difficult to assess underlying lexical meanings, and thus to assess hypotheses that try to relate quantifier and numeral meanings, like the singular-plural bootstrapping hypothesis. On this account, the tasks presented here might not test the bootstrapping theory at all.

However, distinguishing between effects of semantics and pragmatics is difficult, and in some cases, like scalar implicature, the locus of the distinction is highly controversial. For example, by some accounts (Chierchia, Fox, & Spector, 2008), phenomena like scalar implicature are arguably semantic in nature, and are best explained without appeal to pragmatics. Such suggestions highlight that, ultimately, however we distinguish between semantics and pragmatics, the question for acquisition is how children arrive at particular mental

representations given the information they encounter in development. For the current study, the question is how children arrive at quantifier and numeral interpretations, how the information conveyed by these interpretations interacts, and how acquiring new knowledge alters interpretation over development. Currently, there is no evidence that children arrive at specific numeral interpretations (e.g., exactly one) by relating numerals to existing quantifiers (e.g., deriving *one* from *a*). Future studies should investigate whether other tasks, or perhaps other contexts, can provide evidence for such links, and if so, which particular contextual factors affect children's access to exact and non-exact interpretations of numerals and quantifiers (see Barner & Bachrach, 2008, for discussion).

Explaining the cross-linguistic correlation between grammatical number and integer acquisition

If singular-plural morphology is not directly responsible for kicking off the acquisition of numeral meanings, then how can we explain the correlation between quantifier and numeral development? As with all developmental correlations, it is possible that the relationship found here is mediated by a third factor, such as mental age, vocabulary size, etc. The data from this study cannot rule out such possibilities. Our purpose has been to argue that the data *do* rule out one previous proposal. We showed that, as predicted by some accounts, quantifier and numeral development are tightly correlated, but that this relation cannot be explained by the specific mechanisms that have been invoked (i.e., logical relations between singular-plural morphology and numeral meanings). Though we cannot rule out other sources of the correlation, we can note plausible ways in which previous proposals might be amended, based on our data.

One possibility, taken for granted in the accounts of LeCorre, Carey and Sarnecka et al., is that singular-plural morphology is one among many ways to modify sets. Probably the first semantic fact that children learn about singular-plural morphology, numerals, and other

quantifiers, is that they modify sets. This is logically prior to identifying *how* they do so (e.g., exactly or otherwise). In Sarnecka et al.'s (2007) study, children's understanding of other set-relational distinctions was not investigated, leaving open the possibility that Japanese children are delayed not because of a lack of singular-plural morphology, but because of a global delay in their acquisition of quantifiers and set representations in language. In any language, the acquisition of a small set of quantifiers may put children in a better position to infer that numerals, which occur in many overlapping syntactic contexts, also modify sets.

This idea is advanced by Bloom and Wynn (1997), who note several ways in which the syntax and semantics of noun phrases might support children's acquisition of numeral meanings in English. For example, they note that both numerals and quantifiers can precede adjectives, and that both can occur in "partitive" constructions like "all of the cats" and "six of the cats". Perhaps most significant is their observation that numerals occur in many syntactic positions occupied specifically by quasi-cardinal determiners and quantifiers like *a*, *these*, *those*, *many*, *another*, and *the others*. This is important because these words can modify count nouns, which denote sets of individuals and quantify according to number (Gillon, 1999). However, they are never used with mass nouns, which do not typically specify number as a measuring dimension (Barner & Snedeker, 2005). By noting that numerals and quasi-cardinal modifiers are used in similar syntactic contexts, children could learn that numerals, like their quantifier cousins, modify sets of individuals. Bloom and Wynn thus predict correlations between quantifier and numeral development, like those found in here. They also suggest that these relations between quantifier and numeral development should predict cross-linguistic differences in numeral development, and should specifically predict delays in classifier languages like Japanese.

Several specific cross-linguistic differences predict that, by Bloom and Wynn's account, English children should have an easier time acquiring numeral meanings. For one, as Bloom and Wynn observe, neither Japanese nor Chinese marks a syntactic distinction between mass and count nouns. As a result, the languages do not provide robust syntactic cues to distinguish between quantifiers that modify sets versus those that do not. This difference between these languages and English is arguably more fundamental than differences in singular-plural marking, since the singular-plural distinction is subordinate to the mass-count distinction, and only one among many set-relational distinctions represented by count nouns.

Equally striking is that Japanese and Chinese both feature "classifiers" – words that specify units of counting, and come directly between the numeral and the head noun.⁶ For example, in (5) the word "ge" comes between the numeral "yi" (i.e., *one*) and the noun "ren" (i.e., *person*).

- (1) yi ge ren
 one CL-individual person
 "one person"

Classifiers pose two main problems. First, in Japanese and Chinese, as just noted, they intervene between numerals and nouns, preventing the two types of word from appearing adjacently. This differs from English, in which numerals frequently occur directly before the nouns they modify. Second, the presence of classifiers may obscure the relation of numerals and nouns, since mastery of even very common classifiers is incomplete by the age of 6 (see Chien, Lust & Chiang, 2003; Li, Barner, & Huang, under review). Thus, the input available to children when they hear numerals in noun phrases is highly variable, and mostly uninterpretable to very

⁶ Cross-linguistically, classifiers do not always intervene between numerals and nouns.

young children. This difference between Japanese and Chinese versus English and Russian seems just as profound, if not more so, than the availability of singular-plural marking on nouns.

These considerations of how classifier languages differ from English are relevant to two distinct hypotheses about how integer development is related to the acquisition of other set representations in language. On one account, like that proposed by Bloom and Wynn, acquiring quantifiers may facilitate integer acquisition by virtue of their overlapping distributional profiles - i.e., by signaling to children that numerals are a kind of quantifier, and modify sets. A second possibility is that the relation between numerals and quantifiers is more general. Correlations between the two may not be mediated syntactically, but instead by making the semantic hypothesis space of sets more salient to children. By acquiring a small subset of words that modify sets of individuals, children may be more likely to consider set-relational representations as candidate meanings for other words, such as numerals. Studies currently underway are investigating quantifier and numeral acquisition in Japanese to test whether quantifier and numeral development are also yoked in classifier languages. Future studies should also explore classifier languages in which classifiers do not intervene between numerals and nouns. If the syntactic position of classifiers in Japanese and Chinese obscures the status of numerals as words that modify sets (causing the delay in integer acquisition), then children learning classifier languages with different word orders may not experience similar delays.

Do children confuse numerals with plural morphology?

One prediction of the hypothesis that singular-plural morphology drives integer acquisition is that *a* should share a meaning with *one*. Another prediction is that numerals that denote larger sets – like *two*– should initially be treated like plural morphology. As noted in the introduction, recent studies have found both experimental and naturalistic evidence that children use numerals

and plural morphology in complimentary distribution (Clark & Nikitina, in press). Early on they use numerals in place of plural marking, and later use only plural marking without numerals. Later still, they combine numerals and plural marking, like adults (e.g., *two cats*). Based on these results, we might conclude that children truly confuse numerals and plural morphology, a point in favor of the idea that numeral meanings are bootstrapped from the singular-plural distinction.

However, aside from the evidence presented here, two facts suggest that this conclusion is not necessary. According to Sarnecka and Gelman (2004) children may assume that numerals have exact meanings prior to knowing what these meanings are, and thus treat them differently from plural morphology. In their study, 2- to 4-year-old children judged that the application of the words *five* and *six* should change when the cardinality of a set changes, even when they didn't know the meanings of these words. Further, children judged that *six* plus some additional objects does not equal six, though *a lot* plus more is still *a lot*. Before children acquire the meanings of numerals, they may recognize that they are exact, unlike plural morphology and other quantifiers (however, see Condry & Spelke, in press, for evidence from younger children). If this is correct, the children in Clark and Nikitina's study may not have used *two* to mean plural per se. Instead, they may have used it to refer to exactly the amount that was present in the context or a specific amount that they had in mind (e.g., akin to "*These bananas*" or "*Exactly this many bananas*" rather than simply "*Some bananas*"). Future studies should examine this further, and test the logical properties of numerals before children acquire their precise meanings.

A second reason to question whether children confuse numerals with plural morphology comes from cross-linguistic studies of numeral use. In Irish, plural morphology occurs obligatorily on all nouns except when used with the numerals three through ten (and perhaps higher), which do not admit plural marking (Acquaviva, 2006). In this language, numerals are

not confounded with plural markers or used to mean the same thing. Instead, it is a fact about the syntax of the language that the two do not co-occur. This, presumably, is a possible grammar not only for children acquiring Irish, but also for children acquiring any language. Children in Clark and Nikitina's (in press) study may have been exploring these syntactic properties of English, rather than confusing plurals and numerals outright. Future studies should explore the acquisition of numerals in Irish, to determine whether the decoupling of singular-plural morphology and numerals in the input delays numeral acquisition in these children.

The origin of exactness

Perhaps the most striking fact left unexplained by the current study is how children come to assign exact interpretations to numerals, and how they distinguish exact numeral meanings from inexact meanings of quantifiers and determiners like *a*. LeCorre and Carey (2007) provide strong evidence that analog magnitude number representations, present in human infants and various non-human animals (see Feigenson, Dehaene, & Spelke, 2004), could not provide early, exact numeral meanings, by showing that children do not relate numerals to analog magnitudes until *after* they have become CP knowers. Instead, they argue that the exact meaning of early integers derives from “enriched parallel individuation”. According to this hypothesis, early numeral meanings like *one* and *two* are acquired via associations between numerals and tokenings of object representations (stored in memory; see also LeCorre & Carey, 2008). A large body of research has documented a system for object tracking that supports the representation of up to three or four individuals in parallel (see Feigenson et al., 2004). According to some accounts, this system of “parallel individuation” (PI) assigns a distinct symbol for each object in an array, and stores each symbol in a working memory model. Each model is limited to representing up to three or four objects at a time. Crucially, in tasks where children purportedly deploy PI, their

ability to discriminate sets is quite precise, and is not subject to scalar variability (i.e., error in numerical judgments does not increase as a function of the size of the sets involved). For example, 12- and 14-month-old infants readily discriminate between sets of 1 vs. 2, 1 vs. 3, and 2 vs. 3 (e.g., Feigenson & Carey, 2003; 2005).

According to LeCorre and Carey, children might use representations derived from PI to make hypotheses about the meanings of early numerals. This would explain why children can only acquire numeral meanings up to three or four, in absence of counting, since PI cannot represent sets greater than four. Further, LeCorre and Carey believe that PI might provide the concept of exactness. By combining PI with set structures borrowed from language, children might construct exact representations of sets that define the meanings of *one*, *two*, and *three*.

Although this line of reasoning is compelling, it is unclear whether it can explain how some representations in language – i.e., numerals – are assigned exact meanings, while others – i.e., quantifiers – are not. As noted by Gallistel (2007), neither set representations nor PI can alone guarantee the exactness of associated numerals. Many set-relational representations like *some* and *most* do not specify exact set sizes, and neither do singular nouns like *a banana*. Although the set representations that are deployed by language may include exactness in the hypothesis space that they provide, they do not tell us *which* words are exact. LeCorre and Carey (2007) argue that PI provides exactness, since comparisons involving PI are not subject to scalar variability (see p. 402). However, the lack of error in ordinality judgments for small sets does not entail that PI representations are exact. Studies of small number comparison, like those of Feigenson and Carey, argue that infants use one-to-one correspondence to compare the working memory models. One-to-one correspondence is invoked because it explains how infants could make exact *computations* without representing the cardinality of object arrays as sets – i.e.,

without having exact set representations. The problem is that a simultaneous tokening of three symbols is neither exact nor inexact, because the property of exactness applies to the relation between a *single symbol* and the cardinality of a set in the world. PI doesn't provide a single symbol for a set, but a model containing up to three unrelated symbols, or indexes. The relation of such models to sets is a question that is currently open to debate (Barner et al., in press).

If we grant that combining PI and sets could somehow yield exact set representations, it is still not clear how children would discover that *numerals* have exact meanings. Presumably children can generate PI models for any small set that they encounter, and do so equally often when they hear the words *one* and *a*. It must be possible to associate words with tokenings of one individual without forcing children to conclude that the word therefore means *exactly one*. So, the question remains: why do children conclude that *one* is exact but that *a* is not?

Previous studies have documented various ways in which numeral use may differ from the use of singular and plural nouns. For one, singular and plural nouns are often used to describe kinds of things rather than quantities of things, a fact to which young children are sensitive (e.g., cats are furry; these things are elephants). As noted by Clark and Nikitina (in press), 2- and 3-year-olds recognize that numerals should be used in response to "how many?" questions, and that singular or plural nouns do not alone satisfy such requests (though they are ok for questions like "What's in the box?"). This is perhaps related to the fact that, in adult speech, plural nouns do not always specify plural sets. Not only can plural nouns refer to kinds (which are not quantities of "more than one" – e.g., "bananas are my favorite fruit"), they can also refer to empty sets (e.g., no cats; zero cats; there aren't any cats), and can be used to deny the presence of singularities (e.g., "There aren't apples in my grocery bag"; false if there is only one). Similarly, singular nouns often do not exclude sets of more than one. For example, if a person can't get

good coffee in this town, then it is not the case that several *people* can. Also, if I say there isn't a single mouse in my attic, this does not leave open the possibility that there is more than one (Sauerland, Anderssen, & Yatsuushiro, 2006; de Villiers & Roeper, 1991).

Another factor that may distinguish numerals from quantifiers is that only numerals are part of a count list (e.g., *one, two, three, four...*). Not only does this list provide an ordering of the numerals that is important to counting (e.g., acquiring the successor principle), but it tells children that numerals are a class of related words. This may signal to children that the words contrast in meaning (following the principle of contrast of Clark, 1988), and that their meanings contrast along some common dimension (see Wynn, 1992). Once children realize that numerals modify sets (i.e., by analogy to quantifiers), that they contrast in meaning, and that they are as unbounded in number as the set sizes they name, it may not be a giant leap to infer that for each distinct set size there exists a distinct numeral and that numeral meanings are exact (see Barner & Bachrach, 2008, for discussion).

Conclusions

Our investigation of early quantifier and numeral acquisition supports two primary conclusions. First, as predicted by previous cross-linguistic studies of singular-plural and numeral acquisition, English-speaking children's comprehension of numerals is significantly correlated with their acquisition of set-relational quantifiers and determiners like *a, some, and all*. Second, we find no evidence that any particular contrast provided by set-relational quantifiers plays a specific role in acquiring the meaning of individual numerals. In particular, we found no evidence that acquiring the singular-plural distinction facilitates children's acquisition of the word *one*. In two experiments, children assigned an exact interpretation to the

numeral *one* but not to the indefinite determiner *a*. Further, children who did associate *a* with sets of one did not have higher number knower levels than children who did not.

We suggest that differences in numeral acquisition between children and cross-linguistically may be related to differences in their rate of quantifier and determiner acquisition. Quantifiers may play a facilitating role by highlighting the semantic function of numerals, a role which is fulfilled more transparently in English than in classifier languages like Japanese and Chinese. This may be satisfied by one of two mechanisms: (1) the common distributional profiles of numerals and quantifiers may highlight the fact that both modify sets, or (2) learning quantifiers may make the general hypothesis space of sets and individuals more salient as a hypothesis space for integer acquisition. Future studies should investigate the mechanisms underlying this relationship. Studies should also explore children's earliest understanding of exactness, by testing how they come to distinguish the meanings of words like *a* and *one*, and how knowledge specific to counting, like the count list, affects children's appreciation of exactness.

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Figure Captions

Figure 1. The number of objects presented and the questions asked on each trial for the *Truth-Value Judgment* task.

Figure 2. Number of children who gave 0-8 fruits on both trials for the quantifiers: *a*, *another*, *some*, *the other Xs*, *none*, *most* and *all*; or 0-3 fruits on both trials for the quantifier: *both*.

Figure 3. Children's average percent correct for all quantifiers at each number knower-level.

Figure 4. 0- to three-knowers' vs. CP-knowers' average percent correct for each quantifier.

Figure 5. Children's average number knower-level as a function of their performance on each quantifier trial type.

Figure 6. Children's % "Yes" responses for each quantifier in the Truth-Judgment Task.

Figure 7. Number of children who gave 0-8 fruits on both trials for the quantifiers: *a*, *some*, *none* and *all*.

Figure 8. Children's average percent correct for each quantifier at each number knower level.

Figure 9. Children's average number knower level as a function of their performance on quantifier trials.

Figure 10. The number of one-knowers who gave 1 or more than 1 object when asked for *a*.

Figure 11. Children's percent "Yes" responses for each quantifier in the Truth-Judgment Task.

Figure 1. The number of objects presented and the questions asked on each trial for the *Truth-Value Judgment* task.

Quantifier	Question	Number of fruit presented		
<i>a</i>	"Is there a strawberry in the red circle?"
<i>some</i>	"Are some of the strawberries in the red circle?"
<i>most</i>	"Are most of the strawberries in the red circle?"
<i>all</i>	"Are all of the strawberries in the red circle?"
<i>none</i>	"Are none of the strawberries in the red circle?"
<i>one</i>	"Is one strawberry in the red circle?"
<i>two</i>	"Are two strawberries in the red circle?"

Figure 2. Number of children who gave 0-8 fruits on both trials for the quantifiers: *a*, *another*, *some*, *the other Xs*, *none*, *most* and *all*; or 0-3 fruits on both trials for the quantifier: *both*.

Figure 3. Children's average percent correct for all quantifiers at each number knower-level.

Figure 4. 0- to three-knowers' vs. CP-knowers' average percent correct for each quantifier.

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Figure 11. Children's percent "Yes" responses for each quantifier in the Truth-Judgment Task.

Table Captions

Table 1. Examples of how quantifiers/determiners were used in the *Give-Quantifier* task.

Table 2. Definitions of “correct” (adult-like) responses for each quantifier. (* total number of objects: 8 for *a, another, the others, some, most, all, none*; 3 for *both*)

Table 1.

Examples of How Quantifiers/Determiners Were Used in the Give-Quantifier Task

Quantifier	Examples of experimenter request using bananas
<i>a</i>	“Could you put <i>a</i> banana into the red circle?”
<i>another</i>	“Could you put <i>another</i> banana into the red circle?”
<i>the other</i>	“Could you put <i>the other</i> bananas into the red circle?”
<i>some</i>	“Could you put <i>some</i> <u>of the</u> bananas into the red circle?”
<i>most</i>	“Could you put <i>most</i> <u>of the</u> bananas into the red circle?”
<i>all</i>	“Could you put <i>all</i> <u>of the</u> bananas into the red circle?”
<i>none</i>	“Could you put <i>none</i> <u>of the</u> bananas into the red circle?”
<i>both</i>	“Could you put <i>both</i> of the fruits you like into the red circle?”

Table 2

Definitions of “correct” (adult-like) Responses for Each Quantifier (total number of objects: 8 for *a*, *another*, *the others*, *some*, *most*, *all*, *none*; 3 for *both*)*

Quantifier / determiner	Correct response*
<i>a</i>	1
<i>another</i>	1
<i>the other x's</i>	2-7
<i>some</i>	2-7
<i>most</i>	5-7
<i>all</i>	8
<i>none</i>	0
<i>both</i>	2