Title
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From Grammatical Number to Exact Numbers: Early Meanings of ‘One,’ ‘Two,’ and ‘Three’ in English, Russian, and Japanese

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Abstract

This study examines whether singular/plural marking in a language helps children learn the cardinal meanings of the words ‘one,’ ‘two,’ and ‘three.’ First, CHILDES data in English, Russian (which marks singular/plural), and Japanese (which does not) were compared for frequency, variability, and contexts of number-word use. Then, groups of monolingual children (ages 2-10 to 3-6) in the USA, Russia, and Japan were tested on Counting and Give-N tasks. More English and Russian learners knew the meaning of each word than Japanese learners, regardless of whether singular/plural cues appeared in the task itself (e.g., “Give two apples” vs. “Give two”). Authors conclude that the earliest number-word meanings come from the conceptual framework of grammatical number, rather than of positive integers.
From Grammatical Number to Exact Numbers: Early Meanings of ‘One,’ ‘Two,’ and ‘Three’ in English, Russian, and Japanese

Young children use number words in intriguing ways. Consider Ben, age 2-1/2. "He pointed to a picture of two airplanes and said 'two,'" his mother recalls. "But then he pointed to a picture of five airplanes and said 'two.' So much for knowing his numbers."

Ben's error was to treat "two" as a marker of plurality. In other words, he used "two" to mean any set size greater than 1, rather than to mean the exact set size 2. This is a very common error among young children, many of whom not only say "two" to describe larger set sizes, but also give two items when they are asked for higher number words. But English-speaking adults don't use "two" this way, and they don’t give two items when they are asked for “five.” So why do children?

This paper explores the possibility that children first assign cardinal meanings to number words by treating them as words for grammatical number categories such as singular and plural, rather than as words for positive integers (i.e., exact, whole numbers). We examine the number-word knowledge of English, Russian and Japanese preschoolers, to see whether children learning a singular/plural-marking language (i.e., English or Russian) assign cardinal meanings to 'one,' 'two,' and 'three' earlier than children learning a language without singular/plural marking (i.e., Japanese). We also look for differences children’s knowledge of the counting routine, and we analyze CHILDES data from all three languages to compare the frequency, variability, and contexts of number-word input.

Learning Number-Word Meanings

Children encounter number words in different contexts. The word "two," for example, sometimes occurs in a list, with other number words ("one, two, three, . . .") etc.; at other times it
occurs in sentences (e.g., "you can have two cookies"). Children's earliest understanding of number words appears to treat these contexts as separate—almost as if the words were homonyms. That is, children learn to count quite well (both to recite the number-word list and to coordinate this recitation with pointing to objects) before they understand how counting reveals the cardinality of sets.

Separately from learning to count, children learn to use the words "one," "two," and "three" as cardinal quantifiers (e.g., “You can have two cookies. No, not ten—I said two.”) It appears that children always learn the word “one” first, then “two,” then “three.” Children who have learned that "one" means 1 are called one-knowers; children who know that "two" means 2 are two-knowers; children who know that "three" means 3 are three-knowers. Sometime after becoming three-knowers, children figure out what Gelman and Gallistel (1978) termed the 'cardinal principle' of counting. That is, children learn that the last word used in counting (e.g., "one, two, three, four, five") is the cardinal number word for the whole set that was counted. Many scholars have addressed the question of how children induce the cardinal principle (e.g., Klahr & Wallace, 1976; Siegler, 1991; Sophian, 1987, 1997) and there is widespread agreement that the induction requires children to integrate their knowledge of the separate (i.e., counting and cardinal) contexts of "one," "two," and "three." Several recent accounts (Carey, 2004; Carey & Sarnecka, in press; Spelke & Tsivkin, 2001; Spelke, 2003) argue that a child's use of the cardinal principle provides the first evidence that the child has begun to represent the positive integers as positive integers—exact, whole numbers, which are generated by the successor function (N, N+1, [N+1]+1, etc.).

According to these accounts, it is only after inducing the cardinal principle (and, by implication, the successor function) that children can assign positive-integer meanings to higher
number words like "five" and "six." (This is true because children have no way of mentally representing exact, large numerosities like 5 and 6 before they induce the successor function.) But at the age when the cardinal principal induction occurs (around 3-1/2 to 4 years old), children have already known for some time that "one" means 1, "two" means 2, and "three" means 3. How can this be?

In other words, if children represent integers as integers only after inducing the cardinal principle, and if they induce the cardinal principle only after learning the meanings of "one," "two," and "three," then how did they represent the meanings of "one," "two," and "three" before the induction? The answer explored in the present study is that children initially interpret "one," "two," and "three" as markers of grammatical number categories such as singular, dual, and trial, and take the higher number words to mean plural.

Several observations make this idea plausible. First, there is a strong linguistic connection between the word for 1 and the singular indefinite determiner (e.g., a[n]). In many languages, these are the same lexical item. The same was once true in English: “Historically, a apparently derives from an, Anglo Saxon numeral ‘one,’ and the full form one emerges in deictic and anaphoric uses: give me one. This indefinite article form thus signals singular . . .” (Lucy, 1992, p. 28, italics in original.)

Second, children learn the first several number-word meanings in ascending order: First “one,” then “two,” then “three” (Le Corre et al., in press; Sarnecka & Gelman, 2004; Wynn, 1992). This might happen simply because “one” occurs more frequently than “two,” and “two” occurs more frequently than “three,” in everyday speech (Dehaene & Mehler, 1992). On the other hand, it may be a necessary order. The meaning of “three” might build on the meaning of “two,” which builds on the meaning of “one,” in the same way that grammatical-number systems
build on each other. This relation is expressed by Joseph Greenburg’s (1963) universal No. 34—
No language has a trial number category unless it has a dual; no language has a dual unless it has
singular/plural.

Third, the meanings that one-knowers, two-knowers, and three-knowers assign to number
words are the same as the grammatical-number categories of the world’s languages. When
children learn that “one” means singular, they treat other number words as meaning plural; when
they learn that “two” means dual, the higher number words still mean plural—producing a three-
way, singular/dual/plural distinction such as that found in Upper Sorbian (Corbett, 2000).
Learning that “three” means 3 results in a four-way, singular/dual/trial/plural distinction, as is
found in Larike grammar (Corbett, 2000). This pattern is evident whether children are asked to
construct sets of a given size; to guess the number of objects in a picture (the ‘What’s-On-This-
Card’ task, Gelman, 1993; Le Corre & Carey, 2005; Le Corre et al., in press); or to choose the
set of a given size (the ‘Point-to-X’ task, Wynn, 1992).

This is the pattern that children exhibit, but it is not the only pattern we can imagine. For
example, children could interpret high number words as synonyms for "a lot." When applying
the word "a lot," children seem to believe that the more items there are, the better. They choose a
set of 300 items as a better example of "a lot" than a set of 6 items, even if the set of 6 was called
“a lot” by the experimenter at the beginning of the task. This is not true for the word "six." That
is, children do not consider 300 to be a better example of "six" than 6 (Sarnecka & Gelman,
2004).

Alternatively, one could imagine a scenario where children viewed high number words as
denoting approximate numbers. For example, they might see low-number words (such as
“three”) as meaning several/a handful/a small group, and high-number words (such as “six”) as
meaning *many/a large group*. But in fact, one-knowers do not demonstrate even a vague understanding that “five” and “six” indicate larger groups than “two” and “three” (Le Corre & Carey, 2006; Sarnecka & Gelman, 2004; Wynn, 1992).

*A Remaining Alternative: Associative Mapping.*

One possibility (that existing data have not ruled out) is that children might use simple association to map the words "one," "two," and "three" with already-existing mental representations of the integers 1, 2, and 3. By experiencing repeated pairings of these number words (either in counting contexts or in cardinal uses of language) with non-linguistic representations of the numbers (e.g., singles, pairs, and trios of objects in the world), children map ‘one’ to 1, ‘two’ to 2, and ‘three’ to 3. If this is true, then children who hear the number words used more often—either in the context of counting or as cardinal quantifiers in sentences—should complete the mappings earlier.

The English number word “one” is both more frequent and less variable in form than its Russian and Japanese equivalents (see *The Languages*, below)—which should make associative mapping easier in English. Predictions about the associative mapping of 2 and 3 depend on what aspect of number-word input is considered most important. If hearing number words used in counting contexts is most important, then the groups that count better should also know more number-word meanings. If number-word input in cardinal (sentence) contexts is most important, then all the groups should map 2 and 3 at roughly the same time, assuming number-word input is equivalent.

*The Present Study*

The present study explores the grammatical-number and associative-mapping possibilities by looking at number-word input and number-word knowledge in young learners of...
English, Russian, and Japanese. The inclusion of Japanese allows us to examine the role of singular/plural marking, because English and Russian have frequent singular/plural marking, whereas Japanese does not. The inclusion of Russian allows us to examine the role of number-word frequency separately from singular/plural marking, because Russian (like Japanese) uses the word for one only in explicitly numerical contexts, whereas the English word "one" also appears in deictic and anaphoric uses of the indefinite determiner (e.g., This introduction is an enjoyable one.) Thus, “one” is heard far more frequently in English than its equivalents are heard in Russian and Japanese.

In the present study, knowledge of the cardinal meanings of ‘one,’ ‘two,’ and ‘three’ is directly assessed using the Give-N task. Number-word input is assessed in two ways: First, input in counting contexts is assessed indirectly, via children's knowledge of the counting routine. We assume that if parents and preschool teachers in some communities actively teach children to count, and practice counting with them, those children should count better than their age-mates from communities where counting is less often rehearsed. Second, number-word input across a range of linguistic contexts is also assessed by analyzing CHILDES transcripts in each language.

We hypothesize that because English and Russian have singular/plural marking, whereas Japanese (largely) does not, English and Russian learners should learn the cardinal meanings of ‘one,’ and possibly ‘two’ and ‘three,’ earlier than Japanese learners do.

There are two reasons to expect this. First, number words co-occur with grammatical number marking. In English and Russian, when the word ‘one’ precedes a noun, the noun is inflected as singular (e.g., apple); when any other number word precedes a noun, the noun is inflected as plural (e.g., apples). So any speaker who understands singular/plural inflections (which English and Russian learners do by the age of two, see below) can infer from the
inflections alone that “one” has something to do with singularity, whereas all the other number words have to do with plurality.

Of course, this co-occurrence of number words with noun inflections could allow Russian and English learners to identify the meaning of ‘one’ earlier than Japanese learners on either the grammatical-number view or the associative mapping view. Note, however, that co-occurrence with singular/plural marking could not help children learn the meanings of ‘two’ or ‘three.’

The second way that singular/plural marking could help children learn the meanings of number words is if the number words themselves are treated like markers of grammatical number categories. In this case, children learning languages with frequent singular/plural marking might have singular and plural available, as candidate meanings for number words, earlier than children whose languages rarely encode the singular/plural distinction.

The relatively frequent plurality marking of Russian and English is mastered by age two; the relatively rare plurality marking of Japanese is not among the linguistic competencies mastered in early childhood (Downing, 1996; see, e.g., Ogura & Watamaki, 2004; Watamaki & Ogura, 2004). Thus, Japanese learners must extract the meaning 1 or singular solely from instances of the number word itself, whereas English and Russian learners have frequent and multiple cues marking the singular/plural distinction.

None of the three languages under consideration have dual or trial markers (barring relatively rare exceptions such as the English word both), so all children have to learn ‘two’ and ‘three’ the way Japanese children learn ‘one’—that is, from instances of the number words themselves. But the grammatical-number hypothesis implies that the relation among the various levels of number-word knowledge (one-knower, two-knower, and three-knower) may be analogous to the relation expressed by Greenburg’s (1963) universal: Languages with trial
marking always have dual marking, and languages with dual marking always have
singular/plural marking—just as three-knowers always know the meaning of ‘two,’ and two-
knowers always know the meaning of ‘one.’ If learning ‘two’ is not just a matter of associating a
word with a pre-existing integer representation, but actually of elaborating the previous
(singular/plural) system into a new (singular/dual/plural) system, then children who learn ‘one’
earlier have a head start on learning ‘two’ and even ‘three.’ On the other hand, if the process is
one of associative mapping, then although English and Russian learners might map ‘one’ earlier,
children in all three language environments should map ‘two’ to 2, and ‘three’ to 3, at about the
same time (assuming equivalent number-word input).

The Languages

*Singular/plural marking.* Both English and Russian require singular/plural marking on a
variety of sentence elements. English-learning children begin to comprehend singular/plural
marking between 20 and 24 months of age (Barner, Thalwitz, Wood, & Carey, 2005; Kouider,
speech find that children also produce plural marking on nouns by around their second birthday
(Brown, 1973; Cazden, 1968; Fenson et al., 1994; Mervis & Johnson, 1991).

Russian-learning children also understand and produce singular/plural marking before
age two. Leushina (1974/1991) claimed that 15-month-olds are sensitive to plurality marking on
nouns when asked, for example, to build "a little house" versus "little houses" or to bring "a car"
versus "cars." Leushina also wrote that 18-month-old toddlers produce singular and plural nouns
and pronouns in appropriate contexts. Gvozdev (Gvozdev, 1961b; 1961a) reported that his son
Zhenya produced singular/plural marking on nouns in the nominative, accusative, and genitive
cases before his second birthday.
Number words. In English, "one" appears not only in explicitly numerical contexts such as counting, but also as a variant of the indefinite determiner *a(n)*. For this reason, English "one" appears more frequently in the Russian and Japanese words for 1, which are reserved for explicitly numerical contexts.

In Russian, there are two words for 1: *Raz* is the word used in counting, whereas *odin* and its variants (inflected for case, gender, etc.), are used as cardinal quantifiers. The words for 2 and 3 are also inflected for case and gender, producing multiple variants of each number word.

In Japanese, there are two number-word lists. The indigenous Japanese ('IJ') list is made up of bound morphemes (prefixes) that must be attached to a classifier noun—something like the prefixes *uni-*, *bi-*, *tri-*. . . in English. This list of bound morphemes only goes up to ten. The IJ number-word-prefixes commonly appear with the general classifier –*tsu* ('things'). Thus, children counting with the IJ list are literally saying *one thing, two things, three things, . . .* etc. (Which could justify a prediction that Japanese children should actually connect counting with cardinality earlier than other children.) The Sino-Japanese ('SJ') list consists of stand-alone words that continue beyond ten (analogous to the English list *one, two, three, . . .* etc.) Some individual children show a preference for one list or the other; other children use both lists interchangeably (Matsumoto, 1984; 1987; 1993; Naka, 1999; Sanches, 1977).

Previous studies have compared children learning English to those learning Japanese, Chinese, or Korean – languages where the base-10 structure of the number system is relatively transparent (e.g., 11 is called ‘ten-one,’ twelve is called ‘ten-two,’ etc.). Kevin Miller and colleagues found that four- to six-year-old Chinese speakers count higher and with fewer errors than English speakers of the same age (Miller & Stigler, 1987; Miller, Smith, Zhu, & Zhang, 1995). However, Chinese and English speakers performed equally well on a Give-N task where
they were asked to construct sets of two, four, seven, and 12 items. These findings provide additional motivation for the present study: Our grammatical-number hypothesis predicts that Japanese speakers should learn the first few number-word meanings later than English and Russian speakers, because Japanese lacks singular/plural marking. However, the findings of Miller et al. imply that by age four, Japanese speakers (like Chinese speakers) should score better than English speakers on counting tasks, and should perform as well as English speakers on Give-N.

Predictions

To recap: The grammatical-number hypothesis predicts that English and Russian speakers should learn the cardinal meanings of ‘one,’ ‘two,’ and ‘three’ earlier than Japanese speakers, because English and Russian have singular/plural marking whereas Japanese does not.

The associative-mapping hypothesis could make several different predictions, depending on what sort of number-word input is given the most weight. Among these predictions are the following: (a) English speakers should learn ‘one’ earlier, because “one” is more frequent in English than its equivalents are in Russian and Japanese; (b) English speakers should learn ‘one,’ ‘two,’ and ‘three’ earlier, because number-word forms are invariable in English, variable in Russian and Japanese; (c) Number-word knowledge should be correlated with counting skill, because counting practice is an important source of number-word input.

These predictions are based on assumptions—for example, assumptions about the frequency and variability of number-word input in each language. But what we really need to know is how frequent and how variable number words actually are, and how number words are actually used, across languages, in speech to children or in the speech that children overhear. For answers to these questions, we turned to the CHILDES database.
CHILDES Study

Method

Corpora. Ten CHILDES corpora were included in these analyses. These included all the Japanese and Russian corpora available in the database—Aki (Miyata, 1995), Jun (Ishii, 1999), Ryo (Miyata, 1992), Sumihare (Noji, 1973), Tanja (Bar-Shalom & Snyder, 1997; 1998), and Varvara (contributed by Ekaterina Protassova). English corpora included Abe (Kuczaj, 1976), Adam (Brown, 1973), Naomi (Sachs, 1983), and Sarah (Brown, 1973). We analyzed files where the target child was 2-1/2 to 3-1/2 years old, to match the age range of the Give-N study.

Search criteria. The English corpora were searched for cardinal and ordinal forms of the words for one, two, and three, as well as number-word compounds (e.g., "once"), numerical adjectives (e.g., "single"), and numerical nouns (e.g., "duo"). Ordinal forms (e.g., "first") were included in the English and Russian searches to maintain consistency with Japanese, which uses the same forms in both ordinal and cardinal contexts. The asterisk wildcard was used to pick up variations (e.g., searching [one*] returned "one," "ones," "one’s," "once," "one-eyed," etc.) The idiosyncratic phrases "Six Flags" and "Seven-Up" were excluded, as was the phrase "a second" (e.g., "wait a second"). All other tokens returned by the computerized search were included in the analysis.

The Russian corpora were searched for cardinal, ordinal, and collective number words for one, two, and three. The asterisk wildcard was used to pick up variations (e.g., a search for the string odn* would return odna ‘one,’ odni ‘one,’ odno ‘one,’ odnu ‘one,’ odnazhdyi ‘once,’ etc.) All tokens returned by the computerized search were included in the analysis.

The Japanese corpora were searched for the IJ and SJ forms of the words for one, two, and three, as well as for their combinations with any of fifteen common classifiers: ban(me), dai,
hiki, hon, ka, kai, kilo, ko, kuchi, ji\(\text{kan}\), mai, nin, and tsu. All classifier phrases returned by the computerized search were included in the analysis. Coders checked the instances of SJ words search to eliminate homonyms (e.g., san 'three' versus san 'mountain'). One coder was a native speaker of Japanese who was fluent in English; the other coder was a native speaker of English who was fluent in Japanese. Reliability between coders (calculated for 20% of the data) was Cohen’s Kappa = .91, \(p < .001\).

*Coding the contexts of number-word usage.* Each instance of a number word was coded for context. Fuson (1988) discussed the range of contexts in which number words can appear, but to our knowledge this is the first study to investigate the actual frequency of number-word uses in each context, in speech with children. Coding judgments were based on the whole utterance containing the number word, as well as the utterances before and after it; examples of contexts appear in Table 1. At least 20% of each data set was coded by two researchers, one a native speaker of the target language, the other a fluent non-native speaker. Cohen’s Kappas for coder reliability were 0.95 for Russian; 0.75 for English; and 0.78 for Japanese, \(ps < .001\).

*Results and Discussion*

*Frequency of singular/plural marking.* Singular/plural marking is not actually impossible in Japanese; it's just uncommon. By the same token, not every utterance in English or Russian carries plurality marking. Our assumption was that children learning English and Russian hear a lot of singular/plural marking, whereas Japanese learners hear very little. To check this assumption, 400 adult utterances per language (100 from each English and Japanese corpus, 200 from each of the two Russian corpora) were analyzed for singular/plural marking. Singular/plural marking on any element in an utterance (noun, pronoun, determiner, verb, adjective, etc.) was counted.
Singular/plural marking was found on 61% of English utterances and 82% of Russian utterances, but (as expected) on no Japanese utterances. The higher frequency of plurality marking in Russian was attributable to the fact that second-person pronouns and second person verbs (including questions and imperatives) carry plurality marking in Russian but not in English. If utterances with second-person pronouns and verbs are excluded, the frequency of plurality marking in English and Russian is roughly equal.

*Frequency of number words.* Figure 1 shows the frequencies of words for one, two, and three in each language. (Exact counts are listed in the appendix.) As reported by Dehaene and Mehler (1992), 'one' was the most frequently used number word, followed by ‘two’ and then ‘three’ -- note that the Y-axis values differ for each graph. In contrast to Dehaene and Mehler's findings, the present study found differences in the overall frequency of number words across languages, with each word appearing least often in Russian, slightly more often in Japanese, and much more often in English.

Aside from the expected higher frequency of “one” in English (because of its use in non-numerical contexts), it is not clear how to interpret these frequency differences. It is possible that the differences are artifacts of the relatively small language samples available for the present study, which included approximately 450,000 words in English, 300,000 words in Japanese, and only 30,000 in Russian. Dehaene and Mehler’s samples, by contrast, included several million words of adult language use and found no cross-linguistic frequency differences. On the other hand, there might be real differences among adult communities, in the way they use number words to children. A definitive answer requires the analysis of larger datasets than are presently available through CHILDES.
For present purposes, it is sufficient to note that if the cross-linguistic differences in number-word frequency are real, then Japanese appears to occupy a middle ground between English and Russian. This is helpful background information for the Give-N study (below), because should allows us to consider singular/plural marking (which is present in English and Russian, absent in Japanese) separately from the overall frequency of number words.

**Contexts of number-word use.** Figure 1 shows the proportions of number-word tokens used in cardinal (solid black fill), counting (solid white fill), and other contexts (‘scratchboard’ fill). Contexts of number-word use changed systematically as numbers got bigger: Most tokens of ‘one’ appeared in cardinal contexts, whereas tokens of ‘three’ were nearly equally divided between counting and cardinal uses. Overall, these data show that when number words are used, they are used in remarkably similar ways across languages.

**Variability of number-word forms.** Figure 2 shows the forms of each number word found in a cardinal or counting context. The widest variety of forms was found in Russian, despite the fact that the Japanese and English samples were 10 and 15 times larger, respectively, than the Russian sample. If the Russian sample had been as large as the other two, an even wider variety of forms would presumably have been found.

What is harder to guess is how different kinds of variation affect number-word learning. Russian number-word forms vary according to the gender and case of the nouns they modify, producing, for example, 13 different forms of the word ‘one’ alone (Wade, 1992). Japanese number-word forms also vary according to the nouns they modify, but in a different way: In general, IJ number-word prefixes are used with Indigenous Japanese classifier nouns. (For Japanese speakers, there is no sense of ‘foreignness’ about the Sino-Japanese vocabulary, which has been a part of the Japanese language for many centuries—much as English includes French
vocabulary dating from the Norman invasion.) Japanese number-word forms also vary on phonological grounds: For example, the SJ word for one (ichi), can shorten to ikk-, or ipp-, depending on the classifier it precedes.

In any case, it is clear that number words are less variable in English than in either of the other two languages. This should allow us to consider singular/plural marking (which is present in English and Russian, absent in Japanese) separately from variability (which is low in English, high in Japanese and Russian.) Unfortunately, the present data do not allow us to separate frequency from variability, because number words are both more frequent and less variable in English than in the other two languages.

Give-N Study

Method

Participants. Participants included 162 monolingual children at three data collection sites: Ann Arbor, Michigan (English learners); St. Petersburg, Russia (Russian learners); and Kobe, Japan (Japanese learners). The mean age of each group of participants was 3 years, 2 months.

English-speaking participants included 70 children (37 boys, 33 girls), ages 2-10 to 3-6, mean age 3-2. Children were recruited from private and university-affiliated preschools serving mainly middle-class families. No questions were asked about participants’ racial/ethnic identity or socioeconomic status, but children were presumably representative of the midwestern university town in which they were recruited. Additionally, one child (age 39 months) was tested but gave no responses after the first 2 Give-N trials. This child’s data were excluded.

Russian participants included 44 children (25 boys, 19 girls), ages 2-9 to 3-7, mean age 3-2. Children were recruited from public preschools. The Russian preschools (unlike the Japanese
and American preschools) maintained records on parents’ self-identified ethnicity and educational attainment, and made these data available to us. Regarding ethnicity, 91% of parents in our sample described themselves either as Russian or as monolingual Russian speakers of another ethnicity (e.g., Ukrainian, Jewish, etc.); 4% described themselves as bilinguals of non-Russian ethnicity who spoke only Russian with their children; 4% declined to answer. Regarding education, 4% of parents in our Russian sample had completed a secondary education, 22% had completed a ‘specialization’ (analogous to a Bachelor’s degree); 54% had completed an advanced degree; 20% declined to respond.

Japanese participants included 48 children (27 boys, 21 girls), ages 2-9 to 3-6, mean age 3-2. Children were recruited from private and public nursery schools (hoikuen) serving mainly middle-class families. No questions were asked about racial/ethnic identification or socioeconomic status, but preschool administrators believed that all of the children were members of the dominant Japanese (Yamato) ethnic group.

*Standardizing data collection.* All written materials, including parental consent forms, task protocols, and data collection sheets, were generated by a multilingual researcher (the first author, a native speaker of English) in collaboration with native speakers of the target languages. The first author then made videotapes demonstrating the testing procedure in English, Russian and Japanese, with child speakers of those languages. Copies of the videotape were sent to the Kobe and St. Petersburg sites, and the procedure was discussed over e-mail. The researchers in Kobe also made a videotape of pilot testing there. The process of consultation continued until all parties were satisfied that the procedure was as comparable as possible across sites.

*Procedure—Counting task.* The counting task was always given first. Children were presented with arrays of two, three, five, and six rubber erasers (stars, flowers, apples, and teeth)
glued to a board. Arrays of two and three were always presented first, in counterbalanced order; followed by arrays of five and six, in counterbalanced order. Questions were of the form, “Here are some stars. Can you count and tell me how many there are?” Each trial was scored correct/incorrect.

*Procedure—Give-N task.* A puppet and pile of 15 small rubber toys (apples, flowers, eyeballs, soccer balls, or teeth) was placed in front of the child, who was asked to give the puppet a certain number. There were 15 trials, separated into three blocks: In each block, the child was first asked for one item, then for two and three items in counterbalanced order, then for five and six items in counterbalanced order. Scoring criteria were based on Wynn (1992): Children were given credit for knowing a number word if they (a) gave the correct number of items on at least two of the three trials for that word, and (b) gave that number of items no more than once during the other twelve trials.

In English, prompts were of the form “Can you give *two* flowers to the monkey?” If the child hesitated, the experimenter restated the prompt (e.g., “Just take *two* and put them right here / Can you get *two* flowers for the monkey?”) In all languages, restatements were common on the first trial, but were rarely needed on subsequent trials. After responding, the child was asked a single follow-up question, of the form “Is that *two*?” which repeated the initial number word asked for. If a child responded “no” to the follow-up question, the original prompt was repeated.

In Russian, prompts were of the form

*Dai pozhaluista dva tsveta obesyankye*

‘Please give *two flowers* to the monkey’

The follow-up question was of the form

*Eto dva?*
Is that two?

In Japanese, prompts used whichever number-word list the child herself had used in counting. If the prompt was restated, the other list was used. If the child had refused to count, *hitotsu* (the IJ word for ‘one thing’) was used in the first Give-N prompt. Prompts were of the form

*Osaru-san ni futatsu no hana wo watashite kureru?*

‘Will you give Mr. Monkey **two things** of flowers for me, please?’

The follow-up question used whatever form the child had responded to. For example,

*Are wa futatsu?*

‘Is that **two things**?’

**Results** and **Discussion**

**Rate of responses on the counting task.** Some children refused to count aloud in response to the experimenter’s prompt (“Can you count and tell me how many there are?”) Two English speakers shook their heads ‘no’ in response to the prompt (as if to say *No, I can’t count and tell you how many there are.*) Five children in the Russian group repeatedly answered *mnogo* (*a lot*), and in the Japanese group, 17 children would not speak at all, but pointed mutely to each object in the array. Two other Japanese children spoke on only one out of four counting trials. These non-response rates differed significantly across the three languages, one-way ANOVA $F(2, 159) = 18.48, p < .001$. Japanese learners had a mean non-response rate of 1.54 trials (out of a possible 4) per child, which was higher than the Russian rate of 0.57 refusals per child, $t(90) = 2.98, p < .01$, which in turn was higher than the English rate of 0.11 refusals per child, $t(112) = -2.79, p < .01$. 
We cannot be certain why some children refused to count out loud, but children’s willingness to count was not correlated with their performance on the Give-N task in any language group (either in terms of average Give-N scores or in the proportion of children scoring at each level). Still, because we cannot be sure that the non-counters understood what to do, and because the grammatical-number hypothesis predicts that Japanese learners should score lower on the Give-N task, we felt it prudent to exclude the data from those children who refused to count. (If they didn’t know what to do, then including their data could bias the results by artificially lowering the Japanese group scores). Thus, the results reported below are based solely on the data of those 136 children who completed both tasks. Except where noted below, separate analyses of all 162 children found no difference on any measure from analyses of the 136 children who completed both tasks.

*Children counted larger sets than they were able to construct.* As Figure 3 illustrates, the mean score on the Counting task (white apples) was higher than the mean score on the Give-N task (black apples) for each group, indicating that speakers of all languages were able to count larger set sizes than they constructed. Analyzing all language groups together, the mean longest array counted was 4.27 objects; the mean highest number given for Give-N was 1.88. This difference was significant, \( t(134) = 12.43, p < .001 \). Separate analyses of each language group showed the same pattern (\( ps < .001 \)). This replicates the oft-reported finding that counting skill precedes understanding of the cardinal principle (e.g., Baroody, 1992; Fuson, 1988; Schaeffer et al., 1974; Wynn, 1992).

*Counting scores and Give-N scores were not correlated.* There was no correlation between counting scores and Give-N scores were not significant for any group. This supports the claim, made by Fuson (1988, 1992) and others, that the counting and cardinal contexts of number
words are truly separate for young children: If counting were simply an easier task than Give-N (but tested the same knowledge) then scores on the two tasks might be correlated, even if counting scores were higher. The present data offer no evidence of such a correlation.

However, the present data may suffer from a ceiling effect: About half the English and Japanese learners, and a quarter of the Russian learners, counted perfectly on the longest array presented (six items). If children were tested with longer arrays, a correlation between counting and Give-N performance might yet be found.

Counting skill differed by language. As illustrated in Figure 3, counting scores (white apples) differed significantly among groups, $F(2, 30.75) = 9.64, p < .001$. Specifically, the Russian speakers counted significantly fewer objects than either the English speakers, $t(62.99) = 4.17, p < .001$; or the Japanese speakers, $t(59.06) = 2.41, p < .05$. There was no significant difference between the English and Japanese groups' counting scores, $t(40.80) = .87, p = .38$, NS.

Number words were learned in order. As reported in previous studies (e.g., Mix, Huttenlocher, & Levine, 2002; Sarnecka & Gelman, 2004; Wynn, 1990, 1992), children learned the number words in order. That is, children who knew the meaning of ‘three’ also knew ‘two’; children who knew ‘two’ also knew ‘one.’ The proportions of children who fit this pattern were 96%, 93%, and 97% in English, Russian, and Japanese, respectively.

Number-word knowledge differed by language. As illustrated in Figure 3 (black apples), Give-N scores differed significantly among groups, $F(2, 12.32) = 6.23, p < .01$. Specifically, the Japanese speakers scored significantly lower than either the English speakers, $t(54.82) = 3.39, p < .001$; or the Russian speakers, $t(54.28) = 2.67, p < .01$. There was no difference between the English and Russian groups, $t(92.91) = .80, p = .42$, NS.
The proportion of children giving one item upon request was higher in English and Russian than in Japanese. As illustrated in Figure 4 (top graph), the proportions of children who gave 1 item upon request, and gave >1 item for all other number words, differed significantly among groups, Kruskal-Wallis Chi-Square (2) = 36.05, \( p < .001 \). Specifically, the Japanese group contained a lower proportion than either the English group, \( Z = 4.89, p < .001 \); or the Russian group, \( Z = 4.46, p < .001 \). There was no difference between the English and Russian groups, \( Z = .78, p = .44 \), NS.

The proportion of children giving two items upon request was higher in English and Russian than in Japanese. As illustrated in Figure 4 (middle graph), the proportions of children who gave 2 items upon request, and gave >2 items for all other number words, differed significantly among groups Kruskal-Wallis Chi-Square (2) = 7.48 \( p < .05 \). Specifically, the Japanese group contained a lower proportion than either the English group, \( Z = 2.67, p < .01 \); or the Russian group, \( Z = 2.15, p < .05 \). There was no difference between the English and Russian groups, \( Z = .35, p = .73 \), NS.

The proportion of children giving three items upon request was higher in English than in Japanese. As illustrated in Figure 4 (bottom graph), the proportions of children who gave 3 items upon request, and gave >3 items for all other number words, showed a non-significant tendency toward differing among groups, Kruskal-Wallis Chi-Square (2) = 5.65, \( p = .059 \). (If non-counters are included in the analysis, bringing the total \( n \) to 162, the difference among groups becomes significant, Kruskal-Wallis Chi-Square (2) = 11.34, \( p < .01 \).) Specifically, the Japanese group contained a lower proportion than the English group, \( Z = 2.37, p < .05 \); and a non-significant tendency to be lower than the Russian group, \( Z = 1.62, p = .11 \), NS. (If non-counters are included in the analysis, bringing the Japanese \( n \) to 48 and the Russian \( n \) to 44, then the difference
between the groups becomes significant, \( Z = 2.07, p < .05 \) \( ) \). There was no difference between the English and Russian groups, \( Z = .77, p = .44, \) NS.

Many two-knowers had partially worked out the meaning of 'three.' Comparing two-knowers' responses to prompts for 'three' items versus prompts for 'five' or 'six' items, we find that English and Russian two-knowers gave significantly fewer items for 'three,' paired \( t(12) = 2.67, p < .05 \) for English; paired \( t(8) = 2.56, p < .05 \) for Russian. Because there were only four children in the Japanese two-knower group, the difference there did not reach statistical significance, but it followed the same pattern: Japanese two-knowers gave an average of 3.00 items for 'three apples,' and 4.17 apples for 'five apples' and 'six apples.' Over all, two-knowers in all groups gave 3 items upon request on 41 of 78 trials (52%).

The phenomenon was limited to 'three'; two-knowers did not distinguish between 'five' and 'six.' Thus, it seems that the transitions between knower-levels—or at least, the transition from two-knower to three-knower—is gradual. There is a period of time when two-knowers already know something about 'three,' but do not yet meet our relatively strict criteria for being three-knowers (see Procedure—Give-N task, above). For example, they might give 3 items only half the time (which is still more often than chance would predict) or they might give 3 items all the time for 'three,' but also give 3 items for other number words.

In the present study, no evidence of a similar transition was found for one-knowers or three-knowers, but neither are these data really suited to the search. Three-knowers, if they had such a transitional period, would distinguish 'four,' and the present study did not include requests for 'four' items. One-knowers did not distinguish 'two,' but the one-knower period seems to last a long time, at least for English learners (Wynn, 1992); it could be that children who are about to
become two-knowers would distinguish 'two.' Further studies are needed to understand how the transitions occur.

**Russian one-knowers distinguished low-number requests (two items and three items) from high-number requests (five items and six items).** Russian requires special marking on the nouns governed by number words: Nouns following 'one' receive singular inflection; nouns following ‘two,’ ‘three,’ and ‘four’ receive genitive singular inflection; nouns following ‘five’ through 'ten' receive genitive plural inflection. If children partly infer number-word meanings based on co-occurrence with noun inflections, then Russian speakers might assign meanings of *singular, few,* and *many.* That is, instead of assigning the numerical values of a singular/plural system, they might assign the values of a singular/paucal/plural system.

To investigate this question, we compared one-knowers' responses to requests for two or three items to their responses for five or six items. The Russian-speaking one-knowers did indeed give fewer items for low number words than for high number words, paired \( t(15) = 2.38, p < .05. \) The English and Japanese one-knowers made no such distinction. Russian one-knowers also differed from the other groups in their pattern of non-responses, discussed below.

**Pattern of non-responses.** Trials where the child refused to give any objects were called non-responses. Overall, (for all 162 children) the rate of non-responses was very low: Out of 2,430 trials, there were 52 non-responses (a rate of just over 2%). Most of these non-responses were made by Russian one-knowers, on trials requesting five or six items. In fact, when the non-response rates are calculated separately, we find that Russian one-knowers on five-item and six-item trials had 35 non-responses in 120 trials (a rate of 29%), whereas all other children on all other trials made 17 non-responses in 2,130 trials—a rate of less than 1%. Moreover, the Russian one-knowers themselves, on trials requesting one, two, or three, items, always responded (0 non-
responses out of 180 trials), indicating that they were not confused or anxious about the task in general.

This hesitancy to respond on high-number-word trials, along with the pattern of giving different numbers of objects for low versus high number words, suggests that these Russian one-knowers were at least aware of the different inflections on nouns following number words in Russian. If this finding were to be replicated, it would set Russian one-knowers apart from one-knowers in other languages (e.g., English, Japanese, and Mandarin) none of whom have been found to distinguish 'two' and 'three' from 'five' and 'six.' (Le Corre & Carey, 2006; Li, Le Corre, Shui, Jia, & Carey, 2003; Sarnecka & Gelman, 2004; Wynn, 1992).

Follow-Up Study: Give-N-Apples vs. Give-N-Without-Nouns

In the Give-N study described above, prompts always included a number word and a noun (e.g., "Please give two apples to the monkey"). In English and Russian, these nouns carried grammatical-number marking (singular/plural in English, singular/low/high in Russian). Thus, the prompts carried two sources of information about number: The number-word itself, plus the inflection on the noun following the number word.

When we look at the proportions of children in the English and Russian groups who distinguished 'one apple' from 'two apples,' we don't know whether those children actually knew the meaning of the number word 'one,' or simply knew the meaning of the noun inflections. (This question only arises about the one-knowers, because noun inflections do not help to distinguish two from three in either language.)

This follow-up study tested English and Russian speakers with and without singular/plural cues, in order to find out whether including cues in the task itself had any effect
on children's performance. (Japanese speakers were not included in the follow-up because the
Japanese prompts did not contain grammatical-number marking in the first place.)

Method

Participants. Participants included 36 children (21 girls, 18 boys) living in the greater
Boston area. All children were monolingual, native learners of either English (21 children) or
Russian (15 children). The ages of English learners ranged from 2-7 to 3-11 (mean 3-2); the ages
of Russian learners ranged from 2-8 to 4-1 (mean 3-4).

Some English learners were recruited from Boston-area preschools serving primarily
middle-class families; others were recruited by letter and telephone from a commercially
available mailing list of local families. All Russian learners were recruited from private Russian-
language day-care centers. All spoke Russian at home and in day care. As with any minority-
language population, it is likely that the Russian learners had some exposure to English; this was
not problematic for the follow-up study because (a) both English and Russian contain
grammatical number marking, so exposure to English would not introduce such marking to a
child without it (which would be a concern for Japanese speakers in the USA); and (b) the
comparison in the follow-up study is within subjects: We are interested in how the same child
performs on Give-N-Apples versus Give-N-Without-Nouns. (There is no comparison of Russian
to English.) Similarly, the Boston sample of Russian learners likely differs from the St.
Petersburg sample in various ways; the Russian-language day care centers in the Boston area did
not maintain records on parents' ethnic identity or educational attainment, so a direct comparison
is not possible. Again, this was not problematic for the follow-up because the relevant
comparison is within, rather than between, subjects.
Procedure. Each child was given three tasks: Give-N-Apples, Counting, and Give-N-Without-Nouns. The first and third tasks were Give-N-Apples and Give-N-Without-Nouns, in counterbalanced order: the second task was always Counting. The counting procedure and scoring were the same as in the original study.

Give-N-Apples. The Give-N-Apples task was the same as in the original study, except that whereas the original Give-N task had included restatements and follow-up questions without nouns (e.g., "Is that two?"), Give-N-Apples prompts always included nouns (e.g., "Is that two apples?"). Also, requests in the follow-up study were for one item (always requested first), then two items and three items, in counterbalanced order; then four items (always requested fourth); then five items and ten items in counterbalanced order. The objects used in Give-N-Apples were small apples, bananas, and strawberries, 2-3 cm in diameter (a different fruit for each block of trials). Scoring criteria were the same as in the original study: A child who succeeded at a given numeral was one who constructed the correct set size on at least two of the three trials for that numeral, and constructed that set size on no more than one of the other fifteen trials.

Give-N-Without-Nouns. This task was the same as Give-N-Apples, except that requests did not include nouns (e.g., "Give him two" instead of "Give him two apples"). The follow-up question also excluded the noun (e.g., "Is that two?") The objects used for this task were small rubber fish in orange, purple, and green (a different color for each block of trials).

Results and Discussion

Because this was a within-subjects comparison, the English and Russian groups were merged for analysis. However, a separate analysis comparing the groups found that they did not differ on any measure, including mean age of children, \( t(37) = 1.58, p = .13, \text{NS} \); mean score on Give-N-Apples, \( t(37) = .33, p = .75, \text{NS} \); distribution of scores on Give-N-Apples, \( Z = .13, p = \).
.90, NS; mean score on Give-N, t(37) = .12, p = .90, NS; distribution of scores on Give-N, Z = .16, p = .87, NS; mean score on Counting, t(35) = .45, p = .66, NS; or distribution of scores on Counting, Z = .59, p = .55, NS.

*No online effect of singular/plural marking.* Most children received the same score on both versions of the task (Give-N-Apples and Give-N-Without-Nouns), Cohen's Kappa = .66, p < .001; there were no order effects. The distribution of scores on the two tasks is given in Table 2. Most scores fell on the diagonal, meaning that most children succeeded and failed at the same number words with nouns as they did without nouns. There was no evidence that children inferred the number requested (1 versus >1) from the noun inflections. If they had done so, they should distinguish between one and many objects on the Give-N-Apples version of the task, but not on the Give-N-Without-Nouns version. That is, many children's scores should fall into the heavily outlined box in Table 2. In fact, only three children showed this pattern, and two children showed the opposite: They distinguished one from many on Give-N-Without-Nouns, but not on Give-N-Apples. Overall, then, it appears that children's performance on the Give-N task reflects knowledge about the meanings of number words themselves, not just about the meanings of noun inflections.

*Replication of earlier findings.* The proportions of children knowing 'one,' 'two,' and 'three' (on Give-N-Apples) were similar to those of English and Russian learners in first study. Of the 21 English speakers, 18 children (86%) gave one item upon request; 11 children (53%) gave two items; 8 children (38%) gave three. Of the 15 Russian speakers, 14 children (93%) gave one; 11 children (73%) gave two; 5 children (33%) gave three.

On the Counting task, English learners' scores were slightly higher than in the first study (mean 5.25 objects counted): Russian learners' counting scores were significantly higher (mean
From Grammatical Number

5.00 objects counted). We take this to be additional evidence of the independence of counting skill from cardinal number-word knowledge: the St. Petersburg and Boston Russian groups differed in counting skill (presumably the result of different child-care practices in the two communities), but their Give-N scores did not differ.

As in the original study, two-knowers gave significantly fewer objects for 'three' than for high number words—in this case, 'five' and 'ten,' \( t(9) = 3.16, p < .05 \). This replicates the finding that many two-knowers are in the process of working out the meaning of 'three' (see above.) The follow-up study included only three Russian one-knowers, none of whom gave fewer objects for low-number requests than for high-number requests, on either version of the task.

General Discussion

Several decades of research have yielded a remarkably detailed picture of how number words are learned and number concepts develop. The most complete accounts to date (Carey, 2004; Carey & Sarnecka, in press; Spelke & Tsivkin, 2001; Spelke, 2003), which build on many earlier accounts, argue that children learn the cardinal meanings of the words 'one,' 'two,' and 'three' before constructing the representational system that can represent positive integers such as 5 and 6. In fact, part of the information children use to construct this representational system is the knowledge that 'one' means 1, 'two' means 2, and 'three' means 3.

These accounts beg the question: If children don't initially understand 'one,' 'two,' and 'three' to mean positive integers (because children do not yet represent positive integers as such), then how do they initially assign meanings to these words?

The present study argues that children assign these words the meanings of grammatical number categories. That is, when children learn 'one,' they behave as though it means singular and all other number words mean plural. When they learn 'two,' they treat it like a dual marker,
but all higher words still mean *plural*. The same is true after children learn 'three'—each number word is taken to mean *singular, dual, trial, or plural*.

This is different from how the positive-integer meanings of 'five' and 'six' are assigned, after the child induces the successor function. When the child first represents 6 as the meaning of 'six,' she already sees 6 as a positive integer—an exact, whole number generated by the successor function (N, N+1, [N+1]+1, . . . etc.) And because she has grasped the successor function, she understands why the final number word uttered in counting tells the cardinality of the whole set (the cardinal principle). In other words, she knows what numbers are. This was not the case when she learned 'one,' 'two,' and 'three.'

A prediction of this account is that children who are learning languages with frequent singular/plural marking will assign the meaning *singular* to 'one' and *plural* to other number words sooner than children learning languages without singular/plural marking. And indeed, the present study found that the proportion of children giving 1 item for 'one' and >1 item for other number words was higher in the English and Russian groups than in the Japanese group.

A related prediction is that singular/plural marking, by helping children assign meanings of *singular* and *plural* to the number words earlier, will give children a head start on the next steps, which are to assign 'two' the meaning of *dual* and 'three' the meaning of *trial*, both still in opposition to *plural* as opposed to higher exact numbers. In grammatical number systems, each distinction builds on the distinction before it. Hence, Greenburg (1963) observed that no language has a trial unless it has a dual; and no language has a dual unless it has singular/plural. If children learn 'one,' 'two,' and 'three' as though they were successively more elaborate grammatical number systems, then the order of learning is not accidental—each step is actually a prerequisite for the next. So making the singular/plural distinction earlier could actually help
children on the way to the dual and trial distinctions as well. And indeed, the present study found that the proportion of children distinguishing 2 and 3 was higher in the English and Russian groups than in the Japanese group.

A follow-up study compared children's performance on two versions of the Give-N task: One with nouns ("give me two apples") the other without nouns ("give me two"). No differences were found, suggesting that the effect of singular/plural marking on number-word understanding is not limited to sentences where number words and singular/plural inflections actually co-occur, but is a more general effect.

To check for differences in number-word input across languages, the present study also included several analyses of CHILDES data in each language. These analyses found that number words were used in largely the same ways across languages, and were used as often in Japanese as in Russian, although frequencies were highest in English. Thus, the Give-N results do not seem attributable to number words being used differently or less often in Japanese.

CHILDES data were also used to check the variability of number-word input (i.e., the variety of different number-word forms heard by children.) Variability was lowest in English, highest in Russian and Japanese, but the variation in Russian and Japanese was of different types. Russian words have different endings (case and gender inflections) but Japanese has two different root forms of each word, and the Japanese input is quite evenly divided between the two root forms.

Thus, a possible alternative explanation for the Give-N findings is that number words take longer to learn in Japanese because there are two number-word lists. However, several preliminary studies with Mandarin Chinese speakers (Huang, 2005; Le Corre, Li, & Jia, 2003; Li et al., 2003) have found the same pattern as the present study finds for Japanese speakers—
significantly fewer children knowing 'one' than in age-matched English groups. This is true even though Mandarin has only one number-word list.

*Could singular/plural marking help children learn number-word meanings even if positive-integer concepts are not constructed?*

Observing the co-occurrence of number words with singular/plural inflections could help children infer something about the meaning of ‘one’ regardless of whether integer concepts are constructed or simply labeled. But co-occurrence with plurality marking could not help children learn the meaning of ‘two’ or ‘three,’ so the present findings seem most compatible with a constructivist view. Indeed, if positive-integer concepts were already present and just needed labeling, then it isn't obvious why children who had mapped ‘one’ to 1 would take several months more to map two to 2, and yet more time to map ‘three’ to 3. After all, children already know the words ‘two’ and ‘three,’ use them in counting and even as cardinal quantifiers contrasting with ‘one.’ So, if learning the word meanings were merely a problem of identifying which part of the conceptual space to label (i.e., the positive integers), then after ‘one’ had been mapped to 1, it should be possible to 'fast map' the other number words to the other positive-integer concepts. Indeed, such fast mapping is exactly what happens later on, with higher number-word meanings such as 5 and 6, after children induce the successor function and cardinal principle.

*Where do these results fit in with previous comparisons of American to East Asian children?*

Previous studies have taken advantage of the fact that the number-word lists of Chinese, Japanese, and Korean make base-10 structure relatively transparent (e.g., 11 is literally called ‘ten-one’). These studies have shown an advantage for East Asian-language speakers, not only in counting (Miller & Stigler, 1987; Miller et al., 1995), but also on arithmetic tasks that require an
understanding of place value (Fuson & Kwon, 1992a; Fuson & Kwon, 1992b; Miura, 1987; Miura, Kim, Chang, & Okamoto, 1988; Miura & Okamoto, 1989; Miura, Okamoto, Kim, Steere, & Fayol, 1993) Although the present study finds a disadvantage (rather than an advantage) for speakers of the East Asian language, the theoretical point is the same: Idiosyncrasies of the language environment affect how numbers are learned are represented. This is important, not because it implies any long-term differences in mathematical ability, but because it demonstrates that numbers are fundamentally linguistic objects.

Future directions

The present study finds differences in number-word learning among speakers of Russian and English on the one hand, and speakers of Japanese on the other. We interpret these results in terms of the presence or absence of grammatical-number marking in these languages—an interpretation that is supported by similar (although preliminary) findings with Mandarin speakers: Like Japanese, Mandarin lacks singular/plural marking—but Mandarin has only one number-word list.

Just as Mandarin data allow us to separate the variable of singular/plural marking from the variable of multiple number-word lists, additional studies with other languages would allow us to formulate the grammatical-number hypothesis more narrowly. For example, are some types of grammatical number marking (e.g., noun inflections versus verb agreement) more important than others? What role, if any, is played by non-number-word quantifiers like the English "some" and "many"?

Data from younger speakers of the languages included in the present study would also round out the picture. For example, a further test of the grammatical-number hypothesis could be done by comparing the ages at which English and Russian speakers learn the cardinal meaning of
'one.' (In the present study, nearly all the children in the English and Russian groups already knew the meaning of 'one'.) The grammatical-number hypothesis would predict either that both groups learn 'one' at the same time (because both languages have singular/plural marking), or that Russian speakers learn 'one' earlier (because singular/plural marking is actually somewhat more frequent in Russian than in English). The associative mapping hypothesis would predict that English speakers should learn 'one' first, both because the frequency of ‘one’ in English is higher than in Russian, and because the Russian input is more variable (including the forms raz, odin, odna, etc.).

In the meantime, we think that the present findings support a constructivist view of number development. Although human infants and nonhuman animals share preverbal systems capable of representing some numerical content, they cannot represent exact, whole numbers above 3 or 4 without adopting (or inventing) some set of symbols for the purpose. A few brilliant people in history invented new symbols; a few language-impaired people today manage to do it with Arabic numerals; but for normally-developing children, the set of symbols pressed into use for the mental representation of positive integers are the number words of their native language. When we observe the process of children assigning increasingly sophisticated meanings to the number words, we are observing how language is used in the construction of the number concepts themselves.
References


## Appendix

### CHILDES Study: Frequencies and Contexts of Number-Word Use

<table>
<thead>
<tr>
<th>Number Language (total words)</th>
<th>Context</th>
<th>Tokens</th>
<th>Frequency (per million words)</th>
<th>Percent</th>
</tr>
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<tbody>
<tr>
<td>ONE English (474,391)</td>
<td>cardinal</td>
<td>3,748</td>
<td>7,900.66</td>
<td>87.70%</td>
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<tr>
<td></td>
<td>counting</td>
<td>243</td>
<td>512.24</td>
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<td></td>
<td>adjectival</td>
<td>1</td>
<td>2.11</td>
<td>0.00%</td>
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<td></td>
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<td>14</td>
<td>29.51</td>
<td>0.30%</td>
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<td></td>
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<td>53</td>
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<tr>
<td></td>
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<td></td>
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<td>65.35</td>
<td>0.70%</td>
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<td>unclear</td>
<td>17</td>
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<td><strong>TOTAL</strong></td>
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<td>Russian (29,769)</td>
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<td><strong>TOTAL</strong></td>
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<td>37</td>
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<td>Context</td>
<td>Tokens</td>
<td>Frequency (per million words)</td>
</tr>
<tr>
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<tr>
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<tr>
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<td>Measure</td>
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<tr>
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<td></td>
<td>Ordinal</td>
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<td>27.20</td>
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<td>Frequency (per million words)</td>
<td>Percent</td>
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<td>----------------</td>
<td>-----------------------------</td>
<td>---------</td>
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<td>Unclear</td>
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<td>1.50%</td>
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<tr>
<td>TOTAL</td>
<td>274</td>
<td>931.60</td>
<td>100.00%</td>
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</tbody>
</table>
Author Note

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Correspondence concerning this article should be addressed to Barbara Sarnecka at sarnecka@uci.edu, or at the Department of Cognitive Sciences, 3151 Social Sciences Plaza, University of California, Irvine, CA 92697-5100.
Footnotes

1Double quotation marks are used here to enclose actual English words; single quotation marks indicate the English word as well as its equivalents in other languages (‘two’ means the English word “two,” the Russian words dva, dve, dvumia, etc., the Japanese words futa- and ni, etc.). Arabic numerals (e.g., 2) are used to indicate numerosities when the spelled-out word might be ambiguous.

2Equal variances were not assumed for any measure.
Figure Captions

*Figure 1.* Frequencies and contexts of number-word use. Y-axis values represent tokens per million words of speech.

*Figure 2.* Forms of number words appearing in cardinal and counting contexts.

*Figure 3.* Counting and Give-N scores, by language group.

*Figure 4.* Proportions of children who knew the cardinal meanings of ‘one,’ ‘two,’ and ‘three.’
Table 1

Examples of Number-Word Contexts

<table>
<thead>
<tr>
<th>Context</th>
<th>Example(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardinal</td>
<td>• Two mean mans and one mean lady. (Naomi83, Line 650)</td>
</tr>
<tr>
<td></td>
<td>• This is the one Ernie gave her. (Sarah019, Line 72)</td>
</tr>
<tr>
<td></td>
<td>• I draw a picture once. (Adam26, Line 680)</td>
</tr>
<tr>
<td>Counting</td>
<td>• I knock them all down one two three four five six seven five ten five</td>
</tr>
<tr>
<td></td>
<td>• they are all laying down they all taking a nap. (Abe046, Line 109)</td>
</tr>
<tr>
<td>Label</td>
<td>• No, this is channel two. (Adam32, Line 1101)</td>
</tr>
<tr>
<td>Ordinal</td>
<td>• If you can't find it on the first line, then look on the second line.</td>
</tr>
<tr>
<td></td>
<td>(Adam27, Line 502)</td>
</tr>
<tr>
<td>Measure</td>
<td>• For doing something naughty he had to sit on the steps for two minutes. (Adam09, Line 1538)</td>
</tr>
<tr>
<td></td>
<td>• Because you're two years old? (Naomi77, Line 407)</td>
</tr>
<tr>
<td>Written</td>
<td>• Look when this long hand gets between the one and the two, that's when</td>
</tr>
<tr>
<td></td>
<td>• we'll eat. (Abe098, Line 214)</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
</tr>
<tr>
<td>(Adjectival)</td>
<td>• That's a double one. (Sarah063, Line 258)</td>
</tr>
<tr>
<td>(Integer)</td>
<td>• How much is two times two? (Naomi68, Line 1063)</td>
</tr>
<tr>
<td>(Metalinguistic)</td>
<td>• That spells one? (Adam21, Line 121)</td>
</tr>
<tr>
<td>(Nominal)</td>
<td>• Gruesome twosome, gruesome what? (Sarah067, Line 298)</td>
</tr>
<tr>
<td>(Unclear)</td>
<td>• No, sir, one nineteen clock, I not (s)paghetti. (Adam15, Line 1456)</td>
</tr>
</tbody>
</table>
Table 2

Comparison of Give-N-Apples Versus Give-N-Without-Nouns

<table>
<thead>
<tr>
<th>Give-N-Without-Nouns</th>
<th>Ten</th>
<th>Five</th>
<th>Four</th>
<th>Three</th>
<th>Two</th>
<th>One</th>
</tr>
</thead>
<tbody>
<tr>
<td>(none)</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>One</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>Two</td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Three</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Four</td>
<td></td>
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<td>1</td>
<td></td>
</tr>
<tr>
<td>Five</td>
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<td>1</td>
</tr>
<tr>
<td>Ten</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

Note. Values in cells represent numbers of children receiving each combination of scores. Blank cells indicate that no child received that combination of scores.
Figure 1 Frequencies & Contexts

- **ONE**
  - English: 7,500 (All other contexts), 5,000 (Counting), 0 (Cardinal)
  - Russian: 250 (Counting), 500 (Cardinal)
  - Japanese: 2,500 (All other contexts), 5,000 (Counting), 7,500 (Cardinal)

- **TWO**
  - English: 3,000 (All other contexts), 2,000 (Counting), 1,000 (Cardinal)
  - Russian: 0 (Counting), 250 (Cardinal)
  - Japanese: 0 (Counting), 250 (Cardinal)

- **THREE**
  - English: 1,000 (All other contexts), 750 (Counting), 500 (Cardinal)
  - Russian: 0 (Counting), 750 (Cardinal)
  - Japanese: 0 (Counting), 750 (Cardinal)
Figure 2 Forms of NWs
Figure 3 Count vs Give-N

<table>
<thead>
<tr>
<th>Language</th>
<th>Counting Score (n = 68)</th>
<th>Give-N Score (n = 29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>4.79</td>
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</tr>
<tr>
<td>Russian</td>
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<td>0.94</td>
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<tr>
<td>Japanese</td>
<td>4.43</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Objects counted or given

mean Counting score
mean Give-N score
Figure 4: % Giving 1, 2, and 3

- **Children giving 1 for 'one'**
  - English: 94%
  - Russian: 98%
  - Japanese: 54%

- **Children giving 2 for 'two'**
  - English: 57%
  - Russian: 52%
  - Japanese: 21%

- **Children giving 3 for 'three'**
  - English: 39%
  - Russian: 27%
  - Japanese: 10%