Published in final edited form as:
Cogn Psychol. 2007 September ; 55(2): 136–168. doi:10.1016/j.cogpsych.2006.09.001.

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

Barbara W. Sarnecka,
University of California, Irvine

Valentina G. Kamenskaya,
Herzen State Pedagogical University of Russia

Yuko Yamana,
Akita University, Japan

Tamiko Ogura, and
Kobe University, Japan

Yulia. B. Yudovina
University of Amsterdam, The Netherlands

Abstract

This study examined whether singular/plural marking in a language helps children learn the 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 young children in the USA, Russia, and Japan were tested on Counting and Give-N tasks. More English and Russian learners knew the meaning of each number word than Japanese learners, regardless of whether singular/plural cues appeared in the task itself (e.g., “Give two apples” vs. “Give two”). These results suggest that the learning of “one,” “two” and “three” is supported by the conceptual framework of grammatical number, rather than that of integers.

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”[1] as a marker of plurality. In other words, he used it to mean any set size greater than one, rather than using it to mean exactly two. Ben was not alone in this error—it is common for young children not only to say “two” to describe set sizes larger than

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..
Barbara W. Sarnecka, Department of Cognitive Sciences, University of California at Irvine; Valentina G. Kamenskaya, Institute of Childhood, Herzen State Pedagogical University of Russia; Yuko Yamana, Kobe Gakuin University, Japan; Tamiko Ogura, Faculty of Letters, Kobe University, Japan; Yulia B. Yudovina, Faculty of Humanities, University of Amsterdam, The Netherlands.

[2]Equal variances were not assumed for any measure.

[1]Throughout this paper, double quotation marks are used 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.

two, but also to give two items when they are asked for any higher number word (Le Corre, Li, & Jia, 2003;Le Corre & Carey, in press; see also Mix, Sandhofer, & Baroody, 2005, pp. 330-331). But English-speaking adults don't use “two” as a general marker of plurality; we wouldn't call five planes “two,” nor would we give two items when asked for “five.” So why do children?

This paper explores the possibility that children first assign quantitative 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., members of the indefinitely long series of exact, whole numbers related by the successor function). 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 set-size meanings to ‘one,’ ‘two,’ and ‘three’ earlier than children learning a language without singular/plural marking (i.e., Japanese). We also compare children's counting skill, and we analyze CHILDES data from all three languages to ask (A) how often children in each language hear the words “one,” “two,” and “three,” (B) how variable the forms of “one,” “two,” and “three” are in each language, and (C) *how* (i.e., in what contexts) the words “one,” “two,” and “three” are used in each language.

Learning Number-Word Meanings

Children hear number words used in various ways. For example, the word “two” sometimes occurs in a list, among other number words (“one, *two*, three, …” etc.); at other times it occurs in sentences, where it may be the only number word (e.g., “you can have *two* cookies”). It has been suggested that children initially treat these contexts as separate—almost as if the words were homonyms (Fuson, 1988,1992). Children learn to recite the number list up to “five” or higher (Baroody & Price, 1983; Fuson, 1988; Miller, Smith, Zhu, & Zhang, 1995; Miller & Stigler, 1987), and to point to one object with each word, without understanding how counting reveals the number of objects in the set (Baroody, 1992, 1993; Baroody & Ginsburg, 1986; Briars & Siegler, 1984; Fuson, 1988, 1992, Le Corre, Van de Walle, Brannon, & Carey, 2006; Rittle-Johnson & Siegler, 1998; Schaeffer, Eggleston, & Scott, 1974; Siegler, 1991; Sophian, 1987; Wagner & Walters, 1982; Wynn, 1990, 1992).

Separately from learning to recite the number-word list, children learn to use the words “one,” “two,” and “three” in sentences, as 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.” This was shown in a longitudinal study by Wynn (1992) and has been supported by cross-sectional studies (e.g., Condry, Cayton, & Spelke, 2002; Condry, Gramzow, & Cayton, 2003; Condry, Spelke, & Xu, 2000; Le Corre, Van de Walle, Brannon, & Carey, 2006; Le Corre & Carey, in press; Sarnecka & Gelman 2004; Schaeffer et al., 1974).

The developmental progression looks like this: Children first learn (by age 2-1/2 or so) that “one” means one and that all other number words mean something more than one. At this point they can be called *one-knowers*. Next (often around age 3 to 3-1/2) they learn that “two” means two and that all higher number words mean something more than two. At this point they can be called *two-knowers*. By age 3-1/2 to 4, most children are *three-knowers*, meaning that they know the appropriate set sizes for “one,” “two,” and “three”, but still not for any higher number words.

This pattern is evident when children are asked to construct sets of a given size (the ‘Give-N’ or ‘Give-A-Number’ task, Wynn, 1990, 1992; see also Fuson, 1988; Sarnecka & Gelman, 2004; Schaeffer et al., 1974); to tell how many objects are in a picture (the ‘What's-On-This-Card’ task, proposed by Gelman, 1993; used by Le Corre & Carey, in press; Le Corre et al., 2006); or to point to a given number of objects (the ‘Point-to-X’ task, Wynn, 1992).

Furthermore, studies comparing these tasks (Le Corre et al., 2006; Wynn, 1992) have found that individual children generally display the same level of knowledge, regardless of which task is used to test them (e.g., a two-knower on ‘Give-N’ is also a two-knower on ‘What's-On-This-Card, and on ‘Point-to-X’).

During this period, children may apply a principle of contrast (Clark, 1987) or mutual exclusivity (Markman & Wachtel, 1988) to the higher number words—that is, they seem to know that the different number words contrast with each other (Sarnecka & Gelman, 2004). Whether children understand that number words contrast specifically on the dimension of *number* is a matter of some dispute (see Condry, Cayton, & Spelke, 2002; Condry, Gramzow, & Cayton, 2003; Condry & Spelke, 2006; Condry, Spelke, & Xu, 2000).

In any case, sometime after becoming three-knowers children figure out the ‘cardinal principle’ of counting (Gelman & Gallistel, 1978; Schaeffer et al., 1974). That is, they 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 this cardinal principle (e.g., Fuson, 1988; Klahr & Wallace, 1976; Le Corre et al., 2006; Rittle-Johnson & Siegler, 1998; Siegler, 1991; Sophian, 1997) and it seems clear that the induction requires children to integrate the separate contexts (i.e., counting context and quantifier context) of “one,” “two,” and “three.” Several recent accounts (Carey, 2004; Carey & Sarnecka, 2006; Spelke, 2003; Spelke & Tsivkin, 2001) 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, generated by the successor function (N, N+1, [N+1]+1, etc.).

According to these accounts, it is only after inducing the cardinal principle of counting (and, by implication, the successor function underlying it) that children can construct adult-like meanings (that is, positive-integer meanings) for high number words like “five” and “six.” This is true because children have no way of mentally representing precise, large set sizes like five and six without the linguistic symbols for them. 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.

This presents a paradox. For adults, who have concepts for positive integers and the successor function that generates them, “one,” “two,” and “three” are understood to be positive integers, related by the successor function (“three” is one more than “two;” “two” is one more than “one.”) But for children, who do not yet understand the successor function and thus cannot use it to construct a series of positive-integer concepts, “one,” “two,” and “three” cannot be understood within the framework of the positive integers. How then are “one,” “two,” and “three” understood? What is the conceptual framework within which these words can have meaning?

This question is relevant not only for the Carey and Spelke accounts cited above, but for any account proposing that children construct number concepts in the process of learning number-word meanings (see, e.g., Baroody, Lai, & Mix, in press; Mix, Sandhofer, & Baroody, 2005).

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, at each level of knowledge, interpret all higher number words to mean *plural*. This only ends when children induce the cardinal principle of counting (and with it, the successor function) by around age four years.

The idea that “one,” “two,” and “three” are learned as markers of grammatical number categories is plausible for several reasons. First, there is a strong linguistic connection between the word for 1 and the singular indefinite determiner (e.g., *a[n]*). In many languages (e.g., French), 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, there is the order of acquisition. Recall that children first learn the exact meaning of "one," then "two," and then "three." 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 truism about grammatical number systems 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. In the same way, it may be that no child has a concept of *three* without also having a concept of *two*, and that no child has a concept of *two* without also having a concept of *one*.

Third, the early distinctions of meaning assigned to "one," "two," "three," and higher number words are the same distinctions that structure the grammars of human languages. Oneknowers treat "one" and other number words as marking *singular* and *plural*. Two-knowers treat "one," "two" and other number words as marking *singular*, *dual*, and *plural*, mimicking the three-way distinction found, for example, in Upper Sorbian (Corbett, 2000). Three-knowers observe a four-way, singular/dual/trial/plural distinction, as is found in Larike grammar (Corbett, 2000).

The observation that children assign larger number words the meaning *plural* is not a trivial one. There are other meanings children could assign. They could, for example, decide that higher number words like "six" are relative terms like *a lot*, such that a huge pile of objects would be considered a better example of "six" than just a handful of objects-- but they don't (Sarnecka & Gelman, 2004). Similarly, children could decide that higher number words denote large, approximate numerosities—something like *ten-ish*, covering set sizes of approximately six to 14. But in fact, children who have not yet induced the cardinal principle don't demonstrate even a vague understanding that number words coming later in the list (e.g., "ten"), denote larger set sizes than earlier number words (e.g., "five").

What the grammatical number view predicts for other languages—If early meanings for "one," "two," and "three" do indeed come from the conceptual framework of grammatical number, then children learning languages with frequent grammatical number marking should learn these meanings earlier, because a child who has learned the meaning of singular/plural marking on nouns, pronouns, verbs, etc. already has explicit mental representations of singular and plural. (Perhaps not explicit in the sense that the child could describe them to us, but explicit in the sense that they are linguistically encoded.) Thus, when the child is considering possible meanings for the word "one," and other number words, the meanings *singular* and *plural* are readily available as candidates for hypothesis testing. Children who speak non-singular/plural languages may take much longer to come up with these candidate meanings. And because "two" builds on "one" and "three" builds on "two," children who learn "one" earlier should learn "two" and "three" earlier as well.

An Alternative Possibility: Associative Mapping of Words to Pre-Existing Number Concepts

An alternative to the grammatical number view is that children have concepts for the integers 1, 2, and 3 before learning the words for them. If so, then number-word learning would be a matter of forming associations between the pre-existing concepts *1*, *2*, and *3* and the words 'one,' 'two,' and 'three.' If number concepts precede number words, then there is no theoretical problem with children learning the exact meanings of ‘one,’ ‘two,’ and ‘three’ before they induce the successor function. And the fact that children learn ‘one,’ before ‘two’ and ‘two’ before ‘three’ still makes sense, because the word ‘one’ is used more often than ‘two,’ and ‘two’ more often than ‘three,’ across languages (Dehaene & Mehler, 1992).

Broadly, there are two accounts positing preverbal integer concepts that could be associatively mapped to number words. On one account, the number words are mapped to mental magnitudes generated by a nonverbal counting process (see Gallistel & Gelman, 2005, for review), and it is the homomorphism between this process and verbal counting that allows children recognize the number words for what they are (Gelman & Brenneman, 1994; Gelman & Cordes, 2001; Gelman & Williams, 1998). If this account is correct, then from a child's point of view, hearing number words used in *counting* contexts is probably the key to learning their meanings. Furthermore, the more skilled a child is at counting, the more number-word meanings she should know.

The other account proposing that children may have exact-number concepts (at least for small numbers) before learning the meanings of number words is the ‘mental models’ account (Baroody, Lai, & Mix, in press; Huttenlocher, Jordan, & Levine, 1994; Mix, Huttenlocher, & Levine, 2002; Mix et al., 2005). According to this account, infants do not have exact-number representations, but young children do develop the ability to represent the exact numerosity of small sets via mental models. The mental model consists of symbols that can be assigned sequentially, moved through mental space, added, or subtracted. Although the mental models accounts do not make specific predictions about how the linguistic environment should affect children's learning of the exact meanings of ‘one,’ ‘two,’ and ‘three,’ these accounts could, in principle, be compatible with an associative mapping story (e.g., “the mental model for a set … [might] provide an entity that could be labeled,” Mix et al., 2002)

What an associative mapping account would predict for other languages— Associative mapping views predict no differences in number-word learning across languages, provided there are no differences in number-word input. Any cross-linguistic differences in learning the exact meanings of ‘one,’ ‘two,’ and ‘three’ should be attributable to differences in frequency (children who hear the words used more often should learn them faster); differences in the variability of number-word forms (children who hear many different forms of a number word might take time to recognize all the different forms as a single word); or differences in contexts of use (e.g., children who hear number words used mostly as quantifiers might learn their meanings sooner than children who hear the words mostly in non-quantificational contexts, such as in telephone numbers.)

This is particularly true for the words ‘two’ and ‘three.’ The co-occurrence of ‘one’ with singular forms in some languages (e.g., *one girl says she will go* vs. *two girls say they will go)* could, on an associative mapping story, help children learn the meaning of ‘one.’ However, singular/plural marking does nothing to help children distinguish between ‘two’ and ‘three’ (e.g., *two girls say they will go* vs. *three girls say they will go*). So singular/plural marking cannot help children learn these words. Also, there is no reason (on an associative mapping story) that number-word meanings would necessarily have to be learned in order. The concepts for the integers one, two, and three are all available beforehand, so there is no sense in which *three* builds on *two*, or *two* builds on *one*, and no reason that the word ‘two’ or ‘three’ could not, in principle, be learned first.

The Present Study

The present study looks at number-word input (via CHILDES corpora) and number-word knowledge (via controlled laboratory tasks) in young children learning English, Russian, or Japanese. Japanese is included in order to provide a contrast on the dimension of singular/plural

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marking-- English and Russian have frequent singular/plural marking; Japanese does not. Russian is included so that the effects of singular/plural marking can be examined separately from the frequency of 'one.' Russian (like Japanese) uses the word 'one' only in explicitly numerical contexts such as counting and quantificational phrases, (e.g., *That will be one dollar and ten cents*). In English, the word "one" also appears in deictic and anaphoric uses of the indefinite determiner *a(n)* (e.g., *This paper is a fascinating one*.) Thus, 'one' occurs more frequently in English than in Russian or Japanese.

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, Yang, & Carey, in press; Kouider, Halberda, Wood, & Carey, 2006). Studies of productive speech find that children also produce plural marking on nouns by around their second birthday (Brown, 1973; Cazden, 1968; Mervis & Johnson, 1991). Norms provided by the MacArthur Communicative Development Inventory (MCDI; Fenson et al., 1994) indicate that 25% of children produce singular/plural morphology by age 18 months; 50% produce it by age 22 months; and 75% produce it by 25 months.

Russian-learning children also understand and produce singular/plural marking before age two. Leushina (1974/1991) reported that 15-month-olds are sensitive to plurality marking on nouns (e.g., when asked to build "a little house" versus "little houses" or to bring ";a car" versus "cars") and that 18-month-olds produce singular and plural nouns and pronouns in appropriate contexts. 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.

The relatively rare plurality marking of Japanese is not among the linguistic competencies mastered in early childhood (Downing, 1996; see also Ogura & Watamaki, 2004; Watamaki & Ogura, 2004).

Number words—In Russian, there are two words for one: *Raz* is the word used in counting, whereas *odin* and its variants are used as cardinal quantifiers. The word *odin* 'one,' is inflected for case, gender, and even number -- there are four *plural* forms of *odin* (*odni*, *odnikh, odnim,* and *odnimi*) which are used with nouns that cannot occur in the singular, e.g., *odni ochki* 'one pair of glasses.' The words for two and three are also inflected for case and gender, resulting in multiple forms of each number word.

In Japanese, there are two number-word lists. The indigenous Japanese ('IJ') number-word list is made up of bound morphemes (prefixes) that must be attached to a classifier noun. (In other words, there is no way to just say 'two' with this list – you must say 'two things.') The IJ list only goes up to ten. The Sino-Japanese ('SJ') number words are so named because they were among the many Chinese words which were imported into Japanese several centuries ago, and which now make up a significant proportion of the Japanese vocabulary (in much the same way that words of Norman French origin make up a significant proportion of modern English vocabulary). These are stand-alone words that continue beyond ten (analogous to the English list "one," "two," "three," … etc.) There is no clear preference for the use of one list over the other in childhood -- individual children may show a preference for either list, or may use both lists interchangeably (Matsumoto, 1984; 1987; 1993; Naka, 1999; Sanches, 1977).

Previous comparisons of older children in the USA and East Asia (e.g., Fuson & Kwon, 1992a; Fuson & Kwon, 1992b; Miller & Stigler, 1987; Miller et al., 1995; Miura, 1987; Miura, Kim, Chang, & Okamoto, 1988; Miura & Okamoto, 1989; Miura, Okamoto, Kim, Steere, & Fayol, 1993) have found that Japanese, Chinese, and Korean speakers actually have an

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advantage over English speakers, because these languages make the base-10 structure of the number system relatively transparent (e.g., 11 is called ‘ten-one,’ 12 is called ‘ten-two,’ 24 is called ‘two-ten-four,’ etc.). For example, 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 even though four-year-old Japanese speakers outperform English speakers in reciting the number-word list, two- and three-year-old Japanese speakers should actually lag behind English and Russian speakers in learning the set-size meanings of ‘one,’ ‘two,’ and ‘three,’ because Japanese lacks singular/plural marking.

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., “just a second,” “wait a second,” etc.). 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,’ *odn*o ‘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 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(kan), mai, nin, and tsu. All classifier phrases returned by the computerized search were included in the analysis. Two coders checked the instances of SJ words 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 (the first author). 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, indicating whether it was used in counting (e.g., “One, two, three, four … ”), as a quantifier in a sentence (e.g., “Give me two of those”), as a unique identifier (e.g., a telephone number) and so on. A complete list of contexts, with examples of each, appears in Table 1. Coders read the entire utterance in which the word appeared, plus as many utterances before and after it as needed. 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, *p*s < .001.

Results and Discussion

Frequency of singular/plural marking—Singular/plural marking is not impossible in Japanese; merely uncommon. Also, 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 confirm this, 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 rate is higher in Russian than English because only Russian marks plurality on second-person pronouns (*ty* ‘you, informal/singular’ vs. *vy* ‘you, formal/plural’) and second person verbs, including questions and imperatives such as ‘(you) come here’ and ‘what are (you) doing?’

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.’ 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, 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 (for which Japanese occupies a middle ground, between English and Russian.)

Contexts of number-word use—Fuson (1988) discussed the contexts in which number words can appear, but to our knowledge this is the first study to ask how often number words are actually used in each context. Figure 1 shows the tokens of ‘one,’ ‘two,’ and ‘three’ used in cardinal contexts (diagonal lines), counting contexts (solid white), and other contexts (solid black). 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 indicate that number words 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. It is unclear how variability in number-word forms affects number-word learning, nor is it clear whether different types of variability (from a linguistic point of view) should have different effects. 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.’ (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. 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 initial sound of the next word.

What is clear is that number-word forms 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.)

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., Ukranian, 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 or incorrect based on the last number word spoken by the child. For example, a trial with a five-item array was scored correct if the child gave any of the following responses:

- “One, two, three, four, five.”
- “One, two, three, four, five. Five.”
- “One, two, …” (silently points to third and fourth objects) “… five.”
- “Onetwothreefourfive” (Waving hand vaguely toward the array.)
- “Five.”

Correct responses were always accepted. In the case of an incorrect, non-counting response (e.g., “six,” “a lot,” etc.) the child was urged to try again and *count* the objects. The second response was accepted, whether the child counted or not. Children who noticed errors in their own counting (e.g., “Oops,” “I messed up,” etc.) were allowed to start over as many times as they wished. No skipping or double-counting errors were allowed in the scoring– the final number word alone determined the score of correct or incorrect.

Procedure—Give-N task—A puppet and pile of 15 small rubber toys (apples, flowers, eyeballs, soccer balls, or teeth) were 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). For each number word tested, the child received a score of 1 (for success) or 0 (for failure). To succeed, the child had to (a) give the correct number of items on trials requesting that number word, and (b) not give that number of items on trials requesting other number words. One mistake of each type was allowed. For example, a child succeeded at the number ‘two’ if she (a) gave exactly 2 items on trials requesting ‘two’ (one mistake was allowed); *and* (b) did *not* give 2 items on trials requesting other number words (again, one mistake was allowed). Thus, a typical two-knower's responses might look like this (word requested is in italics, Roman numeral represents child's response). *One* (1), *One* (1), *One* (1); *Two* (2), *Two* (3), *Two* (2); *Three* (5), *Three* (6), *Three* (9); *Five* (5), *Five* (9), *Five* (7); *Six* (5), *Six* (6), *Six* (4).

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 thing of flower for me, please?'

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

Are wa futatsu?

'Is that two thing?'

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$_2$ 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.

Quantifier meanings of number words were learned in order—As measured by the Give-N task, children in the present study showed the one-knower, two-knower, three-knower pattern reported by Wynn (1992) and others (e.g., Le Corre, Van de Walle, Brannon, & Carey, 2006; Sarnecka & Gelman, 2004; Schaeffer et al., 1974.). That is, if the child knew the exact meaning of only one number word, that word was 'one.' If the child knew the meanings of only two number words, those words were 'one' and 'two.' If the child knew three number-word meanings, the words were 'one,' 'two,' and 'three.' The proportions of children who fit this pattern were 96%, 93%, and 97% in English, Russian, and Japanese, respectively.

Children counted larger sets than they were able to construct—As Figure 3 illustrates, each group's mean score on the Counting task (white apples) was higher than their mean score on the Give-N task (black apples), 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 objects. This difference was significant, $t(134) = 12.43$, $p < .001$. Separate analyses of each language group showed the same pattern (*p*s < .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 for any group. This supports the claim made by Fuson (1988, 1992) and others, that the counting and cardinal contexts of number words are quite separate for young children. If counting were simply an easier task than Give-N (but a test of the same knowledge) then scores on the two tasks should be correlated, with counting scores being higher. The present data offer no evidence of such a correlation. However, the present data are not sufficient to completely rule out any relation between counting skill and Give-N performance, because they include a ceiling effect—about half the English and Japanese learners, and a quarter of the Russian learners, counted perfectly on the longest array presented. What can be concluded from these data is that (as has been shown previously, see Fuson 1988, 1992), many children use the number words ‘one,’ ‘two,’ ‘three,’ ‘four,’ ‘five,’ and ‘six’ correctly in counting contexts, without being aware of their meanings in cardinal contexts.

Counting scores differed by language—As illustrated in Figure 3, counting scores (white apples) differed significantly among language 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.

Give-N scores 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 who knew the meaning of ‘one’ was higher in English and Russian than in Japanese—As illustrated in Figure 4 (*1*s graph), the proportions of children who gave 1 item upon request, and gave >1 item for all other number words (this included one-knowers, two-knowers, three-knowers, and above) 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. Separate proportions for each knower-level are shown in Figure 5.

The proportion of children giving two items upon request was higher in English and Russian than in Japanese—As illustrated in Figure 4 (*2*s graph), the proportions of children who gave 2 items upon request, and gave >2 items for all other number words (this included two-knowers, three-knowers, and above – a subset of the group represented in the *1*s graph) 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 (*3*s graph), the proportions of children who gave 3 items upon request, and gave >3 items for all other number words (this included only three-knowers and above, a subset of the groups represented in the *1*s and *2*s graphs) 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 these two groups also 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,’ and 4.17 items for ‘five’ and ‘six.’ 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. (For more on gradual transitions between knower-levels, see Baroody et al., in press; Le Corre & Carey, in press; Le Corre et al., 2006; Mix et al., 2005.)

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 (e.g., *one apple*); nouns following ‘two,’ ‘three,’ and ‘four’ receive genitive singular inflection (e.g., two of an apple, three of an apple, four of an apple); nouns following ‘five’ through ‘ten’ receive genitive plural inflection (e.g., *five of apples, six of apples* …). If children partly infer number-word meanings from their 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%). Over half of these non-responses were made by a particular group of children on a particular type of trial -- Russian one-knowers trying to give 'five' or 'six' items. When the rates are calculated separately, we find that Russian one-knowers gave 35 non-responses in the 120 trials asking them for 'five' or 'six' (a rate of 29%), whereas all other children on all other trials gave 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 on 180 trials), indicating that they were not confused or anxious about the task in general.

This hesitancy to respond on high-number trials suggests that Russian one-knowers are at least aware of the different inflections on nouns following low- versus high-number words in Russian (i.e., the *one apple/two of an apple/five of apples* pattern). This provides additional evidence for the grammatical number view, because no such sensitivity to low- versus high-number words has been found in one-knowers who speak other languages (i.e., English, Japanese, or Mandarin—see Huang, 2005; Le Corre & Carey, in press; Li, Le Corre, Shui, Jia, & Carey, 2003; Sarnecka & Gelman, 2004; Wynn, 1992).

Do the English and Russian speakers know what 'one' means, or just what '~s' means?—As reported above, English- and Russian-learners succeed at giving, e.g., 'one apple' versus 'two apples' earlier than Japanese learners do. This could be explained in either of two ways. Either (A) English- and Russian-learners learn the quantifier meaning of 'one' earlier than Japanese learners; or (B) All the children learn the meaning of 'one' at the same time, but English and Russian learners succeed at the Give-N task earlier, because even if they don't know what 'one' means, they can use the plurality marking in the question itself to figure out whether one or more than one thing is being requested. In other words, English- and Russian-learners might hear the requests as 'Give me N apple' versus 'Give me N apple<u>s</u>' whereas Japanese-learners hear every request as 'Give me N apple' versus 'Give me N apple' – the requests are identical because of the lack of plurality marking in Japanese. The follow-up study cleared up this ambiguity.

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

This follow-up study tested English and Russian speakers with and without plurality cues, in order to find out whether 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 never contained plurality marking in the first place.)

Method

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

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

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performs on Give-N-Apples versus Give-N-Without-Nouns. There is no comparison of Russian to English. The Boston sample of Russian learners also differs from the St. Petersburg sample in various ways. Again, this does not matter to the follow-up study because our 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. Unlike in the original study, Give-N-Apples and Give-N-Without Nouns included the words ‘four’ and ‘ten,’ and excluded ‘six.’ (The change in high number words relates to a larger project, of which these data comprised a subset. The change does not relate to the present investigation of ‘one,’ ‘two,’ and ‘three.’)

Give-N-Apples—The Give-N-Apples task was similar to Give-N in the original study, except that whereas the 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*?”). One item was always requested first, then two and three in counterbalanced order; then four; then five and ten 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 (see *Give-N Study / Procedure / Give-N Task*)

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, $t(37) = 1.58$, $p = .13$, NS; mean score on Give-N-Apples, $t(37) = .33$, $p = .75$, 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 achieved 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 the knower-level pattern—As in the original study, children appeared to learn the number words in order, and could be sorted into knower-levels (one-knower, two-knower, three-knower, etc.) Among the 21 English speakers, there were 3 non-number-knowers (14%), 7 one-knowers (33%), 3 two-knowers (14%), and 8 three-knowers and above (38%). Among the 15 Russian speakers, there was 1 non-number-knower (6%), 3 one-knowers (20%), 6 two-knowers (40%), and 5 three-knowers and above (33%).

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 5.00 objects counted). We take this to be additional evidence of the independence of counting skill from cardinal number-word knowledge: Although the St. Petersburg and Boston Russian groups differed markedly in their counting skill, 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 only included three Russian one-knowers. This was too few to test for the singular/paucal/plural pattern (e.g., *one apple / two of an apple / five of apples*) encoded in Russian grammar.

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, 2006; 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. Other accounts have similarly proposed that learning the number words is key to constructing number concepts (e.g., Baroody et al., in press; Mix et al., 2005).

The present study addresses a question raised by all of these accounts, namely: 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 data presented here suggest that the conceptual framework supporting the earliest set-size meanings of ‘one,’ ‘two,’ and ‘three’ are actually that of *grammatical* number. 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 (N, N+1, [N+1]+1, … etc.). Understanding the successor function enables the child to abstract the *rule* for assigning meanings to all of the number words. For example, the meaning of ‘six’ is understood as ‘the number of things you get if you count in the number-word list up to *six*, adding one thing to the set with each word.’ But the meanings of ‘one,’ ‘two,’ and ‘three’ are learned *before* the successor function-- so they must be understood (at least initially) some other way.

The present study began with a series of CHILDES analyses that checked for differences in number-word input across languages. As expected, the frequency of ‘one’ was higher in English, where *one* also occurs as the deictic and anaphoric form of the indefinite determiner *a(n)* (e.g., *I'd like a cookie – give me that big* <u>*one*</u>); the variability of word forms was lower in

English than in Russian or Japanese (e.g., English *two* corresponds to Russian *dva, dve*, and *dvumia*, and to Japanese *futa*- and *ni*); and number words were used in largely the same ways (e.g., counting contexts, cardinal contexts, etc.) across languages.

Next, groups of monolingual two- and three-year-olds in the USA, Russia, and Japan were tested on the Give-N (a.k.a. Give-A-Number) task and on a counting control task, to find out what number-word meanings they knew. A prediction of our grammatical-number 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. Specifically, English and Russian speakers hear the singular/plural distinction marked on most utterances, whereas Japanese speakers receive plurality information quite infrequently—usually in sentences containing either a number word or another quantifier (e.g., *suu* ‘several’ or *takusan* ‘many.’) So Japanese speakers should take longer to form or identify the relevant categories and learn the words' meanings. And indeed, the present study found that the proportion of children who knew that ‘one’ means 1 (including one-knowers, two-knowers, three-knowers, and above) was higher in the English and Russian groups than in the Japanese group. This was true despite the fact that the Japanese speakers were as skilled at counting as the English speakers, and more skilled than the Russian speakers. In other words, the Japanese speakers did not perform poorly in a general way, but only in the specific way predicted by the grammatical number view.

A related prediction was that singular/plural marking, by helping children assign meanings of *singular* and *plural* to the number words earlier, would 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 knowing that ‘two’ means 2 and that ‘three’ means 3 were 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.

What kind of number representations provide the content for early number-word meanings?

Having argued that children assign ‘one,’ ‘two,’ ‘three,’ and higher number words the meanings of singular, dual, trial, and plural, we still face the question of where the quantificational content of these words comes from. In other words, what perceptual or conceptual system yields representations of *singular, dual, trial*, and *plural* that can be adopted as the earliest quantifier meanings for ‘one,’ ‘two,’ and ‘three’?

Could these representations come from the analog magnitude system?—Some researchers have argued that the meanings of ‘one,’ ‘two,’ and ‘three’ are provided, from the very beginning, by the analog magnitude system for number (Gelman & Brenneman, 1994; Gelman & Cordes, 2001; Gelman & Williams, 1998; for general characterizations of the analog magnitude system, see Dehaene, 1997; Feigenson, Dehaene, & Spelke, 2004; Gallistel & Gelman, 2005). This possibility seems least compatible with the present data, because to represent a set as a *plurality* is to ignore its magnitude. Of course a plurality is always more than one, but no other information about magnitude is represented. This is part of the definition of a plurality, along with the fact that pluralities are comprised of discrete individuals, the individuals in the plurality have no particular order, and so forth (Landman, 2000; Link, 1983). This is quite distinct from the approximate-number information yielded by the analog magnitude system.

Furthermore, Le Corre and Carey (in press) have shown that prior to inducing the cardinal principle of counting, children do not assign numerical meanings (even approximate numerical meanings, i.e., magnitudes) to number words higher than “four.” In fact, in Le Corre & Carey's data, children did not appear to connect higher number words with magnitudes until some months *after* inducing the cardinal principle. Before that, children lacked even the vaguest idea that number words coming later in the sequence (e.g., “ten” vs. “five”) denote larger set sizes. It is possible that children connect ‘one,’ ‘two,’ ‘three,’ and ‘four’ with analog magnitudes, but no higher number words. But in that case, the sharp divide between low numbers (1-4) and high numbers (5 and more) becomes an unexplained coincidence. Furthermore, Le Corre and Carey showed that the variability in children's estimates for small set sizes was not scalar (as would be expected if analog magnitude representations underlie the meanings of small number words). Rather, Le Corre and Carey found that the pattern of variability was consistent with the hypothesis that the meanings of small number words are specified by parallel individuation.

Could these representations come from the parallel individuation system?— Some researchers have argued that concepts of oneness, twoness, and threeness are abstracted, wholly or in part, from information given by the parallel individuation system (e.g., Baroody et al., in press; Carey, 2004; Carey & Sarnecka 2006; Leslie, 1999; Mix et al., 2005; Spelke, 2003; Spelke & Tsivkin, 2001; for general characterizations of the parallel individuation system see Feigenson & Carey 2003, 2005; Pylyshyn, 1994; Pylyshyn & Storm, 1998; Treisman, 1998). These accounts are more compatible with the present data than are the analog-magnitude accounts, for two reasons: (1) across languages, only distinctions in the parallel individuation range are grammatically marked; and (2) a main purpose of grammatical number marking is to trace the identities of particular individuals.

First, grammatical number marking is reserved for numerical distinctions in the parallel individuation range (Corbett, 2000; Hurford, 2001). Languages have categories such as singular/plural (1 vs. >1), singular/dual/plural (1 vs. 2 vs. >2), singular/dual/trial/plural (1 vs. 2 vs. 3 vs. >3) or singular/dual/paucal/plural (1 vs. 2 vs. approximately 3-5 vs. >5). Grammars are not built around the approximate, large-number distinctions represented by the analog magnitude system. Thus, whereas many languages have different endings for sets of one individual (e.g., *an apple*) versus more than one (e.g., *apples*), no language has different endings for sets of *approximately 50* versus *approximately 100, give or take 15%*.

Second, across languages, grammatical number marking is used to trace the *identities of particular individuals* across time and space. Consider the case of Japanese, where number marking is relatively rare. When it occurs, it is used most often for anaphoric mentions of human referents. In other words, a group of human beings is introduced in the narrative (initially without number marking), and subsequent references to those *same individuals* are marked for number.

> “The preference for ‘plural marking’ in anaphoric mentions of humans seems to be especially strong with nouns preceded by demonstrative articles, which explicitly mark the fact that the speaker considers the referents to be, not only individuated and specific, but also identifiable to the addressee.” (Downing, 1996, pp. 206)

In the following example, the same men are mentioned three times. Number is not marked when they are first introduced, but is marked on subsequent references. (References to the men are in bold type, number marking on those NPs is underlined.)

> Mention 1: Masutaa-to onaji-yoona katachi-no kitsune-no yoona kao-o motta otoko-ga iku-nin mo suwatte-ita. 'Any number of **men with fox-like faces like the (gas station) owner's** were sitting (there).'
>
> Mention 2: Watashi-tachi shinpei-o ijimeru toki, **kare-ra**-no hosonogai zoo-no yoona me-wa marude bishoo-demo shite-iru yoo data. 'When (they) teased us recruits, **their** beady little eyes seemed to be laughing.'
>
> Mention 3: **Ano otoko-tachi**-mo ima-wa doko-ka-de gasorin-sutando-no shujin-ni natte-iru kamoshirenai. ' **Those men** too are probably gas station owners somewhere now.' (Downing, 1996, p. 207).

It is not only Japanese that uses grammatical number marking to track the identities of individuals. Across languages, number marking is applied in an 'animacy hierarchy' (Corbett, 2000; see also Silverstein, 1976; Smith-Stark, 1974), such that the referents most likely to be marked for number are those referents whose *identities as individuals* matter the most, starting with first-person pronouns (*I* vs. *we*) followed by second-person pronouns (*thee* vs. *you*) and so on. The hierarchy, ordered from most animate (most likely to be marked for number) to least animate (least likely to be marked for number) is as follows: speaker > addressee > 3rd person > kin > human > animate > inanimate (from Corbett, 2000, p. 56.)

In other words, the more individual identity matters, the more grammatical number marking is applied. In some cases, grammatical number marking is used to obscure individual identity for the sake of formality or politeness-- for example, in the use of the 'royal we' by monarchs or in the use of the second-person plural pronoun (Russian *vy*, French *vous*, Spanish *usted*, etc.) to refer politely to singular referents. (In English, the polite form has become the only form, with the familiar *thee* and *thou* having dropped out of common usage.) Thus, grammatical number marking does the same job in language that the parallel individuation system does in perception – it tracks particular individuals (or deliberately fails to track them, when politeness calls for that).

For these reasons, the parallel individuation system seems a more likely source of early number-word meanings than the analog magnitude system. But this raises a different problem: How can the concept of a *plurality* be abstracted from the parallel individuation system? The system contains one symbol for each object being tracked, up to a limit of 3 (for human infants) or 4 (for older humans and monkeys). It contains no summary representation, no description of the set as a whole.

The concepts *singular, dual,* and *trial* could be abstracted from information represented in this system—for example, *dual* is that which is common to all states of the nervous system where an individual and another individual are being tracked. But how could *plural* be abstracted? A plurality can be any set size at all; it doesn't have to be in the parallel individuation range. The parallel individuation system can't represent 200 items, or even 5, but one-knowers apply the word 'two' equally to sets of 2, 5, or 200. Thus, while the parallel individuation seems a more likely source of small-number-word meanings than the analog magnitude system, it does not wholly explain the findings of the present study—namely, that when children take 'one,' 'two,' and 'three' to mean *singular, dual,* and *trial*, they also take all higher number words to mean *a plurality*.

A recently-discovered third option: A nonlinguistic singular/plural distinction— Barner and colleagues (2006) have shown that free-ranging rhesus monkeys and human infants have a (nonverbal, of course) singular/plural distinction. Subjects are able to encode the difference between 1 and 5 items (for monkeys) or 1 and 4 items (for babies) as long as the items in the plurality are (a) clearly individuated (e.g., apples, in the monkey case) and (b) presented all at once, as a set (rather than one at a time.)

Subjects cannot be using their parallel individuation systems to represent this distinction, because in each case the larger set exceeds the limits of parallel individuation for the relevant species (i.e., 3 for human infants and 4 for rhesus monkeys). Nor can they be using the analog magnitude system, because they fail this task when 2 vs. 5 (for monkeys) or 2 vs. 4 (for babies) items are presented. These ratios are well within subjects' ability to discriminate, on tasks where they do deploy the analog magnitude system. The fact that they don't discriminate those ratios in Barner's tasks shows that they are not deploying analog magnitudes to represent the sets. Thus, Barner and colleagues have strong and surprising evidence that monkeys and babies can, under the right conditions, construe a set of individuals as a *plurality* – they represent the difference between a singularity (i.e., a set of 1 individual) and a plurality (i.e., a set of >1 individual) but they do not retain any information about the magnitude of plural sets.

This nonlinguistic singular/plural distinction seems by far the best candidate for the source of the singular/plural distinction that one-knowers assign to ‘one’ versus the other number words. The question in this case becomes, what about ‘two’ and ‘three’? Will researchers eventually find nonverbal representations of *dual* and *trial* that are distinct from the parallel individuation system, analogous to what Barner has found for singular/plural? If so, then these nonverbal *singular/dual/trial/plural* concepts would seem the obvious candidates for the early number-word meanings. Presumably, these would be identical or closely related to the hypothetical ‘mental models’ long discussed by researchers (e.g., Huttenlocher et al., 1994; see also Baroody et al., in press; Mix et al., 2005). In the case that nonverbal concepts of dual and trial do not exist, the most likely explanation would seem to be that children become oneknowers by mapping ‘one’ versus other number words to the singular/plural distinction, and then become two- and three-knowers by abstracting representations of twoness and threeness from states of the parallel individuation system.

Acknowledgements

This research was supported in part by a fellowship from the University of Michigan Culture and Cognition Program to the first author; by NICHD grant HD36043 to Susan Gelman, and by NIH grants RO1 HD038338 and 1T32MH067556-01A1 to Susan Carey. We thank research assistants Anton Babushkin, Candice Chow, Elena Gleikina, Hillary McManama, Mai Takemoto, Miori Ueda, and Sasha Yakhkind for help with data collection and coding. We also thank Nicole Berry, Susan Carey, Summerson Carr, Emily Carrigan, , Andrey Efimov, Ellen Hamilton, Annie Kim, Nicola Knight, Sarah Lopez-Duran Brian Malley, Suzanne Perkins-Hart, Greg Sarnecki, Teddy Sarnecki, Priti Shah, Paulo Sousa, Stephanie Rowley, and Twila Tardif for helpful comments on earlier drafts. Parts of this research were conducted for the first author's doctoral dissertation at the University of Michigan. Thanks are due the dissertation committee: Professor Susan Gelman (chair), and Professors Bruce Mannheim, Marilyn Shatz, and Henry Wellman. Portions of these data were presented at the biennial meeting of the Society for Research in Child Development in April, 2005; at the Boston University Conference on Language Development in October, 2003; and at the annual meeting of the Japanese Educational Psychology Association (*Nihon Kyouiku Shinri Gakkai*) in August, 2003.

Appendix

CHILDES Study: Instances of ‘one,’ ‘two,’ and ‘three’ in each language, by context

Word	Language (total words)	Context	Tokens	Frequency (per million words)	Percent
ONE	English (474,391)	Adjectival	1	2.11	0.00%
		Cardinal	3,748	7,900.66	87.70%

Word	Language (total words)	Context	Tokens	Frequency (per million words)	Percent
		Counting	243	512.24	5.70%
		Identifier	14	29.51	0.30%
		Measure	53	111.72	1.20%
		Metalinguistic	2	4.22	0.00%
		Ordinal	166	349.92	3.90%
		Unclear	17	35.84	0.40%
		Written	31	65.35	0.70%
		TOTAL	4,275	9,011.55	100.00%
	Russian (29,769)	Cardinal	23	772.62	62.20%
		Counting	8	268.74	21.60%
		Ordinal	6	201.55	16.20%
		TOTAL	37	1,242.90	100.00%
	Japanese (294,117)	Cardinal	599	2,036.60	79.50%
		Counting	89	302.60	11.80%
		Ordinal	10	34.00	1.30%
		Measure	11	37.40	1.50%
		Unclear	2	6.80	0.30%
		Written	42	142.80	5.60%
		TOTAL	753	2,560.21	100.00%
TWO	English (474,391)	Adjectival	2	4.22	0.10%
		Cardinal	913	1,924.57	67.30%
		Counting	269	567.04	19.80%
		Identifier	22	46.38	1.60%
		Measure	84	177.07	6.20%
		Nominal	1	2.11	0.10%
		Ordinal	7	14.76	0.50%
		Unclear	34	71.67	2.50%
		Written	24	50.59	1.80%
		TOTAL	1356	2,858.40	100.00%
	Russian (29,769)	Cardinal	20	671.84	66.70%
		Counting	6	201.55	20.00%
		Measure	1	33.59	3.30%
		Ordinal	3	100.78	10.00%
		TOTAL	30	1,007.76	100.00%
	Japanese (294,117)	Cardinal	234	795.60	56.80%
		Counting	85	289.00	20.60%
		Identifier	1	3.40	0.20%
		Measure	9	30.60	2.20%
		Ordinal	52	176.80	12.60%
		Written	31	105.40	7.50%
		TOTAL	412	1,400.80	100.00%
THREE	English (474,391)	Cardinal	202	425.81	43.50%
		Counting	204	430.03	44.00%
		Identifier	2	4.22	0.40%
		Measure	40	84.32	8.60%
		Ordinal	2	4.22	0.40%
		Unclear	4	8.43	0.90%
		Written	10	21.08	2.20%
		TOTAL	464	978.10	100.00%
	Russian (29,769)	Cardinal	8	268.74	38.10%
		Counting	7	235.14	33.30%
		Measure	1	33.59	4.80%
		Ordinal	5	167.96	23.80%
		TOTAL	21	705.43	100.00%
	Japanese (294,117)	Cardinal	128	435.20	46.70%
		Counting	73	248.20	26.60%
		Measure	29	98.60	10.60%

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Word	Language (total words)	Context	Tokens	Frequency (per million words)	Percent
		Ordinal	8	27.20	2.90%
		Unclear	4	13.60	1.50%
		Written	32	108.80	11.70%
		TOTAL	274	931.60	100.00%

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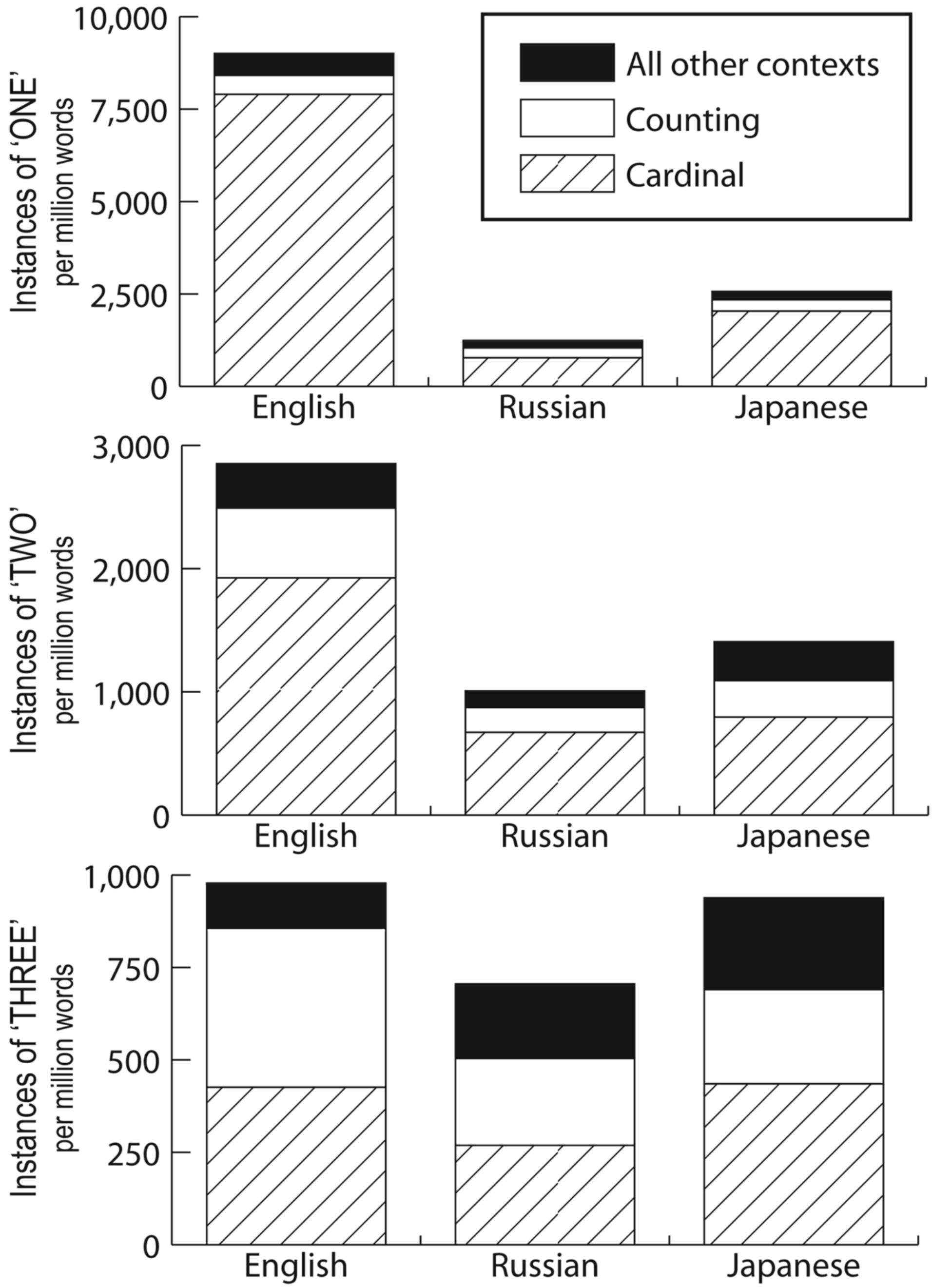

Figure 1.
Frequencies (per million words of speech) and contexts of use for the words 'one,' 'two,' and 'three.'

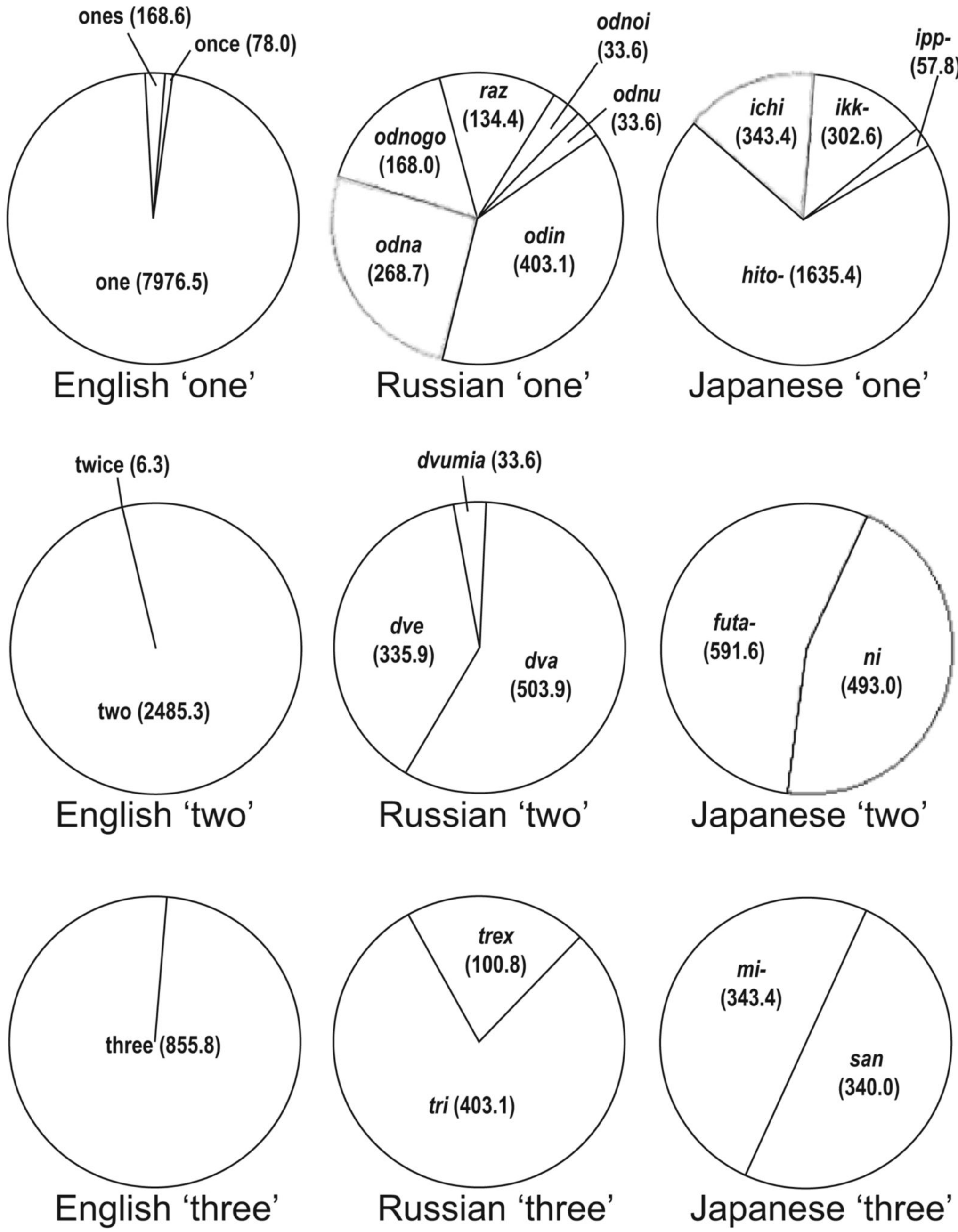

Figure 2.

Forms of 'one,' 'two,' and 'three' that appeared in cardinal or counting contexts. Also given is the frequency of each form, per million words of speech.

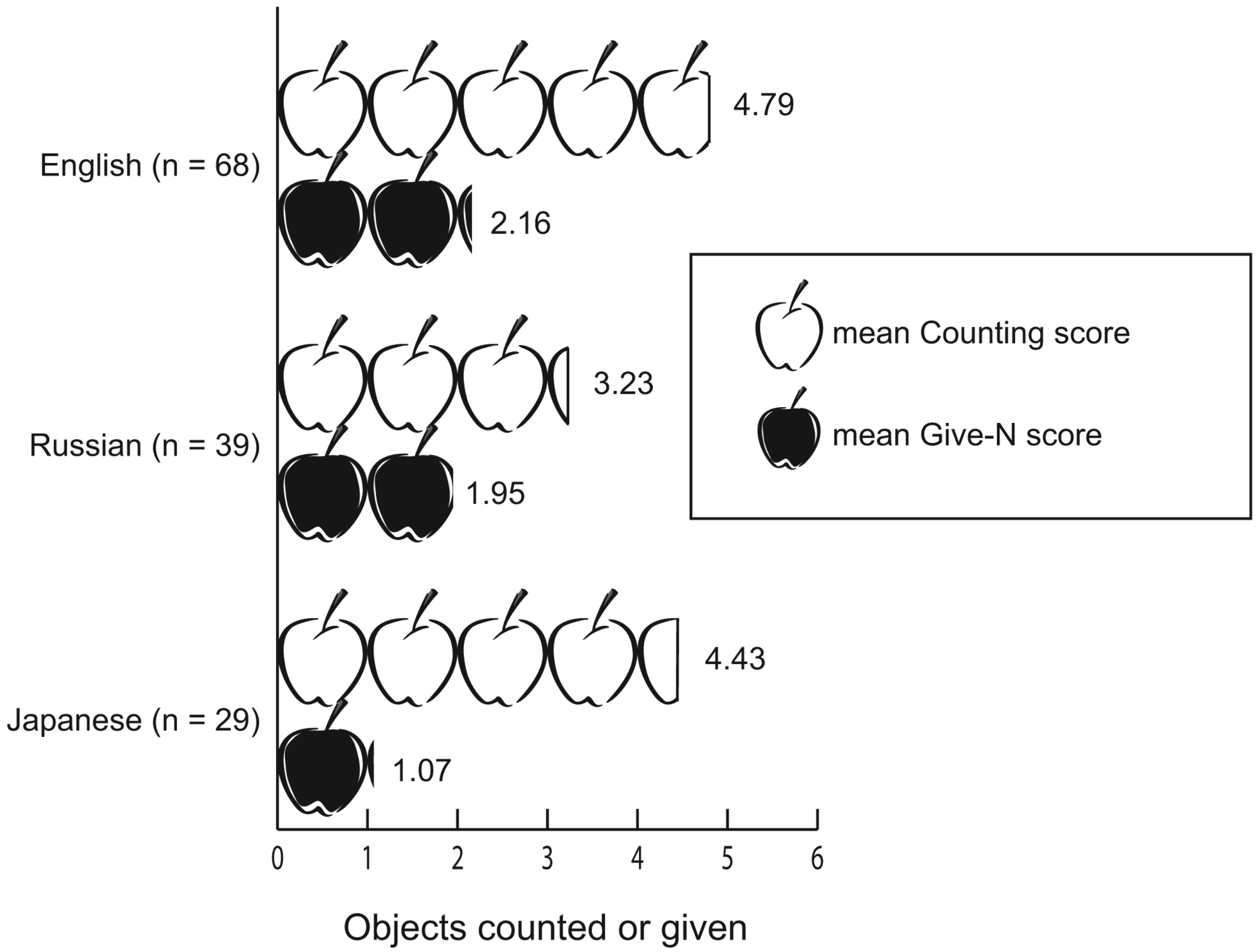

Figure 3.
Mean Counting and Give-N scores.

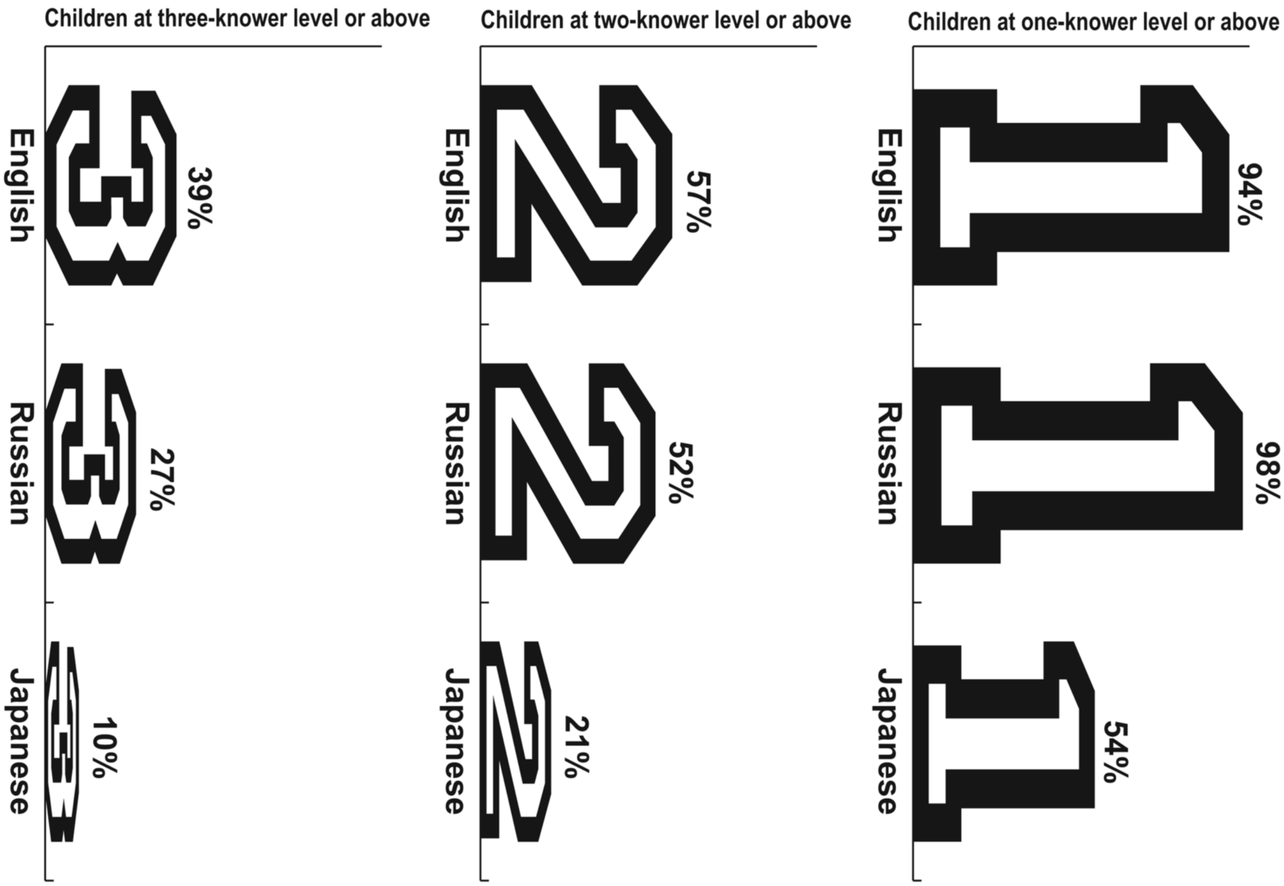

Figure 4.
Cumulative proportions of children who have learned the exact meaning of each number word. Note that each group includes the group(s) below it.

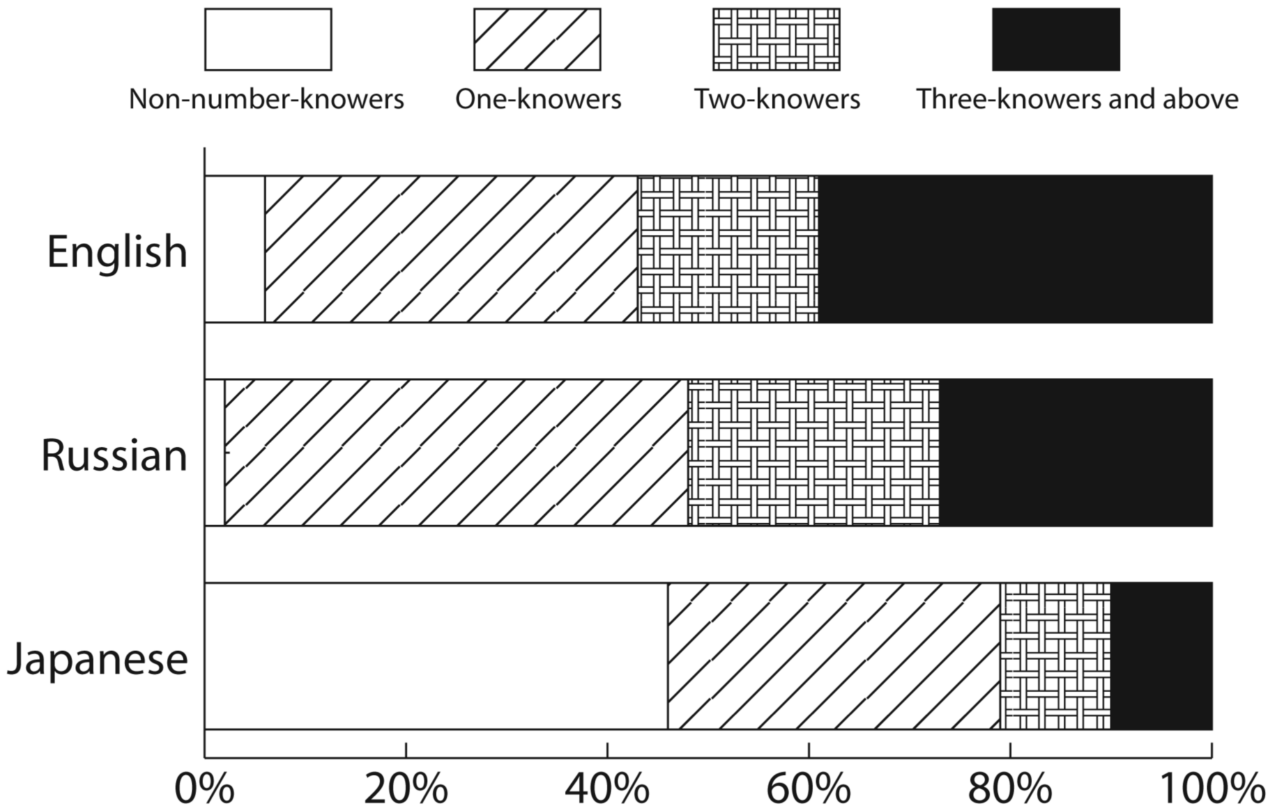

Figure 5.
Give-N results, broken down by knower-level.

Table 1

Examples of Number-Word Contexts

Context	Example(s)
Cardinal	• Two mean mans and one mean lady. (Naomi83, Line 650) • This is the one Ernie gave her. (Sarah019, Line 72)
Counting	• I knock them all down one two three four five six seven five ten five they are all laying down they all taking a nap. (Abe046, Line 109)
Identifier	• No, this is channel two. (Adam32, Line 1101)
Ordinal	• If you can't find it on the first line, then look on the second line. (Adam27, Line 502)
Measure	• For doing something naughty he had to sit on the steps for two minutes. (Adam09, Line 1538) • Because you're two years old? (Naomi77, Line 407)
Written	• Look when this long hand gets between the one and the two, that's when we'll eat. (Abe098, Line 214)
Miscellaneous: (Adjectival) (Integer) (Metalinguistic) (Nominal) (Unclear)	• That's a double one. (Sarah063, Line 258) • How much is two times two? (Naomi68, Line1063) • That spells one? (Adam21, Line 121) • Gruesome twosome, gruesome what? (Sarah067, Line 298) • Fourteen clock no, sir, one nineteen clock, I not (s)paghetti. (Adam15, Line 1456)

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Table 2

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

Give-N-Without-Nouns	Give-N-Apples: (none)	One apple	Two apples	Three apples	Four apples	Five apples	Ten apples
(none)	2	**3**			1		
One	2	7	1				
Two		1	8	1			
Three			1	3		1	
Four					1		
Five						1	
Ten							6

Note. The value in each cell is the number of children with that combination of scores. E.g., the heavily outlined box indicates that three children scored as one-knowers on Give-N-Apples and as non-number-knowers on Give-N-Without-Nouns. This (heavily outlined) cell is where many children's scores should have fallen, if they depended on plurality cues in the task itself (see *Follow-Up Study: Results and Discussion: No online effect of singular/plural marking*).