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Acquiring First Number Words: The Developmental Trajectory of Children's Meanings for "Two"

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How do children begin to acquire the language of numbers? As one of the first mathematical symbols that children learn, the word "two" may be the springboard for further learning about numerical language. Previous research has indicated that children do not understand the exact meaning of "two" until they are nearly three years old (e.g., Wynn, 1992), and that prior to this point, "two" is interpreted as *more than one* but not *exactly two*. In this paper, we lay out some reasons to suspect that children's knowledge of the word "two" starts earlier and follows a more complex trajectory than previous research has described.

In the first part of the argument, we draw on published diary studies and a preliminary CHILDES analysis to suggest that children's first uses of "two" occur very early and, for a brief period of time, refer correctly to sets of two. In the second part, we provide evidence that slightly older children, once they have acquired a stable and precise meaning for the word "two" (i.e., 'two-knowers'), have a surprisingly rich understanding of the semantics of number words despite the fact that they do not understand exactly how number words work or why they refer to exact cardinal quantities. These two arguments have implications for theories about the conceptual underpinnings of number word meanings.

According to Wynn's "knower-levels" description of number development, although children learn to count around the age of two, the process of acquiring meanings for number is cumbersome and slow. Children develop a stable count list around age two, but they fail to show an understanding of the meanings of these words, even one. Children at this stage have been referred to as "pre-counters." A few months later, children become "one-knowers" – they understand and use "two" to represent an unspecified plural (i.e., *some number greater than one*) rather than an exact pair (i.e. *exactly two*; Wynn, 1992; Sarnecka & Carey, 2008; Condry & Spelke, 2008). Around three years, children become "two-knowers" – they know the meanings of one and two, but interpret other numbers as more than two (e.g., Wynn, 1992; Sarnecka & Lee, 2008). Many studies have now corroborated this developmental sequence using a variety of measures and populations, suggesting that the first number words (one, two, and three) are learned slowly, in order, and one at a time. Only around age four do children seem to exhibit specific meanings for all of the numbers that they can count and develop at least a rudimentary understanding about how counting is related to the cardinal value of a set. These children have been dubbed "cardinal-principle knowers," in contrast with "subset-knowers," who only have stable meanings for a subset of their count list.

According to this story, when children become one-knowers, "two" marks a plurality but is not restricted to sets of two. A representative anecdote from the canonical knower-levels literature describes a child who has not yet become a two-knower: "Consider Ben, age 2 ½, '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” (Sarnecka, Kamenskaya, Yamana, Ogura, & Yudovina, 2007).

In contrast, diary studies provide evidence for the correct use of the word “two” in far younger children (Benson & Baroody, 2002; Mix, 2009; Fuson, 1988). These studies track children’s productive use of number words in spontaneous conversations in children’s home environments. They indicate that children begin to use the word “two” very soon after they start speaking, and that their first uses of the word refer to exact pairs, not to generic plurals. For example, Benson and Baroody report:

> By 27 months, Blake was finding many examples of two objects in his life, such as dogs, newspapers, tractors, etc. When Blake identified the collections on his own, his responses were accurate. The first time that Blake labeled a collection of one on his own came after finding collections of two on his own.

Similarly, Kelly Mix (2009) documents Spencer’s early uses of “two.” Initially, these utterances appeared in frozen forms that he appeared to be directly repeating:

> At 23 months of age, Spencer began to use number words to refer to quantities. Specifically, he began to label sets of two objects with the number word ‘‘two.” His very first mapping involved a pair of shoes. He said, ‘‘Two shoes. One. Two.” For several weeks prior to this utterance, Spencer’s nanny had described this and other sets of two in the same way. That is, while they were looking at picture books and object sets around the house, she was overheard saying, ‘‘Two _____. One. Two.”

Importantly, Spencer generalized “two” to novel forms within a short time. Two points are notable here. First, at 24 months, he is a year younger than a typical two-knower, and later in the diary study he begins to overgeneralize “two” to refer to other pluralities. Therefore, it is unlikely that he is a “two-knower” even though his spontaneous production of “two” at this point is restricted to pairs. Second, Mix reports that he rarely, if ever, used “two” to refer to larger quantities; during this short time period, lasting just a month or two, Spencer’s spontaneous uses of “two” seem to refer to pairs.

> At 24 months of age, 7 weeks after labeling two shoes for the first time, Spencer replaced his previous number frame with a modified version that he had not heard previously. He now said, ‘‘_____. _____. Two _____.” For example, he labeled a set of two toy cabooses: ‘‘Caboose. Caboose…Two caboose” (24 months 14 days). He subsequently applied this frame to a variety of different sets. Most of these were objects, including boys, beds, cookies, and pajamas…
>
> Occasionally, he commented on sets of common attributes that were available simultaneously such as spots of blood (‘‘Blood. Blood. Two bloods” [24 months 17 days]), object parts with the same color (‘‘Yellow. Yellow. Two yellows” [25 months 2 days]), and object sizes (‘‘Bigger. Bigger. Two biggers” [25 months 3 days]). On one occasion, he commented on a set of events. Specifically, he fell down twice in a row and said, ‘‘Ow. Ow. Two ows” (25 months 2 days). Once this new ‘‘two” frame appeared, Spencer used it exclusively for 2 months. That is,

> he did not comment on quantity without using this frame. Moreover, he nearly always used it to label pairs and, thus, was nearly always correct in his labeling.

Clark & Nikitina (2009) provide similar examples of D.'s early, correct uses of "two." Interestingly, although these uses are restricted to sets of two objects or events, Clark & Nikitina attribute this pattern to an accident:

> D (1;8.16, at the table, with a toy truck): **wheel.** (then pointing at a second wheel) **wheel two…** In several subsequent uses, he sometimes used two to pick out exactly two objects, *probably by accident* [*italics added*] …
>
> D (1;9.9, carrying two blue racquetball balls upstairs to breakfast) : **Herb racquetball two.**
>
> D (1;9.14, at the table, playing with the two doll-blankets he'd brought upstairs with him and then stashed in his chair): **one, one Blanket.**
> (he then dropped one on the floor): **other blanket floor.**
> (then pulled the second blanket o¤ the table, and dropped it too; and, looking first down on one side, then on the other, at the two blankets now on the floor) **two blanket.**

To summarize: Published diary studies indicate that children use the word "two" fairly soon after they begin speaking. These early uses correctly refer to pairs and not to larger sets, and they are used productively, not just in fixed forms to refer to common objects that come in twos such as eyes or shoes. In these studies, this period of correct use lasts about one or two months and is eventually replaced by the overgeneralization of "two" to refer to any quantity larger than one.

The overgeneralization stage has been well-documented in the literature and matches the age and characteristics of children who are "one-knowers." However, to our knowledge, the earlier period of correct use has not been systematically explored. To test the generality of the diary study findings, we analyzed CHILDES corpora (MacWhinney, 2000) to look for evidence that the pattern of early, correct use of the word "two" characterizes a broader population of children.

Speech samples were drawn from American English corpora that included 18- to 40-month-old children. Databases were prioritized for inclusion if they met one of two criteria: (1) densely sampled data in the target age range from individual children, which would help reveal the hypothesized pattern of early correct followed by over-generalized uses of two; or (2) a large sample of children, which would help reveal whether the pattern noted in the diary studies was characteristic of children in general. The main analysis was a keyword search on children's utterances that included the word "two." Ultimately, 213 utterances from 27 separate children were analyzed. Utterances in which a child was directly repeating himself or a parent within a conversation were subsequently excluded from analysis. A second blind coder analyzed 10% of the data with 95% agreement. Both coders were blind to children's ages.

We focused on cardinal uses of "two" and differentiated these into utterances where "two" probably referred to <u>exactly two</u> entities (correct pair use), <u>more than two</u> entities (incorrect plural use), or <u>more than one</u> entity with no further clues about the actual number (ambiguous plural use). Of 61 codeable utterances with cardinal uses of the word "two," six were uttered by children in the very youngest age range in our sample (18-24 months).

Our main question was whether children's earliest instance of saying "two" would be dominated by correct pair uses rather than incorrect or ambiguous plural uses, and we indeed saw this pattern. In the youngest age group, five of the six utterances (83%) were most consistent with a 'pair' interpretation. By contrast, in the older age groups, pair uses did not rise above 55% (the highest was 10 pair uses out of 22 cardinal utterances in the 31-36 month age group). Because these frequencies are low – only six examples from the earliest age range, from a total of three children – these data are not conclusive. In order to fully evaluate this hypothesis, it would be helpful to analyze longitudinal, densely sampled speech from children younger than 24 months. The present data are most logically seen as lending some additional support to the pattern noted in the diary studies. To give a sense of how children were using the word "two" to mark pairs before the age of two, the five excerpts are presented here.

(1)	*MOT:	how many fingers does mommy have up ?
	***CHI:**	**two, I .**
	*MOT:	yeah, that's two .
(2)	*MOT:	how many hands do you have ?
	***CHI:**	**two .**
	*MOT:	two .
	*MOT:	very good .
(3)	*MOT:	how many socks do you have ?
	***CHI:**	**two .**
	*MOT:	two +/.
	*CHI:	whee, whee, whee, one .
	*MOT:	can Gerry say three ?
	*CHI:	three .
(4)	*CHI:	lady .
	*CHI:	lady !
	%act:	<aft> holding one lady, picking up second lady
	***CHI:**	**two ladies .**
(5)	*CHI:	mother .
	*CHI:	mother !
	%act:	holding two peg ladies
	*CHI:	**two mothers .**

These speech samples suggest that at least some children use "two" as a quantity (not just to refer to age or in a counting routine) before the age of 24 months. These early uses overwhelmingly refer to pairs, not to plurals, and they are productive, not fixed. The accumulating evidence that very young children use the word "two" to refer to pairs, in combination with the marked absence of instances in which they over-generalize "two" to mean a plural, suggests that some children's first meaning for "two" might actually be correct.

This analysis does not refute the knower-levels view. We agree that, when children become one-knowers, they *do* eventually over-generalize two in spontaneous production and in

comprehension tasks. According to most reports, though, most children do not become one-knowers until after 24 months of age. The suggestion here is that there may be an earlier stage with correct usage of "two" before 24 months (at the pre-counter stage), followed by a period of overgeneralization (at the one-knower stage) and subsequent recovery of an exact meaning for "two" (at the two-knower stage).

One possible conceptual source for an early-emerging meaning of "two" is the object-file system, a cognitive system that can represent sets of up to three or four objects (Feigenson & Carey, 2003). Previous theories of the origins of number word meanings have suggested that the first number words (one, two, three, and four) are directly mapped onto this system, which appears to be in place in preverbal infants and robust by twelve months (e.g., Carey, 2004). Because pre-verbal infants can represent the exact quantity of small sets of objects, some researchers have proposed that these representations support the initial acquisition of number word meanings: the word "one" is mapped to a conceptual representation of one object-file at the one-knower stage, "two" is mapped to two object-files at the two-knower stage, and so forth (Carey, 2009).

Furthermore, research suggests that infants do not represent the singular-plural distinction linguistically *or* conceptually until they are about two years old (Barner, Thalwitz, Wood, Yang, & Carey, 2007; Kouider, Halberda, Wood, & Carey, 2006). The object-file system, by contrast, is available much earlier. The canonical view, which posits that children's first meaning of "two" is an unspecified plural, creates a puzzle. Why would two-and-a-half-year-old children map a meaning for "two" onto a recently-acquired concept *plural*, but not onto a better-established concept *two object files*? By contrast, the current proposal – that children' initial meaning for "two" is exactly two and *not* an unspecified plural – allows a more natural alignment between developments in number-relevant concepts and the acquisition of number word meanings. Furthermore, as is evident in the examples above, children's early correct uses of "two" most likely reflect a meaning like ONE AND ANOTHER ONE and not A SET WITH THE CARDINAL VALUE TWO, akin to the conceptual content attributed to the object-file system.

This proposal raises two questions. First, why would children lose their exact semantics of "two" when they become one-knowers? Second, is the semantic knowledge of an older child at the two-knower stage substantively different than the knowledge reflected in exact uses of "two" prior to 24 months? We have a speculative answer to the first question, and some data to address the second. In considering why children might lose an initial correct meaning for "two," we note the suspicious coincidence in the ages when English-speaking children become one-knowers (who by definition over-generalize two) and when they show evidence of a singular-plural distinction in thought and in language (Kouider et al, 2006; Barner et al, 2007). One possibility is that acquisition of the plural concept or plural language eclipses an exact meaning for "two." Because the word "two" frequently co-occurs with plural –s (two apples, two dogs, etc), children's acquisition of plural marking might overshadow their knowledge of "two" and lead them to conclude, incorrectly, that "two" means whatever "–s" means. This is just one idea among many possible mechanisms that might coordinate learning of exact number words like *one* and *two* with acquisition of singular-plural morpho-syntax (see also Barner, Lui, & Zapf, under revision; Clark & Nikitina, 2009). A different possibility, one that draws on conceptual rather than linguistic processes, is that as children begin to notice the difference between singular and plural sets, their attention shifts such that sets of two are conceptualized as members of the category 'plural' more than as pairs (see Li, Ogura, Barner, Yang, & Carey, 2009).

The second question is how children at the two-knower stage represent the meaning of "two." On one story, children's initial number word meanings are tied to a well-documented cognitive system for representing approximate quantities, the Approximate Number System (ANS; e.g., Gelman & Gallistel, 1978; Wynn, 1992). According to this view, children at the two-knower stage know that "two" refers to SET OF TWO. On a different story, children's initial number word meanings are embedded in numerical grammar. Since some languages, like Hebrew, grammatically mark a singular-dual-plural distinction, the initial meaning of "two" might be something akin to a dual marker in such a language, with its conceptual representation grounded in the object file system (Carey, 2004; Sarnecka et al, 2007). According to this view, the initial meaning of "two" is something like ONE AND ANOTHER ONE.

A challenge to deciding between these perspectives is that two-knowers act in a way that is consistent with knowledge of two, regardless of their meaning for it. One way around this problem is to consider evidence about what two-knowers know about their "unknown" number words, those for which they do not seem to have a stable and precise meaning. If children show an understanding that their 'unknown' numbers refer to cardinal values of sets, or they show evidence that they have mapped 'unknown' number words to the ANS, it is more plausible that children have this knowledge for their 'known' number words as well. Here we present, briefly, two lines of evidence in support of the argument that two-knowers understand that number words refer to cardinal values of sets and, further, that they have drawn a connection between verbal number and the ANS even at this early stage.

In the first study (Finder & Shusterman, in preparation), we tested the hypothesis that, during the counting routine, young children focus on the objects that are tagged, as opposed to the total value of the set. For example, as children count a set of four objects, they may mistakenly think that "four" refers to the fourth object instead of the idea that there are four objects in the set. To test this, we drew on the literature on the counting principle of order-irrelevance (Baroody, 1993). The hypothesis was that children who think that "one" refers to the first object, "two" to the second object, and so on, would be reluctant to change which object they tag as "one." Only children who understand that the point of a count is to establish a set should understand that the tagging order is not relevant as long as other counting principles are not violated (e.g., one-to-one correspondence, stable order of counting words).

We asked 85 children a series of questions after they counted sets of three or five objects. For example, we asked *Can you count it again?* and *If I count it this way* (gesturing the reverse direction), *will it still be N?* (reverse trial). In one set of questions, the array to be counted was placed on a lazy Susan and rotated after the child counted; we asked children to count again, and coded whether they kept the "one" object consistent across trials after a 180-degree rotation. In a follow-up condition, we increased the hetereogeneity of the objects in order to elicit evidence that children focused on objects as the referent of number words instead of focusing on the set. We established children's knower-levels using a standard give-a-number protocol (similar to LeCorre & Carey, 2007). To our surprise, subset-knowers, including two-knowers, were very successful at these tasks. When subset-knowers were separated into categories, it became clear that two-knowers understood the tasks but one-knowers did not. For example, on the reverse trials with five heterogeneous objects, 56% of one-knowers correctly answered yes, while 100% of two- and three-knowers did so. Furthermore, more than half of the one-knowers showed a strong response bias, answering either "yes" or "no" to all of the questions, indicating that they were unsure about what we were asking. Not a single two-knower showed this pattern. These

results provide suggestive evidence that, once children reach the two-knower stage, they understand that number words refer to sets and not to the objects tagged in a count.

In a different study, three- to five-year-old children were tested on a battery of number tasks (Shusterman, Carey, & Spelke, 2008). One of these was a rapid estimation task, in which children viewed one-second displays of different set sizes of items on a computer screen (1, 2, 3, 4, 6, 8, or 10). The procedure closely followed the Fast Cards task of LeCorre and Carey (2007), but with different stimuli and training. Prior to the test trials, children viewed a training set, with one fish up to fifteen fish in order, which the experimenter labeled. The purpose of the training set was to model that children should blurt out a number word without counting the items. However, either this small change or another difference in experimental protocol led to a non-replication of the original findings. LeCorre & Carey showed a consistency between children's Give-N level and estimation, such that two-knowers could accurately estimate sets of one and two, but did not give increasing estimates for increasing set sizes for sets larger than two. By contrast, our study found that even children who were assessed as "two-knowers" on the Give-N task had correctly mapped the words one, two, three, and four to the correct set sizes. They also gave increasing estimates for larger sets, such that the average slope was approximately 0.2 for set sizes between six and ten. The coefficients of variation 6, 8, and 10, a measure of the average noise around each child's mean guess for each set size, were consistent with characterizations of the Approximate Number System (COVs of .33, .30, and .36 for set sizes of 6, 8, and 10, respectively). One-knowers did not show any evidence of having mapped numbers higher than one, consistent with the objects-versus-sets study and with the original LeCorre & Carey study. These results suggest that two-knowers have not only realized that number words refer to sets, but (1) that they realize that higher number words refer to larger set sizes and (2) that they have connected number word meanings to the primary cognitive system for representing numerosities.

Together, these analyses suggest that children break into number word meanings earlier than previous research has suggested. The first analysis suggests that children map a meaning to the word "two" early in language development, and correctly. Furthermore, children's usage appears to be productive, with "two" meaning something like *a pair of* ___ where anything can stand in the blank. This meaning is reanalyzed twice: first, it is reinterpreted as a general plural that is not restricted to sets of two, around when children become one-knowers; then, children regain an exact semantics for "two" when they become two-knowers. While it may be true that children's initial meaning of "two" corresponds to a grammatical dual marker or two object files, as some have suggested (e.g., Carey, 2004), this characterization fits better with children's early meaning of two, during the pre-counter stage. Once they are two-knowers, they know that two, and other number words, represent the value of a set. Thinking of two as *a set of* ___, rather than *a pair of* -____, may lay a critical foundation for starting to think about sets with other cardinal values. Although children at this point are clearly missing many pieces of the puzzle that underlie the logic of counting, they understand that number words get meaning from the order of the numbers in the count list, and they have begun to connect this verbal structure with a preverbal cognitive system for representing quantities.

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