Partial Knowledge in the Development of Number Word Understanding

Connor D. O'Rear, Nicole M. McNeil, and Patrick K. Kirkland

University of Notre Dame

Corresponding Author:
Connor O'Rear
Department of Psychology, University of Notre Dame
390 Corbett Family Hall, Notre Dame, IN 46656
corear@nd.edu

Research Highlights

- Children who correctly give the number above their knower level on give-*N* ("*N*+1 Givers") exhibit more growth in number knowledge than their knower-level matched peers
- *N*+1 Givers perform worse on concurrent number word measures when compared to their peers who are strictly classified as knowers of *N*+1
- Children may exhibit partial knowledge of number words that is not captured by traditional ways of coding performance on the give-*N* task

Abstract

A common measure of number word understanding is the give-*N* task. Traditionally, to receive credit for understanding a number, *N*, children must understand that *N* does not apply to other set sizes (e.g., a child who gives three when asked for "three" but also when asked for "four" would not be credited with knowing "three"). However, it is possible that children who correctly provide the set size directly above their knower level but also provide that number for other number words ("*N+1* givers") may be in a partial, transitional knowledge state. In an integrative analysis including 191 preschoolers, subset knowers who correctly gave *N+1* at pretest performed better at posttest than did those who did not correctly give *N+1*. This performance was not reflective of "full" knowledge of *N*+1, as *N+1* givers performed worse than traditionally-coded knowers of that set size on separate measures of number word understanding within a given timepoint. Results support the idea of graded representations (Munakata, 2001) in number word development and suggest traditional approaches to coding the give-*N* task may not completely capture children's knowledge.

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Imagine a group of children instructed to retrieve three checkers from a box. All children pick out exactly three red checkers. Success! Next, the children are asked for four black checkers. Some select four, some select three, and some grab a handful. Those who select four clearly understand more about "four" than those who select three or a handful, but how does the knowledge of the latter two groups compare? Is it the same? Consider the children who incorrectly selected three black checkers after they had correctly selected three red checkers. Do they actually understand "three?"

This scenario parallels a widely-used task for assessing children's understanding of number words: the give-*N* task (Wynn, 1990, 1992; see also Colome & Noel, 2012; Davidson, Eng, & Barner, 2012; Gibson, Gunderson, Spaepen, Levine, & Goldin-Meadow, 2019; Le Corre, Van de Walle, Brannon, & Carey, 2006; Mix, Sandhofer, Moore, & Russell, 2012; O'Rear & McNeil, 2019; Posid & Cordes, 2015; Sarnecka & Carey, 2008; Shusterman et al., 2017; vanMarle, Chu, Li, & Geary, 2014; Wagner & Johnson, 2011). In Wynn's original coding of this task, children's knowledge of a number word, *N*, was measured both by their ability to consistently provide that number when requested and also by whether or not they consistently provided that number for other number words. Children who give three reliably when asked for "three" but also consistently provide three for other number words would be coded as "two knowers." This seems sensible, as knowledge of "three" requires not only providing three when asked for three, but also knowing not to provide three when asked for "four" or "five." However, it is possible such performance reflects "partial" knowledge of three.

Broadly speaking, early in the learning process, representations can exist in a relatively weak state (e.g., Munakata & McClelland, 2003; Garber, Alibali, & Goldin-Meadow, 1998).

With more experience, representations become stronger, allowing them to more readily influence behavior (e.g., Alibali & Goldin-Meadow, 1993; Munakata, McClelland, Johnson, & Siegler, 1997; Siegler, 1976). During the strengthening process, these representations may appear as "partial" knowledge, wherein they can guide some behaviors but not others. For example, a child with partial knowledge of "three" may have a strong enough representation to give three when asked for "three," but not strong enough to prevent giving three when asked for "four."

The possibility of partial number word knowledge fits with research suggesting word learners do not suddenly develop a complete understanding of new words (e.g., Apfelbaum & McMurray, 2017; Yurovsky, Fricker, Yu, & Smith, 2014). In the cross-situational word learning task, participants are shown multiple novel items simultaneously while hearing novel labels. On any given trial it is unclear which label applies to which object, requiring the learner to track the objects and labels across trials to learn each object-label pairing. Individuals who try but fail to make the correct mappings in one trial block are significantly more likely to make the correct mapping on a subsequent trial block, suggesting that although learners do not display a correct understanding initially, there is something about their knowledge state that accelerates later learning (Yurovsky et al.).

There also is specific evidence that children can show knowledge beyond what their give-*N* knower level would suggest (e.g., Barner & Bachrach, 2010; Gunderson, Spaepen, Gibson, Goldin-Meadow, & Levine, 2015; Wagner, Chu, & Barner, 2019). For example, children who are developing an understanding of number words show better performance labeling small set sizes when they gesture (e.g., put up three fingers) than when they have to verbalize the correct number word (e.g., "three;" Gunderson et al., 2015). Additionally, children are more likely to give the correct set size directly above their knower level on the give-N task than would be expected by chance alone, leading researchers to characterize children's mappings of small number words to meanings as "noisy" (Wagner, Chu, & Barner, 2019). Note that "noisy" here refers to the mappings, not to the meanings themselves as in the approximate number system (ANS). Taken together, these findings reveal that when looking within a single timepoint, the traditional way of coding the give-N task does not capture the entirety of children's knowledge.

However, no study to date has differentiated children who consistently give a number (e.g., 2) both when asked for that number (e.g., "two") and when asked for another number (e.g., "three") from other children at the same knower level. Furthermore, previous studies have not looked at development across time when considering children's knowledge of number words not captured by traditional give-*N* coding.

Here we investigated the possibility that *N*-knowers who can give *N+1* reliably, but also give *N+1* for higher numbers, are in a transitional state on their way to becoming "strict" *N+1* knowers who correctly provide *N+1* only when it is requested. We hypothesized that these children, hereafter referred to as "*N+1* givers," would be more likely to develop into strict *N+1* knowers than their fellow *N* knowers who do not reliably provide sets of *N+1*. Although both groups of children would be coded as *N* knowers at pretest, *N+1* givers should be more likely to progress to the next knower level by posttest if *N*+1 giving is reflective of partial knowledge of *N+1*.

Integrative Data Analysis

Participants

The first set of analyses included data from six pretest-posttest studies that examined three-to-five-year old children's performance on the give-*N* task and lasted between 2-5 weeks.

Interventions in these studies involved scripted counting practice or a print awareness intervention completed individually with an experimenter.[1] Because we were interested in the *development* of number word understanding, only the 191 subset knowers (one through four knowers) were included (there were 38 pre-knowers [children who had yet to show an understanding of "one"] and 105 CP-knowers [children who showed a consistent understanding of "five" and the set sizes below]). This sample included 100 girls and 91 boys (M_{age} = 47.46 months, *SD* = 8.27).

Design

We conducted an integrative data analysis (IDA) of performance on give-*N* (see Tables 1 and 2). By pooling participants across multiple studies, IDA allows for a more powerful test of the hypotheses (e.g., Curran & Hussong, 2009).

Measures

Give-*N* (Wynn, 1990). Children were asked to provide sets of between one and six items from a pile of 15 to a stuffed animal. Administration followed a titration method (e.g., Wynn, 1992). Children were first asked for one item. If correct, they were then asked for two, but if incorrect they were again asked for one. This pattern continued until children failed on a given number twice or provided the correct number on at least two out of three trials for a given set (and all smaller sets). Children were never told to count, but were allowed to do so spontaneously.

[1] Excluding participants in the print awareness intervention does not alter the pattern of results.

Children's knower level was coded as the highest number word they demonstrated understanding of, while also demonstrating understanding for all smaller number words. Children were credited with understanding a number word if they had at least twice as many successes as failures for the number word (e.g., Sarnecka & Carey, 2008).[2] Successes for *N* meant providing the correct amount when *N* was requested. Failures for *N* meant either (a) providing an amount other than *N* when *N* was requested or (b) providing *N* when another number word was requested (e.g., giving two when asked for "three" would be considered as a failure for "two" in addition to a failure for "three").[3]

Children were coded as pre-, one-, two-, three-, four-, or CP-knowers. To qualify as a CP-knower, children needed to show evidence of understanding "five" and all set sizes below. Additionally, children were coded as *N+1* givers if they consistently provided *N+1* correctly when asked for *N+1* (i.e., on at least 2 out of up to 3 attempts) but were not credited with being a "knower" of that set size because they gave *N+1* for another number word. A two-knower who provided three for both "three" and "four" was coded as a three-giver, whereas a two-knower who did not consistently provide three when asked for "three" was not coded as a three-giver.

Count Disks (Mix et al., 2012). Children were shown 20, one-inch disks placed an inch apart on a foam board. The disks were arranged in a straight line and alternate in color. The highest number counted while maintaining a stable-sequence (counting in the correct order) and one-to-

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[2] Coding knower level according to Negen, Sarnecka, & Lee (2012) does not alter the pattern of results.

[3]Based on this coding system 11 children received knower levels that were at least two set sizes below the highest set size they could consistently provide (e.g., one child provided sets 1-6 correctly at least twice but also provided one for other number words, leading to a coded knower level of "pre-knower" because the child could not be credited with knowledge of "one"). Such children are excluded from the analyses, as the coded knower level did not seem to adequately capture their knowledge and may be seen as biasing results in favor of the hypothesis. However, including these children does not alter the pattern of results.

one correspondence (counting each disk in order and only once) was coded as the highest count. The task was administered twice in each session in five of the studies, but only once in one of the studies (study six in Table 1). To equate coding across studies, the first attempt completed was used for analysis.

Results

To test whether being an *N+1* giver predicts posttest knower level, we conducted an ANCOVA with *N+1* giver status (0 = no, 1 = yes), pretest knower level (1-4), and their interaction as predictor variables and posttest knower level (0-5) as the dependent variable. Count disks performance at pretest was included as a covariate.[4] Study was included as a random factor.[5] There were significant main effects of *N+1* giver status, $F(1, 177) = 7.241$, $p = .008$, $\eta_p^2 = .039$ and pretest knower level, $F(3, 177) = 28.964$, $p < .001$, $\eta_p^2 = .329$. Neither the effect of pretest count disks performance $F(1, 177) = 2.942$, $p = .088$ $\eta_p^2 = .016$ nor the effect of study $F(5, 177) = .979$, $p = .432$, $\eta_p^2 = .027$ was significant. The interaction between *N+1* giver status and pretest knower level was not significant, $F(3, 177) = 2.584$, $p = .055$, $\eta_p^2 = .042$.

Posthoc visual inspection of the data suggested that the effect of *N+1* giver status was driven by two, three, and four knowers (see Figure 1). For one-knowers, there was not evidence of an association between *N*+1 giver status at pretest and posttest knower level, $F(1, 37) = .238$,

[4]Age was not included as an additional covariate because initial analyses showed that it was unrelated to growth on give-*N* (*p* = 783).
[5]Including the interaction between study and being an *N+1* giver did not suggest that the effect of *N+1* giver differed across studies (*p* = .477)

$p = .628$, $\eta_p^2 = .006$, but for two through four knowers there was, $F(1, 134) = 7.803$, $p = .006$, $\eta_p^2 = .055$. Thus, two, three, and four knowers who consistently provide *N+1* at pretest show greater understanding of number words at posttest than do those who do not provide *N+1* at pretest.[6]

The above analyses suggest that *N+1* giver status for two-, three- and four-knowers at pretest is associated with a greater average knower level at posttest. However, knower level may be better conceptualized as an ordinal rather than continuous variable (e.g., the advancement from a two to three knower does not necessarily reflect the same difference in knowledge as the advancement from a three to four knower, though progression across knower levels is believed to follow a given order). To address this possibility, and to ensure robustness of our findings, we reanalyzed the data using ordinal regression. We conducted the ordinal regression with *N+1* giver status (0 = no, 1 = yes) and pretest knower level (2-4, ordinal) as the independent variables and knower level at posttest as the outcome variable.[7] We again included count disks performance as a covariate. Similar to the ANCOVA, being an *N+1* giver at pretest predicted posttest knower level, $\hat{\beta} = 1.49$, $Wald(1, N = 146) = 11.96$, $OR = 4.42$, $p < .001$.[8]

Mini-meta Analysis

[6]Similar analyses comparing the one, two, and three knowers who are *N*+1 givers to "full" knowers of that set size did not provide evidence that these groups differ at posttest ($p = .744$). The same held for just two and three knowers who are *N*+1 givers ($p = .511$).

[7] The R Code for the ordinal and binary logistic regression models is available at https://osf.io/u5ya6/

[8] A binary logistic regression also showed the same pattern of results, with *N+1* givers being more likely to improve ($\hat{\beta} = 1.54$, $Wald(1, N = 146) = 12.15$, $OR = 4.68$, $p < .001$)

The IDA suggests that two, three, and four knowers who consistently give *N+1* correctly at pretest may have partial knowledge of *N+1*. However, it could be the case that *N+1* givers are "full" knowers of *N+1* who are unfairly penalized for providing *N+1* for *N*+2. In other words, these *N+1* givers may be better characterized as full knowers of *N+1*. To investigate this possibility, we conducted a mini-meta analysis (e.g., Goh, Hall, & Rosenthal, 2016) using the above studies looking at how *N+1* status on give-*N* is related to concurrent performance on other measures of number word understanding. Note that this comparison is different than the one above. Above we compared an *N*-knower who grabs a bunch when asked for *N+1* to an *N*-knower who correctly gives *N+1* consistently when asked for *N+1* but also when asked for another number. Here we compare an *N*-knower who gives *N+1* with an actual *N+1* knower. If *N+1* givers do *not* have "full" knowledge of *N+1* then a full knower of a set size should outperform them. For example, three knowers should outperform two knowers who give three when asked for "three", but also give three when asked for "four."

Participants

Five of the six studies from above included a reliable second measure of number word understanding in addition to give-*N*, so they were included in the mini-meta analysis.[9] For these analyses, we compare *N+1* givers to children who are knowers of the next number word but not

[9] Study six included an older version of the WOC task script that was administered in such a way that children did not consistently provide numerical responses. Studies one and three also used WOC, but with an improved script that resulted in children being likely to answer with a numerical response.

N+1 givers. For example, this allowed us to see how a four knower who could provide five compared to a child who demonstrated full knowledge of five (i.e., CP-knowers). Thus, the comparison here takes the 1-4 knowers who are *N+1* givers and compares them to 2-5 (i.e., CP) knowers who are not *N+1* givers. Table 3 displays participant characteristics for each study.

Design

Not all studies included the same second measure of number word understanding, so a mini-meta analysis was conducted to investigate the effect of being an *N+1* giver versus having full knowledge of the set size. By pooling the effect sizes across several studies with conceptually-related measures of number word understanding, it allows for a more wholistic view, and a more powerful test, of the effect of being an *N+1* giver (e.g., Goh et al., 2016).

Additional Measures

Modified Give-*N*. For the meta-analysis, children received a modified knower level score based on the highest set size they could consistently provide (at least two out of three attempts), while also being able to give all set sizes below. This allows *N+1* givers to be coded as knowers of *N+1*, so we can then compare to "full" knowers of *N+1*.

What's on this card? (WOC; Le Corre et al., 2006). Children were introduced to a stuffed zebra who had forgotten his number words. On each trial they were shown a card displaying a homogeneous set (carrots, ladybugs, or helicopters) arranged in a straight line and were asked to help Zebra determine what number word should be used. There were three decks, with each deck containing set sizes one through six. The first two cards of the first deck (a set of one followed by a set of two) were used as example cards where children received feedback (e.g., "This *is* a carrot. But remember, Zebra forgot his *number* words. So, what *number* word should we tell Zebra?"). Within each deck the cards were pseudo-randomly arranged where children always saw a set of one to begin the deck, then either two or three, followed by four, five, or six. Children were not asked to count but were allowed to do so spontaneously. Children received a score from 0-16 based on the number of cards for which they provided the correct number word.

Point-to-*X* (P*X*; Gunderson & Levine, 2011). Children started with two sets of black squares, one set of one and one set of five, and were asked to "point-to-one." They received feedback on their response before moving to the test trials. Each test trial had sets between one and six items, and children were asked to point-to-*X*. The sets for each trial consisted of black boxes arranged in a line. Children were never asked to count, but were allowed to do so spontaneously. Children completed a total of 16 trials and received a score from 0-16.

Results

For each study we conducted an ANCOVA with either P*X* or WOC as the dependent variable, *N+1* giver status, modified pretest knower level (2-5), and their interaction as fixed factors and count disks performance as a covariate (see Figures 2 and 3). None of the ANCOVAs revealed a significant interaction between modified knower level and *N*+1 Giver status. A meta-analysis was then conducted using the adjusted marginal means and the spreadsheet from Goh et al. (2016). This spreadsheet allows entry of the group means and standard deviations for each study. It calculates Cohen's *d* (see Table 4) and conducts a fixed-effects meta-analysis of *d* using inverse variance weighting. There was a significant, negative effect of being an *N+1* giver (Mean d = -.411, p = .007). Thus, subset knowers who are *N+1* givers perform worse when compared to full knowers of that set size on another measure of number word understanding.[10]

[10] A similar mini meta-analysis was conducted to investigate whether *N*+1 givers outperformed children of the same unmodified knower level (i.e., their knower level from the IDA) who were not *N*+1 givers. These *N*+1 givers did not perform significantly better within the same time point than the other children at their knower level (Mean Cohen's d = .261, p = .103).

Discussion

We found that children have partial knowledge of number words that is not reflected in traditional ways of coding give-*N*. Two-, three-, and four-knowers who gave *N+1* for both *N+1* and other number words progressed to a higher knower level, on average, when compared to their fellow *N*-knowers who did not reliably give *N+1*. Moreover, this pattern of results did not indicate that traditional ways of coding children's understanding are wrong. Indeed, when looking within the same timepoint, children who reliably gave *N+1* were generally outperformed by "full" knowers of that set size on separate measures of number word understanding. Also, an adult-like understanding of a number word (e.g., "three) requires knowing not to provide that number of items (e.g., 3) when another number (e.g., "four") is requested.

Results have implications for how children's performance on the give-*N* task is conceptualized. Some researchers have treated number word development as something that occurs in an all-or-none, stage-like fashion, but our results replicate and extend a general pattern of findings suggesting that children's knowledge of number words is not fully captured under the traditional coding of the give-*N* task because children can show knowledge beyond their give-*N* knower level (e.g., Barner & Bachrach, 2010; Gunderson et al., 2015; Wagner et al., 2019). Novel to the current study is the pattern of knowledge change *across* time, with children who show evidence of partial knowledge of the next number word being more likely to grow in their understanding. What remains a question for future research is the nature of the underlying representations that are driving children's behavior. The tendency for children to correctly give the number immediately above their knower level may reflect early strengthening of representations connecting that number word to its appropriate quantity.

Although we found patterns of behavior consistent with partial knowledge, it is unclear whether this behavior reflects a typical developmental progression in number word learning. There may be individual differences in whether or not children display partial-*N* behavior before becoming full knowers of number words. It also remains possible that partial-*N* behaviors reflect an unmeasured individual difference variable associated with growth.

Finally, it should be noted that the method for administering give-*N* in the present studies allowed children to count, but did not explicitly prompt them to count. It is unclear if partial-*N* behavior would be affected by asking children to count the set. Having children count a set they constructed may provide additional support, allowing them to perform more similarly to "full" knowers of a set size. Studies suggest that asking children to count during give-*N* increases the number of children categorized as CP-knowers (Krajcsi, 2019) and that briefly training children to count-and-label sets improves give-*N* performance (Posid & Cordes, 2019). These approaches should be examined specifically with *N+1* givers to test if methodological differences influence the tendency to find *N+1* givers.

In summary, results support past work suggesting that children know more about number words than is captured by traditional ways of coding give-*N*. They are consistent with studies suggesting that the give-*N* task, on its own, underestimates children's knowledge of number words (Baroody et al., 2017). Additional research is needed to determine how best to design and code measures to capture individual differences in children's understanding of number words. In the meantime, researchers may benefit from including multiple measures of understanding to provide converging evidence of where children are in their development.

Data Availability Statement:

The data that support the findings of this study are available at https://osf.io/u5ya6/

Author Note: An earlier version of this integrative data analysis (IDA) was presented at the 40th Annual Meeting of the Cognitive Science Society (O'Rear, McNeil, Kirkland, 2018). This paper uses data from previous studies completed by Connor O'Rear (O'Rear & McNeil, 2018), Alice Tollaksen, Alexander Boehm, Alex Viegut, Alex Bohnsack, and Lori Petersen (Petersen et al., 2014) under the direction of Nicole McNeil. This project was supported by the National Science Foundation (NSF) under Grant No. DRL-1661086.

References

Alibali, M. W., & Goldin-Meadow, S. (1993). Gesture-speech mismatch and mechanisms of learning: What the hands reveal about a child′ s state of mind. *Cognitive psychology*, *25*, 468-523.

Apfelbaum, K. S., & McMurray, B. (2017). Learning During Processing: Word Learning Doesn't Wait for Word Recognition to Finish. *Cognitive science*, *41*, 706-747.

Barner, D., & Bachrach, A. (2010). Inference and exact numerical representation in early language development. *Cognitive psychology*, *60*(1), 40-62.

Baroody, A. J., Lai, M. L., & Mix, K. S. (2017, October). *Assessing early cardinal-number knowledge*. Poster presented at the Thirty-Ninth Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education. Indianapolis, IN

Colomé, À., & Noël, M. P. (2012). One first? Acquisition of the cardinal and ordinal uses of numbers in preschoolers. *Journal of experimental child psychology*, *113*(2), 233-247.

Curran, P. J., & Hussong, A. M. (2009). Integrative data analysis: the simultaneous analysis of multiple data sets. *Psychological methods*, *14*, 81-100.

Davidson, K., Eng, K., & Barner, D. (2012). Does learning to count involve a semantic induction?. *Cognition*, *123*, 162-173.

Garber, P., Alibali, M. W., & Goldin-Meadow, S. (1998). Knowledge conveyed in gesture is not tied to the hands. *Child development*, *69*, 75-84.

Gibson, D. J., Gunderson, E. A., Spaepen, E., Levine, S. C., & Goldin-Meadow, S. (2019). Number gestures predict learning of number words. *Developmental science*, *22*(3), e12791.

Goh, J. X., Hall, J. A., & Rosenthal, R. (2016). Mini meta-analysis of your own studies: Some arguments on why and a primer on how. *Social and Personality Psychology Compass*, *10*(10), 535-549.

Gunderson, E. A., & Levine, S. C. (2011). Some types of parent number talk count more than others: relations between parents' input and children's cardinal-number knowledge. *Developmental science*, *14*(5), 1021-1032.

Gunderson, E. A., Spaepen, E., & Levine, S. C. (2015). Approximate number word knowledge before the cardinal principle. *Journal of Experimental Child Psychology*, *130*, 35-55.

Gunderson, E. A., Spaepen, E., Gibson, D., Goldin-Meadow, S., & Levine, S. C. (2015). Gesture as a window onto children's number knowledge. *Cognition*, *144*, 14-28.

Krajcsi, A. (2019, March 19). Follow-up questions influence the measured number knowledge in the Give a number task. https://doi.org/10.31234/osf.io/fky69

Le Corre, M., Van de Walle, G., Brannon, E. M., & Carey, S. (2006). Re-visiting the competence/performance debate in the acquisition of the counting principles. *Cognitive psychology*, *52*, 130-169.

Mix, K. S., Sandhofer, C. M., Moore, J. A., & Russell, C. (2012). Acquisition of the cardinal word principle: The role of input. *Early Childhood Research Quarterly*, *27*, 274-283.

Munakata, Y. (2001). Graded representations in behavioral dissociations. *Trends in cognitive sciences*, *5*, 309-315.

Munakata, Y., & McClelland, J. L. (2003). Connectionist models of development. *Developmental Science*, *6*, 413-429.

Munakata, Y., McClelland, J. L., Johnson, M. H., & Siegler, R. S. (1997). Rethinking infant knowledge: Toward an adaptive process account of successes and failures in object permanence tasks. *Psychological Review*, *104*(4), 686.

Negen, J., Sarnecka, B. W., & Lee, M. D. (2012). An Excel sheet for inferring children's number-knower levels from give-N data. *Behavior research methods*, *44*, 57-66.

O'Rear, C. D., & McNeil, N. M. (2019). Improved set-size labeling mediates the effect of a counting intervention on children's understanding of cardinality. *Developmental science*, e12819.

O'Rear, C. D., McNeil, N. M., & Kirkland, P. K. (2018, January). Evidence of Partial Number Word Knowledge on the Give-N Task. *Proceedings of the 40th Annual Conference of the Cognitive Science Society*. Madison, WI: Cognitive Science Society.

Petersen, L. A., McNeil, N. M., Hall, C. J., Carrazza, C., Devlin, B. L., Tollaksen, A.K., et al., (2014) Counting practice with pictures, but not objects, improves children's understanding of cardinality. *Proceedings of the 36th Annual Conference of the Cognitive Science Society.* Austin, TX: Cognitive Science Society.

Posid, T., & Cordes, S. (2015). Verbal counting moderates perceptual biases found in children's cardinality judgments. *Journal of Cognition and Development*, *16*(4), 621-637.

Posid, T., & Cordes, S. (2019). The effect of multimodal information on children's numerical judgments. *Journal of experimental child psychology*, *182*, 166-186.

Sarnecka, B. W., & Carey, S. (2008). How counting represents number: What children must learn and when they learn it. *Cognition*, *108*, 662-674.

Shusterman, A., Cheung, P., Taggart, J., Bass, I., Berkowitz, T., Leonard, J. A., & Schwartz, A. (2017). Conceptual correlates of counting: Children's spontaneous matching and tracking of large sets reflects their knowledge of the cardinal principle. *Journal of Numerical Cognition, 3(1),* 1-30.

Siegler, R. S. (1976). Three aspects of cognitive development. *Cognitive psychology*, *8*, 481-520.

Van Marle, K., Chu, F. W., Li, Y., & Geary, D. C. (2014). Acuity of the approximate number system and preschoolers' quantitative development. *Developmental Science*, *17*, 492-505.

Wagner, K., Chu, J., & Barner, D. (2019). Do children's number words begin noisy?. *Developmental science*, *22*(1), e12752.

Wagner, J. B., & Johnson, S. C. (2011). An association between understanding cardinality and analog magnitude representations in preschoolers. *Cognition*, *119*(1), 10-22.

Wynn, K. (1990). Children's understanding of counting. *Cognition*, *36*, 155-193.

Wynn, K. (1992). Children's acquisition of the number words and the counting system. *Cognitive Psychology*, *24*, 220-251.

Yurovsky, D., Fricker, D. C., Yu, C., & Smith, L. B. (2014). The role of partial knowledge in statistical word learning. *Psychonomic bulletin & review*, *2*, 1-22.

Table 1. Characteristics for the participants and studies included in the IDA.

Study	N	*M* (*SD*) Knower Level	*M* (*SD*) Age (months)	*M* (*SD*) Count Disks	% *N+1* givers at pretest	Weeks between pre and post
1	23	2.04 (1.02)	42.04 (4.45)	5.13 (4.07)	35	4
2	39	2.72 (1.07)	49.92 (8.53)	7.28 (4.98)	21	5
3	63	2.49 (1.05)	54.59 (6.13)	7.89 (5.25)	30	5
4	37	2.08 (.92)	41.02 (3.23)	5.46 (5.20)	32	3
5	10	2.10 (.88)	40.51 (3.26)	8.30 (6.57)	10	2
6	19	2.11 (.88)	41.56 (3.24)	7.53 (4.50)	26	4

Table 2. Give-*N* Knower Level and *N*+1 giver status

Knower Level	**Not an *N*+1 Giver**	***N*+1 Giver**
One	22	23
Two	56	12
Three	36	9
Four	24	9

Table 3. Characteristics for the participants and studies included in the meta-analysis.

Study	**N**	***M* (*SD*) Modified Knower Level**	***M* (*SD*) Age (months)[11]**	***M* (*SD*) Count Disks**	**% *N+1* givers**	***M* (*SD*) Point to *X***	***M* (*SD*) What's on this Card**
1	32	3.44 (1.32)	41.71 (4.09)	7.66 (6.20)	28	-	9.69 (4.15)
2	79	4.03 (1.17)	50.73 (7.82)	9.67 (6.05)	11	13.38 (2.23)	-
3	100	3.66 (1.28)	56.70 (6.11)	10.18 (5.80)	21	-	10.71 (3.85)
4	54	3.07 (1.21)	42.28 (4.09)	7.80 (6.10)	31	11.48 (2.85)	-
5	18	3.89 (1.32)	41.74 (3.60)	9.00 (7.11)	06	12.78 (2.37)	-

Table 4. The effect of being an *N+1* giver when compared to performance of full knowers on a separate measure of number word understanding.

Study	**Cohen's *d***
Study One (WOC; $N = 32$)	-.679
Study Two (P*X*; N=81)	-.269
Study Three (WOC; $N = 101$)	-.384
Study Four (P*X*; $N = 54$)	-.313
Study Five (P*X*; $N = 18$)	-1.593
Mean Cohen's *d*	**-.411**

Note: Study five had the largest effect, but excluding it from the meta-analysis does not alter conclusions (Mean $d = -.386$, $p = .012$)