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Picture Book Features Influence the Use of Complex Modifiers During Shared Number Book Reading

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Abstract

In English, adjectives typically appear in a position where the modifier precedes the noun (*e.g., "the blue car," "three ducks"*). Utterances in which the modifier comes after the noun (*e.g., ducks, we have three*) are far less common. Despite this, recent studies suggest that hearing number words after the groups of objects they describe help children learn the meaning of number words (Ramscar et al., 2011; Gibson et al., 2020). The current study explored how specific features of number books might influence the frequency of number-after-noun utterances during a shared book reading session between parent-child dyads. We hypothesized that number books that vary the category of objects counted across sets (e.g., *one puppy, two lambs, three kittens*) would encourage the number-after-noun construction. We used data from an existing study in which parent-child dyads (n = 157; child's M_{age} = 44 months; 88 girls, 69 boys; 91.72% of parents self-reported as white) were randomly assigned to read two number books. Results revealed that parent-child dyads who read number books that change the referent category across sets use more number-after-noun utterances (*e.g., "Oh look, a ball. We have three.")* than those who read books with the same referent category across sets (*one puppy, two puppies, three puppies*).

Keywords: Number Talk; Shared Book Reading; Learning Design

Introduction

There is wide variability in the age at which children demonstrate understanding of cardinality. While some demonstrate understanding as early as the age of three, others do not demonstrate understanding until the age of five (Sarnecka & Lee, 2009). Research continues to investigate ways to mitigate these differences and improve children's understanding of the cardinality principle (Assis & Corso, 2020; Hannula-Sormunen et al., 2020; Orrantia et al., 2022; O'Rear & McNeil, 2019; Paliwal & Baroody, 2020). A developing area of interest within this domain is the influence of linguistic structure on the acquisition of number words- specifically, how positioning numerical information (simple prenominal modification versus more complex modification) affects children's learning of number words. In English sentences, these modifiers are used in information structures intended to highlight object-feature relationships. In the simple prenominal modification, the modifier precedes the object with the typical structure: Determiner-Cardinal-Noun (e.g., "The three balls"), whereas in more complex modification, the object precedes the modifier (e.g., "Look at the balls, there are three!"). The simple prenominal modification is a key syntactic feature of adjectives in the English language, as modifiers predominantly appear before the noun. In contrast, the complex structure (also referred to as modifier-after-noun in this study) is less common because it doesn't follow this pattern (Thorpe & Fernald, 2006).

Despite the modifier-after-noun being structurally more complex than the simple prenominal modifiers in English, evidence suggests that, in the case of number modifiers, the more complex structure may facilitate children's learning of cardinality (Ramscar et al., 2010). Ramscar, Dye, Popick, and O'Donnell-McCarthy (2011) conducted a study to examine whether children might learn number words based on the linguistic structure used to teach them. Using picture slides, young children learned about numbers by hearing the noun precede the number modifier ("What can you see? Balls. There are two.) or prenominally ("What can you see? There are two balls."). Results revealed that providing number information with the complex modification significantly improved children's understanding of number words. Similarly, studies that included the use of number words after the noun label in parent-child storybook sessions found that children in these sessions improved their

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counting skills and cardinal understanding (Carrazza & Levine, 2024; Gibson et al., 2020). These findings support the idea that how number language is structured and presented to children influences their understanding of the cardinal meanings of number words. A plausible explanation is that the simple prenominal modification focuses on the noun (there are three BALLS), whereas the more complex description first focuses on the noun (Look at the BALLS) and then on the number (there are THREE). Hearing number words in this complex structure directs and encourages children to think about how the number relates to the set it describes (how "THREE" relates to "BALL").

Given this limited but emerging research on the connection between modifier-after-noun structure and children's number learning, the current study aimed to investigate the frequency of modifier-after-noun number descriptions in parent-child interaction during a shared number book reading interaction. We focused on shared number book interaction because it is suggested as one of the most effective ways to introduce children to mathematical concepts, thereby improving their understanding of numbers (Uscianowski et al., 2018; Mix et al., 2012; Ginsburg et al., 2018; Wade & Moore, 1988). To our knowledge, no research has investigated the frequency of using modifier-after-noun structure in the descriptions of cardinality.

Particularly, the current study aimed to answer whether the features of counting books influence the occurrence of modifier-after-noun structure during the interaction. The focus on counting books is motivated by the wide variety of these books available to parents. Furthermore, research demonstrates that shared reading of picture books is effective in introducing children to early mathematical concepts such as counting and cardinality (Ginsburg et al., 2018; Purpura et al., 2021; Purpura et al., 2017; O'Rear & McNeil, 2019; Jennings et al., 1992; Mix et al., 2012; Petersen et al., 2014). Counting books vary in features such as the number of ways a cardinal value is represented, the highest value included, the patterns in which countable objects are presented, representational status, and so on. These features may influence how individuals interact with the books. For example, O'Rear et al. (2023) analyzed the role of counting book features on parental input, specifically use of comparison talk. Comparison talk entails both counting and providing a cardinal label for the same set of objects in close temporal contiguity (e.g., "Look, this page has three crackers. Let's count them: 1, 2, 3!"). This talk facilitates the understanding that the cardinal label and the last word counted convey the same meaning (Mix et al., 2012; Paliwal & Baroody, 2018). O'Rear et al. found that comparison talk was significantly higher when reading books that contain a high word count and multiple representations of number.

The current study specifically examined whether the objects being counted in counting books (use of a same referent category versus different referent categories) influence how dyads use modifiers after nouns. Books in which the *same referent category* is counted across pages involves using sets of a consistent type of object to represent cardinal labels (e.g., one ball, two balls, three balls). In contrast, those in which *different referent categories* are counted across pages vary the types of objects to represent cardinal labels (e.g., one ball, two cars, three chairs). We hypothesized that dyads who read picture books featuring different categories would use more modifier-after-nouns (highlight the referent category before introducing number words) than those who read books featuring the same referent category across pages. This hypothesis is based on a simple assumption that the presence of different categories in books naturally encourages dyads to explicitly label and differentiate the distinct category labels on each page, prompting a possible increase in modifier-after-noun use (making both the category and number word salient). In contrast, the presence of a same referent category may reduce the need for explicit labeling on every new page, since the repeated category provides familiarity, potentially leading to a reduced reliance on modifier-after-noun structure.

Method

Participants

164 parent-child dyads were recruited from the broader South Bend, Indiana community in the United States. A total of seven parent-child dyads were excluded from the study: one dyad because most of their book-reading conversation was not in English, one dyad because they were non-verbal, one dyad because of parental interference during task administration, and four dyads because the child did not assent to working with the experimenter. The final participant sample included 157 participants (child's M_{age} = 44 months; 88 girls, 69 boys; 125 mothers, 22 fathers; 144 white, 2 Asian, 2 Black, 4 Hispanic, 1 American Indian, 4 Biracial or Multiracial).

This data was obtained from a larger NSF-funded project focused on examining the effect of tactile book features on reading behavior. Each dyad was randomly assigned to either a tactile or non-tactile book condition. Within each tactility condition, two out of six possible books were randomly selected by dyads to read.

Book Conditions

Some counting books read by dyads in the study used the same referent category across all the counted sets (e.g., one penguin, two penguins, three penguins; *see Figure 1a*). Other books used different referent categories across sets (e.g., one fox, two beavers, three skunks; *see Figure 1b*). The original study was not designed to test our question, but dyads read two randomly assigned counting books during their session, so we could categorize dyads into into one of three conditions based on the number of books they read that used different referent categories across sets:

Zero: Neither of the counting books used different referent categories across the presented sets.

One: One book used the same referent category, and the other book used different referent categories.

Two: Both books used different referent categories.

Figure 1a: Sample pages from one of the counting books that used the same referent category across sets

Figure 1b: Sample pages from one counting book that used different referent categories across sets

Coding

A previous study coded the book reading sessions between dyads for numerical utterances such as cardinal labels, counting, and comparison talk. The present study. also coded for dyads' frequency of use of modifier-after-noun during interactions on number words.

Complex Modifier (Modifier_after noun) included instances where the category label was highlighted before introducing number words (e.g., "Oh look a puppy, we have one"). Coding was restricted to the to-be-counted set, rather than any random mention of a category. Coders assigned a score of one if the category was mentioned before either a new cardinal label and/or count and a score of zero if a category was mentioned after either a cardinal label and/or count. Two trained coders coded for modifier-after-noun to ensure reliability. Inter-rater agreement was 94.5%.

Cardinal labels included parent-child use of any number words. On a page with just one category, if an individual stated "one" without pointing gestures, it was coded as a label. However, the mention of just "one" was not recorded as a label on a page with a larger set size. The total frequency of cardinal labeling was calculated as the sum of the frequency of parent labels and child labels. This total provided a measure of the overall frequency of labeling during the book reading sessions. A second coder assessed the transcriptions for a randomly chosen 20% of the dyads first book reading. Inter-rater agreement was 96.8%.

Counting included any string of number words, regardless of correctness. On a page with just one category, counting was scored as a number word accompanied by a pointing gesture (e.g., Child [points to the ladybug]: "One ladybug"). A parent, child, or a combination of both could also complete a count. The score for total count frequency was calculated by summing the total independent child count, independent parent count, and parent-child team count. A second coder assessed the transcriptions for a randomly chosen 20% of the dyads first book reading. Inter-rater agreement was 93.5%.

Comparison talk was coded for when the last word of a count matched a labeled utterance on the same set for our analysis. Interruptions of a count or non-matching labels were not coded as comparison talk (e.g., The parent counted four items on the page, and the child labeled the set as six). Additionally, instances where, after counting items, an individual talks about the category before providing the correct set label were still coded as comparison talk. For example, if a child counted three penguins and talked about the penguin before they stated that there were three penguins, it was considered comparison talk. Each instance of comparison talk was further coded according to who the speaker was and whether or not talk was spontaneous (i.e., extratextual talk). Comparison talk could be completed by the child, parent, or a combination of both. For example, if the child counted to eight and the parent labeled the same set as eight, it would be considered a comparison talk. A second coder assessed the transcriptions for a randomly

chosen 20% of the dyads first book reading. Inter-rater agreement was 97.7%. It is important to note that compared to studies investigating parents' naturalistic and spontaneous comparison talk (Goldstein et al., 2016; Mix et al., 2012), the comparison talk data used in this study was more holistic, consistent with O'Rear et al. (2023). The data included parents' independent comparison talk, children's independent comparison talk, and a combination of both, thus providing an extensive view of the learning environment children are exposed to during number talk.

Results

The goal of this study was to investigate whether counting books with different referents predict dyads' use of modifer_after noun talk. Descriptive statistics of dyad interactions and book features are presented in Table 1.

To test whether the book referent condition (both same, one same and one different, or both different) affected dyads' use of modifier-after-noun structure, we conducted a one-way ANOVA with the frequency of use of modifier-after-noun structure as the dependent variable and the book referent condition as the fixed factor. To provide a wholistic view of the number of modifier-after-nouns used during a shared book reading session, the total number of complex modifications for parents and children was combined to provide an overall measure of the dependent variable. There was a significant main effect of book condition on dyad's use of modifier-after-noun, $F(2, 154) = 12.713$, $p < .001$, $\eta^2 = .142$. To examine whether books with different referent categories would increase dyads' use of modifier-after-noun talk, we conducted a polynomial contrast analysis. Results revealed a strong linear trend $F(1,154) = 22.328$, $p < .001$, indicating that as referent variation increased, so did the use of modifier-after-noun structure. A planned comparison showed that dyads who read *Two* books with different referent categories ($M = 5.89$, $SD = 5.430$) produced significantly more modifier-after-noun structures than dyads who read books with *Zero* different referent categories ($M = 1.89$, $SD = 1.950$) and *One* book each of same and different referent categories ($M = 2.93$, $SD = 2.526$). The quadratic trend analysis was not significant $F(1, 154) = 3.35$, $p = .069$.

To further contribute to the discourse on the benefits of modifier-after-noun for numerical understanding, we ran a post hoc exploratory analysis to investigate whether there was a correlation between book referent condition, dyads' use of modifier-after-nouns structure, and comparison talk. Our focus on comparison talk is grounded in prior research suggesting that labeling a cardinal set and immediately counting it rapidly improves children's cardinal understanding (Mix et al., 2012). Given recent findings on the benefits of modifier-after-noun structure for children's number learning, we sought to explore how these two beneficial factors might relate. We explored potential mediation, with book features as the independent variable, comparison input as the outcome, and modifier-after-noun input as the mediator.

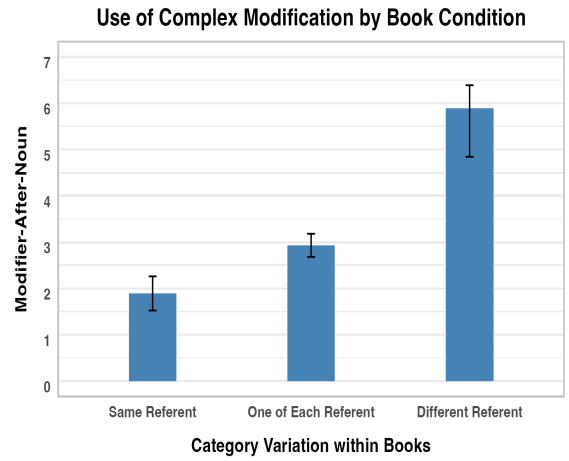

Figure 2: Mean use of Complex Modification in the different book referent conditions

In the first step, we conducted a linear regression to investigate whether book features predicted the use of comparison talk, while controlling for the total words per book in the counting books. Results indicated that book referent condition significantly predicted dyads' use of comparison talk ($\beta = 3.892$, $p = 0.02$), with dyads who read books containing different referent categories engaging in more comparison talk, even after accounting for word count per book. Next, we investigated the association between the use of modifier-after-noun structure and comparison talk, again controlling for the total words per book. Results showed a positive association between modifier-after-noun structure and comparison talk ($\beta = 0.409$, $p = 0.01$).

We also performed a series of robustness checks, to examine whether other book features might account for our findings. First, we considered the language structure of the book, noting that 12 of the 13 possible books were written in a prenominal format (modifier_before noun). Controlling for the influence of the one exception book did not alter the significance of our original result. Also, in controlling for either number of words per book or number of sentences per book, separately, in both linear regression and mixed-effect model models, the effect of book referent condition on the use of modifier_after noun remained significant.

Variable	Min.	Q1	Q3	Max	Med.	Mean	SD
Total Dyad Turn	16	41.00	83.00	204	56.00	66.56	34.88
Total Child Turn	0	14.00	35.00	100	22.50	26.68	17.04
Total Parent Turn	1	26.00	48.00	103	34.00	38.72	17.77
Modifier_After Noun (Dyads)	0	.00	2.00	19	1.00	1.60	2.07
Modifier_Before Noun (Dyads)	0	9.00	11.00	20	10.00	9.85	2.41
Total Words per Book	52	122.00	258.00	326	164.00	181.36	84.96
Total Sentence per Book	10	15.00	32.00	46	21.00	23.91	11.99

Table 1. Descriptive Statistics of Dyadic Interaction, and Book Feature

Twelve of the thirteen books in the study featured a rhyming structure, though not all rhymes consistently appeared on each page. The one exception, which did not include rhyming, belonged to the same referent category.

Finally, to examine potential mediation, we conducted a mediation analysis, including book referent condition and modifier-after-noun structure as predictors while controlling for words per book. The analysis revealed that modifier-after-noun structure was a significant predictor of comparison talk. Specifically, the Average Causal Mediation Effect (ACME) was found to be statistically significant ($\beta = 0.398$, $p = 0.03$), while the Average Direct Effect (ADE) was not significant $\beta = 1.682$, $p = 0.24$). These findings suggest that the book referent feature facilitates the use of modifier-after-noun structure. In turn, the use of modifier-after-noun structure leads to more comparison talk. This finding suggests that the modifier-after-noun structure may play an important mediating role in the link between book features and comparison talk.

General Discussion

The current study aimed to examine how a specific feature of counting books affects the use of modifier-after-noun structure in the utterances of parent-child dyads during a shared book reading session–specifically, whether books featuring different referent categories across pages prompted more frequent use of modifier-after-noun utterances (noun labels before introducing number words), compared to books using the same categories across all pages. Results revealed that the type of counting book influenced dyads' use of modifier-after-noun structure. Parent-child dyads were more likely to highlight the category of an object first before counting or labeling it when they encountered a variety of different object categories within a counting book. These results suggest that book design may be a tool for scaffolding parent-child behaviors during shared book reading. Furthermore, our exploratory analysis revealed that exposure to books with a variety of different referent categories encourages parent-child use of the complex modification structure, which in turn may facilitate increased use of comparison talk, a book reading behavior that has been shown to improve children's understanding of cardinality (Mix et al., 2012; Paliwal & Baroody, 2018).

The current study provides a valuable foundation for exploring how specific picture book features, such as the inclusion of different referent categories, can support the development of children's number knowledge and broader numerical reasoning skills. Research on the benefits of reading counting books suggests that it is a powerful tool to improve children's early mathematical skills, especially counting and understanding the cardinality principle (Mix et al., 2012; Wade & Moore, 1998; O'Rear & McNeil, 2019). For example, Petersen et al. (2014) found that children who practiced counting with picture books demonstrated an increased understanding of cardinality compared to children who practiced with physical objects. Similarly, a structured parent-child book reading study revealed that picture number books significantly improve children's numeracy

development (Gibson et al., 2020). These results suggest it may be helpful to incorporate picture counting books in the learning environment to promote children's numerical understanding.

Research on picture books is gradually extending to focus on the specific book features and contents that support children's development. For instance, interactive picture books with manipulative features (e.g., lifting flaps to cause the animals to move) have been shown to impede children's learning about labels and facts (Tare, et al., 2010; Chiong & DeLoache, 2013), and the numerosities offered in picture books (e.g., 1-3 or 4-6) affect children's number knowledge (Gibson, et al., 2020). However, despite various extensive systematic analyses on the features of picture books in mathematics (Splinter et. al., 2022; Ward et. al., 2017; Powell & Nurnberger-Haag, 2015), research on how the book features influence children's mathematical understanding remains limited. This gap includes investigating the book feature examined in this study (presence of same or different referent categories) and its relation to children's understanding of cardinality—association that potentially exists based on our exploratory analysis.

In a similar focus on number learning, recent research also suggests that the use of modifier-after-noun structure in stating number words might be beneficial for promoting understanding of cardinality (Ramscar et al., 2011; Carrazza & Levine, 2024; Gibson et al., 2020). Just as picture books are suggested as beneficial within the learning environment, evidence from studies including modifier-after-noun structure highlights that the linguistic details of the number words children encounter may distinctly influence their learning of the cardinal meaning of words. Research on complex modification reflects a broader principle on how information structure significantly shapes children's learning process. This is especially significant in mathematical contexts, as children are never exposed to numerical sets in isolation when learning number words. For example, a child may encounter "three dogs" or "three apples" but will never encounter a "set of three" independent of a specific referent category, and must therefore learn to discriminate between the meanings of number words and words describing other category features (Ramscar et., 2011). Future research could further explore the relationship between book features, specifically linguistic features such as rhyming, prosody and intonation and the improvement of children's early math knowledge.

One limitation of this study is that it focuses on how a specific book feature within counting books elicits modifier-after-noun structure within a single parent-child shared book reading session. While the books assigned to participants were random, there may have been other features within each book and session that influenced parent-child interaction but were not captured in the coding. Additionally, the data for this study were focused solely on parent-child book reading in a single session, providing only a snapshot of interactions rather than a comprehensive understanding of how these interactions vary with repeated exposure to counting books. Lastly, the sample in this study was fairly homogeneous, with most parents (> 90%) self-identifying as White and being from the Midwestern United States. Results may not generalize, particularly when considering that research has identified race-related differences in the features of books that best facilitate early number understanding. Research suggests that Black and non-Black children may exhibit differing rates of learning when exposed to books with tactile versus non-tactile features (Cobb et al., 2022).

Overall, this exploratory study deepens our understanding of how early numeracy can be shaped by linguistic and literacy inputs such as complex modifier structures and design features of picture books. Further theoretical development and empirical work in this area may foster the design and co-creation of new strategies for supporting children's understanding of numbers through language-rich instructional contexts.

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