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Morphological Bootstrapping in Children's Small Number Concepts: Evidence from Mandarin-English Bilinguals

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Early numerical cognition research shows that preschool children gradually map number words onto pre-existing nonverbal representations of quantity, such as object tracking for small sets and the approximate number system for larger sets [1,2]. Classic work using the Give-N task demonstrates that children pass through knower-levels: "one-knower," "two-knower," etc., before they become cardinal-principal knowers who can generate any set within their counting range. In addition, learning the exact meanings of small number words is a protracted process that can take 18–24 months even after children begin to say the words.

A substantial body of work argues that grammatical morphology helps children construct these early mappings, a view often called "morphological bootstrapping" in numerical cognition [3,4]. In languages such as English that obligatorily mark singular vs plural on count nouns, children can use these markers to infer a basic "one vs more than one" distinction even before they fully understand number words. For example, 22- to 24-month-old English learners look longer when a plural noun phrase ("there are some cars in the box") is followed by the reveal of only one object, showing that plural morphology alone encoded expectations about numerosity [5]. Similarly, Kouider et al., reported that around 20 to 24-month-old, English-speaking children begin to mark and comprehend the singular-plural distinction and initially rely on an analytic strategy that uses free morphemes and lexical items (e.g. a, some, two) rather plural -s alone. Such findings suggest that grammatical number provides an early, pervasive cue to individuation and early numerical concepts [3].

Cross-linguistic comparisons reinforce this idea. Le Corre and colleagues compared English-learning and Mandarin-learning children and found that English learners are six months ahead of the Mandarin learners when acquiring the exact meaning of "one", despite similar performance on nonverbal numerical tasks [6]. In addition, work with languages that mark a singular–dual–plural distinction (e.g., Slovenian, Saudi Arabic) shows that children in dual-marking languages learned the meaning of "two" earlier and at higher rates than English learners, implicating morphological number as a driver of small-number word learning [7]. Together, these studies suggest that children exploit morphological paradigms to narrow down candidate meanings for early number words.

At the same time, more recent research nuances this picture. Studies of bilingual preschoolers show that the construction of counting principles appears to be language-general, whereas the meanings of small number words are acquired independently in each language.

Wagner and colleagues (2019) studied English Spanish bilinguals and found that children often learn to count to larger numbers (e.g., five and above) around the same time in both languages, but they may know the exact meaning of "one," "two," or "three" in one language but not the other. They suggested that delays in number-word learning reflect difficulties in mapping words to concepts rather than in constructing numerical concepts themselves. From this perspective, morphology is a crucial type of mapping cue among many, operating alongside input frequency, discourse context, and pragmatic contrast.

Classifier languages such as Mandarin add another layer to the morphology of numerical constructions. Instead of using inflectional markings on plural nouns, classifiers are obligatory in quantification constructions in Mandarin Li & Thompson [8]. Classifiers typically appear in a numeral–classifier (CL)–noun frame, for example "yi ge ren" ("one CL person"). There are approximately over 1,000 classifiers in modern Chinese Jiang, but the general classifier (ge) is repeatedly reported as extremely frequently used and can be used with a wide range of nouns especially in colloquial language McEnery & Xiao, and it is mastered by Mandarin-speaking children as early as age of two Erbaugh [9-11]. The general classifier is also highly grammaticalized and lost its original meaning (i.e. bamboo sticks used for counting), and now it signifies individual units and serves as a function word as opposed to other classifiers that are less grammaticalized and cares more semantic weight [12].

Abundant research has been done on the syntactic and semantic aspect of the general classifier (e.g. Chan, but few has investigated general classifier's role in individuation [12]. Cheung, Barner and Li worked on how individuation is realized in Mandarin [13]. They investigated with Mandarin-speaking adults and older children regarding how the general classifier "ge" and the diminutive suffix -zi facilitate the concept of individuation. Their results indicate that these two grammatical morphemes are indeed associated with individuation in acquisition, but they may not contribute critically to the meanings of nouns in acquisition. Other studies such as Le Corre and colleagues tend to make indirect inferences, and correlation between the acquisition of "ge" and the concept of one or individuation without direct measurement [6]. More precisely, Le Corre, et al., reported that the complexity of classifiers and the lack of morphological inflection for singular and plural notions contributed to Mandarin children's delay in acquiring early numerical concepts. However, their analysis on classifiers is based an online dataset which is independent of their study and they did not test their participants directly on their knowledge of classifiers including the general classifier.

Given how ubiquitous the general classifier is in Mandarin and how it indicates individual units, there has been work on whether generic classifier serves a role analogous to English "a/an" in children's early number word learning. Atagi and Sandhofer studied in Japanese, another classifier language with generic and specific classifiers, and showed that parents' use of numeral classifiers changes with age and that increased use of specific classifiers is associated with children's number understanding [14]. They argue that generic classifiers offer a consistent morpho-syntactic frame for numerals, potentially facilitating the mapping between number words and their meanings. Yet most of this work has focused on classifier acquisition and general number knowledge, not on the fine-grained individuation function of a single general classifier such as Mandarin ge in toddlers.

Furthermore, cross-linguistic morphology studies rarely target children younger than three, in part because classic tasks like Give-N are challenging for 2-year-olds. This leaves open how morphology and classifiers interact with very early numerical cognition in the 2–4 age range, particularly in bilingual children who experience two different systems of individuation (such as English and Mandarin). Bilingual work indicates that small number words are learned separately in each language Wood et al., but has not yet tested whether specific morphosyntactic devices, such as ge versus "a/an" support comparable individuation of objects in bilingual toddlers [5].

Together, these strands of work converge on a picture in which early numerical cognition is grounded in robust nonverbal quantity representations, but the pace and pathway of small number–word learning are shaped in important ways by the morphosyntactic resources of each language. Grammatical number in languages like English appears to give children an especially transparent route into the "one vs more than one" contrast, while dual systems further privilege "two," and classifier systems like Mandarin offer an alternative route via obligatory quantificational frames, i.e. the classifier noun phrase frames. At the same time, bilingual evidence suggests that children's core counting principles remain largely language-general, and that morphology functions primarily as a set of language-specific mapping cues—alongside input frequency, discourse structure, and pragmatics—rather than as the sole determinant of numerical concept acquisition. Crucially, despite extensive work on plural morphology and on classifier semantics, we still know little about how particular morphosyntactic devices that signal individuation, such as English a/an and Mandarin ge are used by very young children to link small number words to discrete units, especially in bilingual contexts. This gap motivates a focused investigation of 2- to 4-year-old Mandarin–English bilinguals that directly measures their knowledge and use of ge and a/an and relates these to their emerging understanding of small numbers, to clarify how the morphology of quantification structures interfaces with the earliest stages of numerical concept development.

The Participants

The children recruited in this study were two Mandarin–English bilingual children residing in suburban regions of New Jersey. Both participants' dominant language at home was Mandarin, and their language of schooling was English. Both children began attending daycare at 18 months of age. At the time of data collection, Child 1 was a 27-month-old (2 years 3 months), and Child 2 was a 37-month-old (3 years 1 month). The parents of both children were immigrants from China, all with graduate-level education or higher, and the families' income levels were in the middle-class range (see table 1).

Table 1: The Participants

Participant	Age	Gender	Preschool experience	Home language	SES	Parental Education
Child One	27-month- old	Female	9 months	Mandarin	Middle class	Graduate and
Child Two	37-month- old	Male	19 months	Mandarin	Middle class	above Graduate

Table 2: Summary of Results

Participant	Counting		Give-N task		Give-N task	
	Mandarin	English	Mandarin	English	Mandarin	English
Child One	10	4	2	0	12/16	8/16
Child Two	10	10	4	4	14/16	16/16

Data were collected in the children's homes in a quiet location with minimal distraction, with the children seated on their mothers' laps. Data collection took place on weekday afternoons after the participants returned from preschool. The participants did not attend the same preschool, but the schools were similar in curriculum design and teaching philosophy, and both schools were located in the same neighborhood. Thus, their immediate school contexts were expected to be relatively homogeneous. Both participants started preschool at 18 months; therefore, at the time of the experiment, Child 1 had been in school for 9 months and Child 2 for 19 months. Preschool experience was treated as equivalent to English exposure, because both children's home language was Mandarin and preschool constituted their main source of English input. In addition, Child 1 was female and Child 2 was male, and parents reported typical early development in Mandarin for both children.

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The Tasks

This project investigated whether and how language development interacts with early numerical concepts. Specifically, it addressed the following questions:

1. How do these two children differ in their early numerical cognition, such as rote counting and the cardinal principle?
2. How do these children differ in their language development in terms of linguistic constructions for individuation?
3. How do these children's performances differ in their home and school languages?

To address these questions, the project used three tasks.

Task 1: Rote counting

The participants were asked to count to the largest number possible. Wooden blocks were provided to facilitate counting, and the highest number the child could verbally count to was recorded. Prior research indicates that rote counting is more closely related to language and memory than to children's understanding of the numerical meanings of number words [15]. Therefore, rote counting in this study served primarily as an indicator of early language development rather than numeracy.

Task 2: Give-N task

The Give-N task is a classic developmental paradigm used to measure children's understanding of number words and the cardinal principle [1]. It reveals children's grasp of the one-to-one mapping between number words and the quantities they denote. Therefore, this task was designed to tap children's early numerical concepts.

In this task, the participants were asked to give a specified number of wooden blocks to the experimenter. The highest number the child could consistently provide was taken as their number-knower level [2]. Specifically, when a child could not correctly give N+1 (e.g., four) blocks after three consecutive trials, N (e.g., three) was registered as the child's knower level.

Task 3: Elicited imitation of individuation constructions

Elicited imitation is an oral repetition task widely used as a language assessment tool to measure proficiency and implicit grammatical knowledge [16]. This task is appropriate for young children in early stages of language development because spontaneous production tasks can demand linguistic resources beyond their current repertoire. The goal of this task was to assess participants' sensitivity to linguistic structures used to describe individual objects/nouns in the target language and their ability to reproduce these structures. Failure to imitate likely indicates that the child either had difficulty detecting the linguistic structures or understood them but could not repeat them due to memory constraints.

Participants imitated the experimenter in reading a list of quantifying noun phrases, using picture cards as prompts. Cards were selected based on two criteria: (1) the depicted object/noun was likely to be familiar to the participants, and (2) the noun took classifiers falling into three categories: (a) general classifier, (b) specific classifiers, and (c) classifiers for animals. The participants were not expected to produce the nouns before hearing the interviewer. Only their accuracy in imitation was used as an indicator of language development. For a comprehensive list of cards and classifiers, see table 3.

Table 3: Elicited Imitation List

No.	English	Mandarin	Target elicitation/E	Target elicitation/M	Classifier
1	Doll	doll [wáwá]	A doll	A doll	[gè], generic classifier, meaningless, indicate individuation
2	Apple	Apple [pínggao]	An apple	An apple	
3	Ice cream	Ice cream [bīng-jīlíng]	An ice cream	An ice cream	
4	Ball	Ball [qíu]	A ball	A ball	
5	Bus	Bus (gōng-jiāochē)	A bus	A bus	vehicle[liàng], classifier for vehicle
6	Flower	Flower [huā]	A flower	A flower	flower[duo], classifier for cloud shaped things
7	Tree	tree [shù]	A tree	A tree	tree[kē], classifier for plants
8	Umbrella	Umbrella [yu-san]	An umbrella	An umbrella	put[ba], classifier for things operated by hands
9	Caterpillar	[máomáochóng]	A caterpillar	A kapok	only[zhī], classifier for in human animated things
10	Buffalo	[shuiníu]	A buffalo	A head of water	head[tóu], classifier for big sized animals
11	Elephant	Elephant [dàx-iàng]	An elephant	An elephant	head[tóu], classifier for big sized animals
12	Snake	Snake [shé]	A snake	A snake	strip[tiáo], classifier for slender, thin, long, narrow objects/artifacts
13	Duck	Duck [yāzi]	A duck	A duck	
14	Butterfly	Butterfly [húdié]	Two butterflies	Two butterflies	Only [zhī], classifier for in human animated things
15	Bear	Bear [xióng]	Three bears	Three bears	
16	Fox	fox [húli]	Four foxes	Four foxes	

All tasks were conducted in Mandarin and English. The sequence of tasks was administered flexibly to maintain participants' engagement, and children were allowed to take breaks between tasks.

Results and Discussion

Even though the two children were raised in broadly similar environments and differed in age by only 10 months, their language and early numerical cognition differed. The older child appeared to be ahead of the younger child on all three measures in this experiment (see Figure 1). Both children were able to count from one to ten in Mandarin, but in English, Child 1 counted to four while Child 2 counted to ten. Child 1's knower level in Mandarin was two and zero in English. Child 2's knower level was four in both languages. Child 1 was more accurate in imitation in Mandarin than in English, whereas Child 2 was more accurate in Englishthan in Mandarin (see Figure 2).

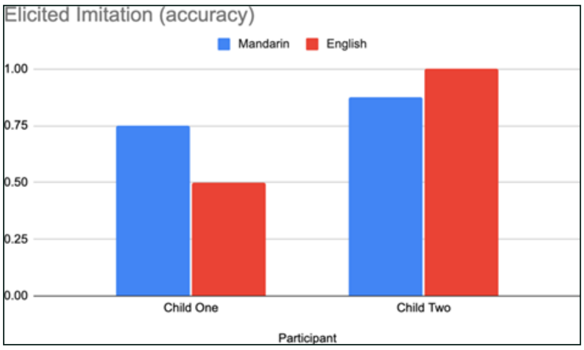

Figure 1: Early Numerical Concepts

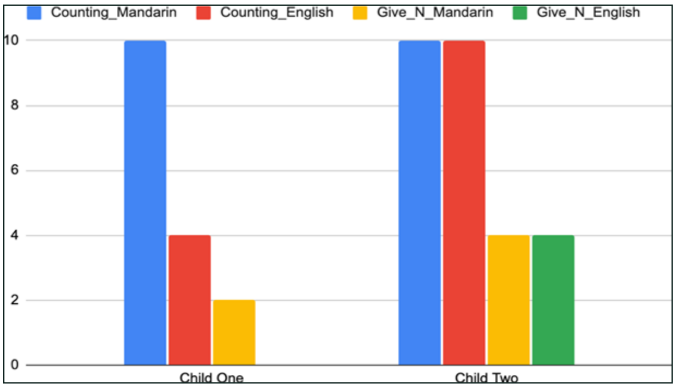

Figure 2: Individuation Structure Imitation Accuracy

Early Numerical Cognition: Rote Counting and Cardinal Principles

Rote counting may have limited direct relevance to numerical cognition. Child 1 was able to recite numbers from one to ten but could not give numbers greater than two. Similarly, Child 2 could rote count to ten and understood numbers up to four. This pattern aligns with prior findings that rote counting primarily reflects language and memory, rather than conceptual understanding of number [1,2,15].

The older child was ahead of the younger child in numerical cognition. The 37-month-old child counted to ten and knew the numerical concepts of one, two, three, and four. When asked to give five, the child grabbed a handful of blocks and then added two more (for a total of six blocks) on two trials and confirmed that this was "five" {Child 2, 1:54}. The way the child grabbed the blocks suggested that "five" meant "a lot" for him. In contrast, when he counted from one to four, he picked up blocks one by one, indicating that he used the blocks as mental tools for counting individual objects and registering the numbers. The 27-month-old child recited numbers from one to ten but could not give numbers greater than two in either language. This suggests that the 27-month-old was still at an early stage of learning number-word meanings.

This pattern is consistent with prior findings that children typically begin to learn the exact meanings of "three" and "four" between 2.5 and 3 years of age (Le Corre & Carey, 2007).

Language Development in Individuation Constructions

The older child outperformed the younger child in the imitation task in both languages. The 37-month-old imitated the experimenter with near-perfect accuracy (see Figure 2), omitting only two phrases in Mandarin. In contrast, the 27-month-old repeated the phrases approximately half of the time. Children around 2 to 3 years of age are developing language rapidly, including a wide range of grammatical and lexical features [17]. Additionally, both children performed similarly across languages in the imitation tasks. Child 1's accuracy in Mandarin was comparable to her accuracy in English, and Child 2's accuracy in Mandarin was similar to his accuracy in English. This suggests that children in this age range are adept at detecting structural patterns across their two languages.

Theories of language development propose that children rely heavily on statistical learning mechanisms, enabling them to identify and exploit distributional cues in linguistic input without discriminating based on typological differences [18]. From this perspective, the children's ability to imitate individuation constructions in both Mandarin and English is consistent with the view that young learners can generalize structural patterns across languages given sufficient exposure.

Performance in Home vs. School Language

The participants performed similarly in their home language, suggesting that they were likely at comparable developmental stages in their first language, Mandarin. In contrast, the older child was more advanced in all English measures relative to the younger child. The 37-month-old could count to higher numbers, knew more exact number words, and performed better in imitation than the 27-month-old. In particular, when imitating the English noun phrases (e.g., "a caterpillar"), the younger child frequently omitted the article and only repeated the head nouns (e.g., caterpillar). The 37-month-old, by comparison, was more advanced in recognizing and repeating the English article.

This pattern is consistent with the literature, which shows that English-monolingual children begin to use articles such as a and the around age 2–3 and typically master them after age 4 [19]. In addition, the older child's progress in English is likely attributable to greater school experience, given that the older child had 19 months of English exposure while the younger child had 9 months. Preschool experience is pivotal because both children's dominant language at home is Mandarin, and school is their primary source of English input. Thus, it is plausible that more school experience contributed to better performance in English and facilitated development in the second language [20].

The Significance of Input in Early Bilingual Language Learning

Beyond the older child's advancement in English, both children showed clear effects of their school experience. For instance, the older child counted in English even when the instruction was given in Mandarin {Child 2, 0:47}. He insisted on using English when counting. This was not surprising to his mother, who reported that he often speaks English at home and that she sometimes interacts with him in English, including in conversations and shared book reading.

The younger child also provided an interesting case. During the elicited imitation task, she often named the object or animal on the card before the interviewer and predominantly used Mandarin. However, when she saw the bus {Child 1, 2:04} and the flower {2:16}, she opted for the English words even though the test was in Mandarin. This may be because flower and bus were words she acquired in preschool, likely in meaningful interactions with teachers and peers.

The older child's greater school experience appears to highlight the importance of input quantity, and the younger child's selective use of English words underscores the importance of input quality. Quantity refers to the frequency of exposure, whereas quality refers to how well input is contextualized and embedded in meaningful interactions [17,21]. It is generally predicted that words presented in rich, interactive contexts are more likely to be retained than words presented in decontextualized formats, such as being read from a list or displayed on a board [17]. In this sense, the quantity and quality of preschool input created conditions that allowed these young learners to acquire a second language that they did not use at home.

An Interesting Observation

When the younger child imitated classifier-embedded noun phrases, she tended to transfer the previous classifier to the next noun. For example, after hearing and imitating *yī bă yŭsăn* ("one CL[handled object] umbrella") {child 1, 2:33}, she saw the next image, a buffalo, and produced yī ba niú ("one CL[handled object] buffalo") {2:40}. This was not the only instance of such transfer; across eight unique individual classifiers, she attempted to transfer five of them.

In other words, she appeared to pick up a classifier from one imitation and extend it to the next structure. She may have quickly recognized the pattern "one + classifier + noun," or she might have acquired this frame earlier and, upon encountering a new classifier, immediately tested it in a novel context. However, it remains unclear why the transfer always involved the immediately preceding classifier. That is, the child never attempted to use a classifier heard several phrases earlier. The current project cannot address this question because of its task design. To determine whether transfer can occur across longer distances, future designs would need to present nouns sharing the same classifiers at varying distances and examine learning effectiveness at those distances.

Limitation and Future Directions

One major limitation of this experiment concerns the number of blocks provided. Instead of preparing 10 blocks, the experimenter should have prepared at least 20. There are two reasons for this. First, when only 10 blocks are offered, a child is more likely to count to 10 and stop; if the child can count beyond 10 but only 10 blocks are available, their true counting ability is masked. Second, in the Give-N task, when only 10 blocks are available and trials are administered in ascending order, by the time the child is asked to give four, they may have only four blocks left. In that case, they can simply hand over what remains and treats that as "four," even if they do not truly understand the quantity four. Providing more than 10 blocks would mitigate this issue.

The elicited imitation task design also needs to be more interactive and engaging for young children. The task in this project included 16 classifier noun phrases, which may have been too many for the participants. Although the experimenter attempted to maintain the children's attention using onomatopoeia and mimicking animal sounds, Child 1 quickly lost interest in repeating and refused to cooperate in the English portion of the experiment. She also attempted to reverse roles during the Mandarin elicited imitation task. She took the cards and asked the experimenter, "What is this?" {4:06}. She then failed to imitate the interviewer because she wanted to take the lead and ask questions rather than follow instructions and imitate her interlocutor.To maintain young participants' engagement, future studies could reduce the number of classifiers tested and focus on a smaller subset, such as animal classifiers or shape classifiers.

Finally, elicited imitation is inherently constrained by what is elicited, and imitation is not equivalent to spontaneous production, which is often considered a closer index of underlying language competence [16]. Future investigations should therefore include language production tasks such as picture description, story narration, or semi-structured interview questions. With such production data, additional analyses, such as mean length of utterance and lexical diversity, could provide richer insights into children's language development [22-27].

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