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PARALLEL DEVELOPMENT OF NUMERALS AND NUMERAL CLASSIFIERS IN CHILDREN'S ACQUISITION OF MANDARIN CHINESE

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ABSTRACT

In light of the view that numeral classifiers and numeral bases function as multiplicands (Greenberg 1990, 293; Her 2012a; Her et al. 2017; 2018), this study investigates Mandarin-speaking children's acquisition of numerals (Num) and numeral classifiers, which consist of sortal classifiers (C) and mensural classifiers (M), in the construction of [Num C/M N]. We conducted four elicitation experiments with four age groups, from 2 to 5. In line with previous studies, the results show that Cs appeared before Ms, and before the children were able to use various appropriate C/M for different nouns, *ge*[5], the general classifier, appeared as a placeholder, indicating their understanding of the requirement of a C/M when quantifying N with Num. More importantly,

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the findings for the first time reveal a parallel development between numeral bases and C/M. This robust correlation implies that children's grasp of numerals and numeral bases facilitates their acquisition of C/Ms. This finding, in turn, lends support to the view that numeral bases and C/M converge cognitively as multiplicands.

KEYWORDS

Numeral classifier **N**umeral base **M**ultiplication **L**anguage acquisition

1. INTRODUCTION

Typologically, Mandarin is a textbook example of classifier languages (e.g., Allan 1977; Cheng and Sybesma 1998; Erbaugh 2002; Zhang 2012). Numeral classifiers come in two varieties. A sortal classifier (C) indicates a particular inherent semantic feature of the noun, e.g., *ben* in (1a) refers to a bound volume, while a mensural classifier denotes a quantificational unit, e.g., *ping* 'bottle' in (1b).

(1) a.	三本书		
	san^{1}	ben^{3}	shu^{1}
	three	C	book
	'three books		
b.	三	瓶	水
	san^{1}	ping^{2}	shui^{3}
	three	$M_{\text{-bottle}}$	water
	'three bottles of water'		

Her (2012a; 2012b) demonstrates that C/M occupy the same structural position in the [Num C/M N] construction and are mutually exclusive, and functionally converge as the multiplicand of Num, the multiplier, but diverge in their respective mathematical values, i.e., a C necessarily denotes the numerical value of 1, while the values of Ms can be numerical, e.g., 2, 6, 12, etc., or non-numerical, e.g., weight, length, volume, etc. This mathematical view, which renders the relation between Num and C/M as multiplicative, offers a fresh perspective on the cognition, and also children's acquisition, of numeral classifiers.

The multiplicative view has been supported by a number of studies, e.g., in terms of syntax: Her (2012b), Her, Chen and Tsai (2015), Her (2017a), and Her and Tsai (2020), in terms of formal semantics: Wu and Her (2021), in terms of typology: Her (2017b), Her, Tang, and Li (2019), and Tang and Her (2019), and in terms of psycholinguistic and neurolinguistic experiments: Her, Chen, and Yen (2017; 2018), Chen, Her, and Yen (2018), and Tang, Chen, Yen, and Her (2021). Nonetheless, the implications for language acquisition have yet to be explored.

For children to acquire classifiers, they need to acquire both the syntactic structure and the semantic constraints. Previous studies have thus focused on the emergence and comprehension of the grammatical structure of the classifier phrase and the semantic compatibility between C/M and the head noun. In light of the multiplicative view of numeral classifiers, this study explores the implications of C/M as a multiplicand and the different mathematical values Cs and Ms encode in language acquisition.

The paper is organized as follows. Section 2 offers a distinction between Cs and Ms under the multiplicative view and demonstrates that numeral bases and C/M function similarly as multiplicands. Section 3 summarizes previous studies on children's acquisition of numerals and numeral classifiers. Section 4 presents the motivation and methodology of this experimental study. Section 5 reports the results of the experiments, and section 6 discusses the implications. Section 7 concludes the paper.

2. NUMERAL CLASSIFIERS AND NUMERALS

We will first examine the convergence and divergence between numeral bases and numeral classifiers and that between Cs and Ms under the multiplicative view.

2.1 Numeral bases and numeral classifiers

Most languages employ addition and multiplication in their numeral systems (Comrie 2013). Comrie (2006) proposed a general formulation for the composition of both addition and multiplication in the numeral systems, as in (2).

(3) $(x \times \text{base}) + y$, where $y < \text{base}$

In Chinese, the base is an exponential of 10, e.g., *shi* '10', *bai* '100', *qian* '1000', etc. The composition of *yi-bai san-shi jiu* (一百三十九, one-hundred three-ten nine) ‘139’ can thus be rendered as [(1 × *100*) + (3 × *10*) + 9], where the numeral bases are multiplicands, and the preceding numerals, multipliers. In line with Dowker, Bala, and Lloyd’s (2008, 525) criteria for the regularity, or transparency, of a spoken number system: ‘the degree to which it gives a clear and consistent representation of the base system (usually base 10) used in the language and the consistency of conformity between the spoken and the written number system (usually the Arabic number system)’, Chinese is well-known for its highly transparent number-naming system.

Her (2012a; 2017a; 2017b) further explored Greenberg’s (1990, 293) initial insight that numeral bases and C/M ‘harmonize’ in word order in classifier languages and explicitly stated such harmonization in terms of word order parameters.

(4) Base-parameter & C/M-parameter

a. Base-parameter: base-final [*n base*] or base-initial [*base n*]

b. C/M-parameter: C/M-final [Num C/M] or C/M-initial [C/M Num]

(5) Harmonization between base-parameter & C/M-parameter

c. C/M-final order ⇒ base-final numerals

d. C/M-initial order ⇒ base-initial numerals

Mandarin, like all Chinese languages, has a base-final system, e.g., 三百 *san-bai* (three-hundred) ‘300’, and a C/M-final order, e.g., 三本书 *san-ben shu* (three-C book) ‘three books’. A natural consequence is thus the adjacency of numeral bases and C/M, e.g., 三百本书 *san-bai-ben shu* (three-hundred-C book) ‘three hundred books’.

Numeral bases and classifiers thus converge mathematically as multiplicands, while they diverge in their syntactic categories: numeral bases are part of the numeral system, and classifiers form a unique grammatical category different from numerals and nouns. However, the convergence and harmonization of numeral bases and classifiers imply a close connection between the acquisition of the numeral system and that of classifiers.

2.2 Sortal classifiers versus mensural classifiers

Cs and Ms are conventionally seen as two subcategories due to their different semantic properties (e.g., Allan 1977; Cheng and Sybemsa 1998; 1999; Erbaugh 2002; Zhang 2012). Her (2012a) proposed an alternative, though complimentary, and viewed that the functional relation between Num and C/M in a noun phrase is multiplication; Cs and Ms thus converge in their functions as the multiplicand, but diverge in their respective values, as in (5).

(6) C/M Distinction in Mathematical Terms (Her 2012a, 1679)
[Num X N] = [[Num × X] N], where X = C *iff* X =1, otherwise X = M.

Consider the Cs in (6a) and Ms in (6b). Though each of the three different Cs in (6a) highlights a different semantic aspect of the fish, their mathematical values as the multiplicand of the multiplier 3 are identical, i.e., 1. The three Ms in (6b), however, differ significantly in the mathematical values they denote as the multiplicand of the multiplier 3.

(7) a. 三条/尾/只 鱼 [[3 × 1] FISH]

san^{1}	tiao^{2}/wei^{3}/zhi^{1}	yu^{2}
three	$C_{\text{-elongated}}$/$C_{\text{-tail}}$/$C_{\text{-animate}}$	fish

'three fish'

b. 三群/斤/箱魚 [[3 × school/catty/carton] FISH]

san^{1}	quan^{2}/jin^{1}/xiang^{1}	yu^{2}
three	$M_{\text{-dozen}}$/$M_{\text{-pound}}$/$M_{\text{-basket}}$	fish

'three schools/Chinese kilos/cartons of fish'[1]

Under this mathematical view, the values of Cs are numerical and fixed at 1, while the values of Ms are not 1 but can otherwise be numerical or non-numerical, and fixed or not fixed. Accordingly, Ms can be classified into four subcategories (Her, Chen, and Yen 2017).

Table 1.
Types of C/M Based on Mathematical Value

Numerical or Not	Fixed or Not	Examples		C/M Type
Numerical	Fixed	***1***	个 ge^5, 只 zhi^1, 条 tiao^2, 本 ben^3, 朵 duo^3	**C**
		¬***1***	2 双 shuang^1, 对 dui^4; 6 手 shou^3; 12 打 da^3	**M_1**
	Variable	>***1*** (¬***1***)	排 pai^2 ‘row’, 群 qun^2 ‘group’, 帮 bang^1 ‘gang’	**M_2**
Non-numerical	Fixed	¬*n* (¬*1*)	斤 jin^1 ‘catty’, 升 sheng^1 ‘liter’, 码 ma^3 ‘yard’	**M_3**
	Variable	¬*n* (¬*1*)	滴 di^1 ‘drop’, 节 jie^2 ‘section’, 杯 bei^1 ‘cup’	**M_4**

Those Ms with a fixed numerical value, such as *shuang^1* (双, 2), *dui^4* (对, 2) ‘pai^r’, *shou^3* (手, 6) ‘hand’, and *da^3* (打, 12) ‘dozen’, are of the M_1 type. Given the fixed numerical values of the M_1 type classifiers, they resemble numeral bases the most, since the latter also must have exact numerical values, i.e., exponentials of 10. M_1 classifiers thus provide the best examples for the generalization that numeral bases and numeral classifiers converge mathematically as multiplicands, e.g., *san^1 shi^2* (三十, three ten; 3 × *10*) and *san^1 da^3* (三打, three dozen; 3 × *12*). In contrast, those of the M_2 type, e.g., *pai^2* (排) ‘row’, *qun^2* (群) ‘group’, and *bang^1* (帮) ‘gang’, have unspecified numerical values larger than 1. Ms with non-numerical values likewise come in two types, one with fixed values, and the other, variable values. Ms of the M_3 type, e.g., *jin^1* (斤) ‘catty’, *sheng^1* (升) ‘liter’, *ma^3* (码) ‘yard’, and *chi^3* (尺) ‘foot’, have fixed non-numerical values. Ms of the M_4 type, such as *di^1* (滴) ‘drop’, *jie^2* (节) ‘section’, *bei^1* (杯) ‘cup’, *xiang^1* (箱) ‘box’, and *wan^3* (碗) ‘bowl’, have variable non-numerical values.

Cross-linguistically, Her, Hammarström, and Marc Allassonnière-Tang (2022) have adopted this view and constructed WACL (World Atlas of Classifier Languages), by far the largest database of classifier languages. In this database, 723 languages among 3,338 languages examined have been identified as having a numeral classifier system.

Such a mathematical C/M distinction has intriguing implications for research on Mandarin-speaking children’s acquisition. First of all, we can examine the acquisition of numeral classifiers in terms of the C/M distinction, which suggests that children acquiring Mandarin should eventually be able to distinguish Cs from Ms. There are two possible acquisition sequences. One possibility is that Mandarin-speaking children acquire C and M in different fashions from an early stage on, while the other possibility is that children acquire C/M in a similar fashion at an early stage and develop an awareness of the C/M distinction at a later stage. The other implication of the mathematical view concerns the connection between the acquisition of numeral classifiers and the development of multiplication in numerals. Therefore, the primary aim of this study is to understand Mandarin-speaking children's acquisition patterns of Cs and Ms and the potential connection between C/M and numerals.

3. ACQUISITION OF CLASSIFIERS AND NUMERALS

3.1 Acquisition of classifiers

Numeral classifiers are a common feature in East and Southeast Asian languages (Yamamoto 2005); thus most of the studies of children's acquisition of classifiers are concerned with some of these languages, e.g., Japanese (e.g., Matsumoto 1987; Uchida and Imai 1999), Thai (e.g., Gandour et al. 1984; Carpenter 1992), Cantonese (e.g., Wong 2000), and Mandarin (e.g., Chien, Lust, and Chiang 2003; Erbaugh 1984; 1986; Fang 1985; Hu 1993a; 1993b). These studies are mostly concerned with the acquisition of the syntactic structure of the classifier phrase, [Num C/M N], the semantic aspect of classifiers, or the acquisition order of different classifiers, especially the use of the general classifier, e.g., *ge*^{5} (个) in Mandarin.

Erbaugh (1984; 1986) compared children's acquisition of numeral classifiers to the historical development of the classifier system in Chinese. Based on both elicited data and longitudinally collected conversations produced by four different children, from 1;0 to 3;10, Erbaugh observed three developmental stages: (a) children before 2;6 use Cs as lexical items and do not use Cs according to their specific features, (b) children expand their vocabulary of Cs and use specific Cs only with prototypical nouns at around 2;6, and (c) by the age of 3, children notice semantic features and generalize the use of Cs and thus apply Cs to new and non-prototypical nouns.

Fang (1985) examined the acquisition order of 12 Mandarin numeral classifiers on the basis of elicited data from three groups of children: four-year-olds, five-year-olds, and six-year-olds, and a developmental trend was observed: *ge*^{5} (个), *shuang*^{1} (双), *ben*^{3} (本), *zhi*^{1} (只), *tiao*^{2} (条), *pi*^{1} (匹), *jian*^{4} (件), *ke*^{1} (棵), *ke*^{1} (颗), *liang*^{4} (辆), *zhang*^{1} (张), *kuai*^{4} (块), and *zuo*^{4} (座). At the first stage, children use the general classifier *ge* in overextension. Then, they demonstrate the awareness of semantic features and use the corresponding classifiers, such as *ben* (本, for books) and *shuang*[1] (双, for paired objects). Finally, they are aware of special perceptual semantic features, such as *zhang*[1] (张, for two dimensional items) and *zuo*[4] (座, for three dimensional items). Children thus seem to first form a conceptual understanding of the classifiers on the basis of their respective concrete referents and then apply such concepts to other compatible items.

Hu (1993a; 1993b) examined 24 Mandarin-speaking children's production and comprehension of 12 Mandarin numeral classifiers selected from four semantic domains: animacy, arrangement, function, and shape. Results showed that the children first use the general classifier to hold the place for the potential classifiers, and then they develop the awareness of the semantic features of classifiers and acquire the use of the proper classifiers. In addition, Hu also observed a slow acquisition pace of these selected classifiers. The emergence of first one or two classifiers was observed at around age 3, and by age 5 these children appeared to use three classifiers on average, and by the age of 6 the children were found to use around only five classifiers. Hu's comprehension study further indicated that the children appear to comprehend more classifiers than what they actually produce.

The disparity between children's comprehension and production of classifiers is further consolidated by Chien, Lust, and Chiang's (2003) study, where they investigated 80 Mandarin-speaking children's comprehension of 14 Cs and 4 Ms. They found that children's understanding of classifiers appears to be much better than their production. At around age three these children are able to comprehend about half of the 14 Cs and 4 Ms, and they can comprehend nearly as adults do at around the age of seven.

In the past few decades, researchers who are concerned with Mandarin-speaking children's acquisition of classifiers have apparently turned their focus to the hypothesis, proposed by Cheng and Sybesma (1998), that classifiers can be used to encode the mass-count distinction syntactically in Mandarin. The study by Li, Barner, and Huang (2008) was purportedly the first empirical study to test this hypothesis. With the findings obtained in three experiments, they indicated that although children aged from four to six might not have had a good command of the distinction of count-mass classifiers, they were found likely to match syntactic phrases to their corresponding objects. This in turn may have shown their understanding of count-mass distinction in Mandarin classifiers. In a following study, Li, Becky, and Hsiao (2010) observed that children are found able to use classifiers to specify shape first. As reported, the two-year-olds were found to know little about classifiers, and the three-year-olds were found able to generalize the rudimentary uses of classifiers, while the four-year-olds can have developed rudimentary knowledge of most mensural classifiers. In addition, they also reported that the children's use of quantifiers can be considered to develop after they have acquired numerals, and it is safe to say that the grasp of numerals seems to be a driving force for children to acquire classifiers, particularly quantifiers.

Moreover, Huang (2019) investigated how countability is encoded in Mandarin nominals, wh-pronouns, and quantifiers. She pointed out that classifiers appear to determine the countability of the head nouns, and argued that the count-mass distinction in Mandarin Chinese is syntactically determined, but not semantically. This study's findings thus lend further support to the theoretical framework adopted in the present study that the function of classifiers, Cs or Ms, are syntactically determined, although their respective mathematical features and values can differ.

3.2 Children's acquisition of numerals

Children are generally found to understand numerals, such as *one, two, three, four* and *five*, at around the age of 2, and English-speaking children's comprehension of numerals is found to be closely related to their awareness of quantifiers (Barner, Chow, and Yang 2009). While the ability to recite a series of numerals does not necessarily indicate that they have developed the meaning of numerals, children are found to develop numeral meanings between 3 and 4 years of age (Le Corre and Carey 2007; Le Corre, Van de Walle, Brannon, and Carey 2006; Wynn 1990). Wynn (1992) further noted that the acquisition of the cardinal meaning of number words does not necessarily mean the ability of sequence counting or enumerating objects. On the other hand, Hwang's (2021) study indicated that children's rote counting ability seems to predict their comprehension of complex numerals. Hwang also pointed out that preschoolers are able to comprehend complex numerals, particularly those involving a multiplicative relationship between a digit and a numeral base, before they develop the ability to produce them.

Developing the concepts of numerals and quantifiers can be hard, and children may deal with such difficulties by using syntactic or semantic priming (Gleitman, 1990; Grimshaw, 1981; Pinker, 1984). English-speaking children may take advantage of the structure of an NP, where a numeral or quantifier modifies the head noun, and infer the meaning of numerals and quantifiers (Bloom and Wynn, 1997). With the NP bootstrapping, English-speaking children gradually develop the following concepts: that both numerals and quantifiers can modify count nouns (e.g., *three cats/many cats*), that both can denote some part-whole relation (e.g., *three of the cats/some of the cats*), that neither can appear between an adjective and the head noun (e.g., *the little smelly cat, *the big three/many cats*), and that the numeral *one* and the determiner *a* both denote sets of one, while other numerals and quantifiers denote sets of "any number but one" (Barner and Snedeker 2005; Carey 2004; Li, Le Corre, Shui, Jia, and Carey 2003).

In spite of the rich body of research on English-speaking children's acquisition of numerals and Mandarin-speaking children's development of numeral classifiers, few research findings are yet available concerning the connection between children's development of numeral classifiers in a classifier language such as Chinese, Japanese, and Vietnamese and their acquisition of numerals and numeral bases. The purpose of this study, therefore, is to shed some light on such a connection under the multiplicative view of numeral classifiers.

3.3 Research Questions

The findings in the literature are presented and discussed under the simple assumption that Cs and Ms are semantically different. The underlying mathematical convergence and divergence between Cs and Ms have thus far not been taken into account in any study of L1 acquisition. Previous studies do treat C/M as one syntactic category, given their identical syntactic position. However, their different mathematical values as multiplicands of Num, the multiplier, imply that children's comprehension and production of Cs and Ms may come at different stages. Therefore, one aspect of this study is to investigate whether Mandarin-speaking children acquire Cs and Ms in an identical fashion and at what stage they become aware of the C/M distinction.

In addition, an important finding in the literature shows that Mandarin-speaking children first use the general classifier *ge*[5] (个) as a placeholder to indicate their awareness of the [Num C/M N] construction. It is thus an intriguing question: What motivates children to become aware of this? Under the multiplicative view of C/M, we can hypothesize that children's awareness of simple numerals, e.g., *er*[4] (二) 'two', *san*[1] (三) 'three', and *si*[4] (四) 'four', and complex numerals with numeral bases, e.g., *er*[4]*-shi*[2] (二十) 'twenty', *san*[1]*-shi*[2] (三十) 'thirty', and *si*[4]*-shi*[2] (四十) 'forty', is closely related to that of C/M and that children acquire the mathematical concepts in numerals before they acquire C/M. An awareness of the multiplicative relationship between Num and C/M is thus assumed to motivate the acquisition of the [Num C/M N] structure.

The multiplicative relation in the [Num C/M] construction and the interlocking relationship between numerals and C/M nonetheless have not been examined and tested by secondary empirical data from language acquisition (cf. Barner et al., 2009). The other aspect of this study therefore attempts to investigate the connection between the development of numeral system and that of children's acquisition of C and M. This interlocking relationship may presumably lie in children's developmental pattern of concepts of numerals and multiplication and in their acquisition sequence of C and M. As pointed out in the literature, children may develop the ability to count numbers before they can actually comprehend the meaning of numerals. Children may develop their comprehension of numerals on the basis of the syntactic and semantic information suggested in all the NPs they are exposed to. By the same logic, children may rely on the syntactic and semantic information in [Num C/M N] and foster their mathematical comprehension of multiplication. This study will be based on this assumption and explore the connection between numerals and C/M. Specifically, this study aims to answer the following research questions:

(a) At what age do Mandarin-speaking children grasp such mathematical concepts as numerals?

(b) At what age do Mandarin-speaking children acquire the distinction between Cs and Ms, particularly in the mathematical sense?

(c) What is the connection between Mandarin-speaking children's acquisition of C/M and the development of numerals and multiplication?

4. METHODOLOGY

4.1 Experiment design

Following Tse, Li, and Leung (2007) and Tran (2011), the experiment in this study was designed to prompt children to spontaneously produce the target NP with the required use of C/M. Specifically, picture cards and Lego blocks were designed to elicit children's spontaneous production of [Num C/M N]. We have thus not adopted the techniques of syntactic frames to prime children's production of C/M, where the children would not have many linguistic cues of the intended C/M. The experiment consisted of a set of four tasks: (i) the rote counting task, (ii) the block counting task, (iii) the matching task, and (iv) the C/M match task (cf. Barner et al. 2009).

Rote counting task

This task aimed to obtain the maximal number to which each participant could count by rote. The experimenter asked the participants whether they could count by rote and then they were asked to count starting from one. The maximal number reached by each participant served as the reference number for the following two tasks, i.e. the block counting task and the matching task.

Block counting task

The block counting task aimed to test the child participants' ability to count objects. All the participants were given five trials within their rote counting limits to find out whether they could count objects as well as they could in rote counting. For example, if a child participant was found to be able to count to 20 by rote, then s/he would be given blocks in five different numbers under 20, and s/he was expected to count the blocks of the given numbers without errors. If a participant erred in any of the five trials, s/he was given an additional trial to see if the error was accidental. The results of this task indicate that they have developed the awareness of numerals, instead of just having memorized the entire numeral sequence.

Number matching task

The matching task aimed to elicit the children's comprehension of numerals. The participants were given five random numbers within their rote counting range to demonstrate if they understood the numerals as well as they could count. Similar to the block counting task, the participants had five trials, and in each trial, they were given a certain number, and then they were asked to pick the same number of blocks out of a box. Again, if they made an error in one of the five trials, they were given one additional trial.

C/M matching task

Finally, the C/M matching task aimed to examine the participants' ability to use the appropriate C/M with the corresponding nouns in the prompt. The participants were randomly shown 15 pictures of various objects whose number is within their counting capability, and all the objects were selected based on the fact that the participants could name them without doubt on a prior visit. Then, they were asked the following questions consecutively: *zhe^4 shi^4 she^{2}mo^5?* (这是什么？) 'What is this?' and *you^3 duo^{1}shao^3 ne^5?* (有多少呢？) 'How many are there?' The pictures used in this task are shown in the Appendix. The first question was to ensure they know the name of the objects in the picture, and the second question prompted them to quantify the noun, so as to have them produce the target C/M spontaneously. In the task they would not be given any additional trials if they fail to provide the correct C/M, but two additional pictures involving Ms were shown to those who made no errors in the 15 trials to further ensure they have actually grasped the use of Ms.

4.2 Scoring

In the rote counting task, the scoring was the maximal number that the child could count. The scoring of the other three tasks, i.e. block counting, number matching, and C/M matching, was recorded in terms of the number of correct responses; each correct response gets two points. In addition to the accurate use of C/M, in the C/M matching task, we also recorded the frequency of C/M uses in all the trials given to the child participants as well as the types of C/M used by them. Their frequency of C/M uses were recorded in percentage and the types of C/M were noted in type counts.

4.3 The Procedure

Participants were required to complete all four tasks. All participants, parents, and kindergarten teachers were informed of and agreed to this requirement, the procedure, and their rights beforehand.[2] To minimize any learning effect, the first three tasks, i.e. rote counting, block counting, and number matching, were conducted consecutively, in one meeting, while the final task, i.e. C/M matching, took place a week later.

The experiment was carried out by two trained experimenters. One of them directed the tasks and the other observed the process and kept field notes. All tasks performed by all participants were recorded with a camcorder.

4.4 Participants

The participants were 64 Mandarin-speaking children aged from 2 to 5, as suggested by Chien et al. (2003) and Barner et al. (2009).[3] The children were recruited from three different kindergartens: two in northern Taiwan and one in southern Taiwan. They were grouped into four groups: 12 children in the two-year-old group, 19 in the three-year-old group, 14 in the four-year-old group, and 19 in the five-year-old group.

5. RESULTS

The results of the experiment are summarized in Table 2, including the number of participants with valid trials, the maximal number in rote counting, the scoring of the other three tasks, and the frequency of C/M uses in all valid trials.[4]

Table 2.

Mean scores of the four tasks across age groups

Age	Age Range (months)	Mean Age	*N*			Block Counting	Number Matching	Correct C/M	Use of C/M	Rote Counting
			Total	M	F					
2	24~34	31.5	12	9	3	1.50	3.00	2.67	28.92%	<20
3	36~47	40	14	6	8	5.92	5.85	7.08	92.44%	20~50
4	48~57	53	13	8	5	7.08	6.62	31.38	97.56%	50~100
5	63~70	66	18	12	6	9.89	8.22	21.44	99.63%	>100

5.1 Rote counting of numerals

As seen in Table 2, all participants have grasped some understanding of numerals. The children of the two-year-old group could generally count by rote up to 20 without errors or interruptions. The three-year-olds could count higher than 20 and some reached 50. The four-year-olds counted higher than 50 and some reached 100. Finally, the five-year-olds generally counted to 100 and above. Again, the number reached by rote counting does not necessarily mean that they understand what the number represents. Two more tasks, i.e. block counting and number matching, were conducted to test their true understanding of the numbers.[5]

5.2 Block counting

The scoring of the block counting task is shown in the fourth column of Table 2. The scoring indicated in the table is based on the correct trials to the total trials each child took part in, with 10 as the full mark. The overall scoring of the block counting task shows that the children's understanding of numerals developed with age. Although most two-year-olds were able to count to 20 by rote, their understanding of the numerals appears to be premature. They failed most of the trials and got only around one trial correct (mean score at 1.50). The three-year-olds demonstrated a rudimentary understanding of the numerals since they successfully counted the blocks in more than half of the trials (mean score at 5.92). The performance of the four-year-olds was quite similar to that of the age three group, though they scored a bit higher. Finally, the five-year-olds performed the best and succeeded most of the time, and some were able to complete the task perfectly (mean score at 9.89).

5.3 Number matching

The scoring of this task is shown in the fifth column of Table 2. The performance in the number-matching task appears quite similar to that in the block-counting task. The two-year-olds did the poorest, succeeding in around one and a half out of the five trials (mean score at 3.0), while the five-year-olds did the best, completing four and five out of the five trials (mean score at 8.22). Again, the difference between the three-year-olds and four-year-olds appears to be quite minimal (mean score at 5.58 and 6.62 respectively). In general, the children's grasp of the numeral concepts appears to develop with age, and such a tendency is statistically significant on an ANOVA analysis ($F(3, 52)=22.64$, $p<0.001$ for block counting and $F(3, 52)=11.06$, $p<0.001$ for number matching). A regression analysis indicates that the children's both abilities appear to develop with age ($R^2 = .899$, $F(1, 54) = 26.25$, $p < .001$ for block counting and $R^2 = .895$, $F(1, 54) = 26.81$, $p < .001$ for number matching).

Putting the results here together with the results reported in rote counting of numerals in Section 5.1, we can draw the following inferences. First, the two-year-olds may have developed concepts of numerals, though rudimentary, but have not yet grasped concepts of numeral bases. Second, children around the age of four have a good command of the numerals and are likely to have developed concepts of numeral bases, since they were found to demonstrate complex numeral competence by using the numeral base *shi*^{2} (十) 'ten', as in *er*^{4}-*shi*^{2} (two × ten, 二十) 'twenty', *san*^{1}-*shi*^{2} (three × ten, 三十) 'thirty', *si*^{4}-*shi*^{2} (four × ten, 四十) 'forty', etc. The five-year-olds may have developed the concepts of numeral bases, as they were able to count over one hundred by rote, indicating that they have grasped two different numeral bases, i.e. *shi* 'ten' and *bai* 'hundred', and to match the numerals with equivalent numbers of blocks.

5.4 Use of C/M

The children's scoring in the C/M matching task is analyzed in two aspects. One aspect is whether the children use a C/M when quantifying the objects in the pictures. The other concerns the accuracy of the C/M used. Their use of C/Ms noted in percentage is presented in the seventh column under the 'Use of C/M' heading, which means how frequent the children use a C/M in all the test trials. The mean score of their correct use of C/Ms is reported in the sixth column under the 'Correct C/M' heading. The percentage regarding the children's use of C/M shows a clear discrepancy between the age two group and the other groups. As seen in Table 2, the two-year-olds used C/M in the [Num C/M N] constituent only occasionally, around 30% of the trials. On the other hand, the children of the other three age groups were found to use C/M almost all the time when required. The results indicate that the two-year-olds demonstrate a limited grasp of the [Num C/M N] construction, while older children have grasped the nominal construction. A regression analysis indicates that the children's use of C/Ms appears to develop with age ($R^2 = .942$, $F(1, 54) = 44.84$, $p < .001$).

5.5 C/M accuracy

As to their correct use of C/M, there is a notable difference between the two-year-olds and the three-year-olds. The children in the two-year-olds barely used C/M correctly in the [Num C/M N] construction, succeeding in only around 2 of all the trials (mean score at 2.67). The three-year-olds got 3.5 and more of all the trials correct (mean score at 7.08), and the four-year-olds did the best and succeeded in nearly all of the trials (mean score at 31.38), and the five-year-olds on average got more than two-thirds of the trials correct (mean score at 21.44). This age-related development is tested to be significantly different on a one-way ANOVA analysis ($F(3, 52)=48.39$, $p<0.001$).[6] A regression analysis also indicates that the children's accuracy of C/Ms also appears to develop with age ($R^2 = .735$, $F(1, 54) = 8.619$, $p < .001$).

In addition to the accurate use of C/M, the types of C/M these children were able to produce in the experiment are also remarkable. Table 3 below summarizes the types of C/Ms used by the four groups. The distribution of these Cs and Ms among the age groups is shown in Figure 1 and Figure 2, respectively.

Table 3.

Types of numeral classifiers used by all groups

	Age 2	Age 3	Age 4	Age 5
C	个 ge^5	个 ge^5,只 zhi^1,颗 ke^1,台 tai^2, 节 jie^2	个 ge^5, 只 zhi^1, 颗 ke^1, 朵 duo^3, 顶 ding^3, 辆 liang^4	个 ge^5, 只 zhi^1, 颗 ke^1,台 tai^2, 朵 duo^3, 顶 ding^3,件 jian^4
M2				群 qun^2
M4		块 kuai^4	瓶 ping^2, 杯 bei^1, 盒 he^2, 箱 xiang^1	块 kuai^4, 瓶 ping^2, 杯 bei^1, 盒 he^2, 包 bao^1, 篮 lan^2, 份 fen^4

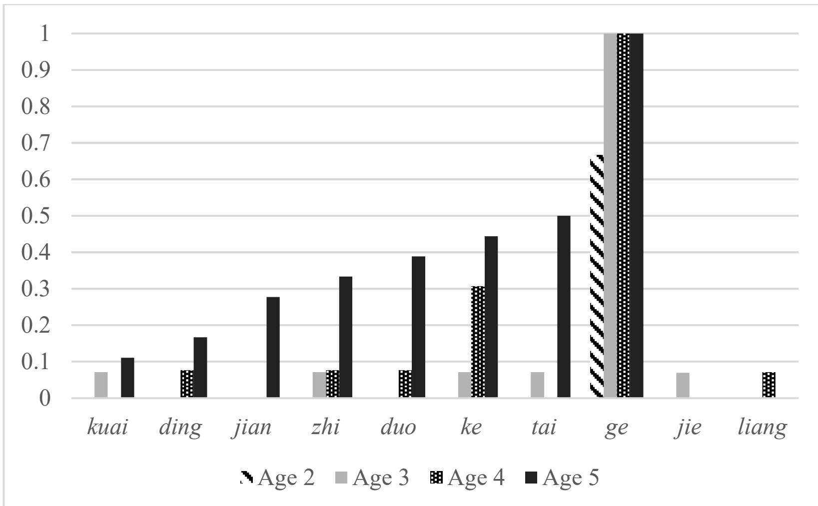


Figure 1. The distribution of sortal classifiers across the age groups

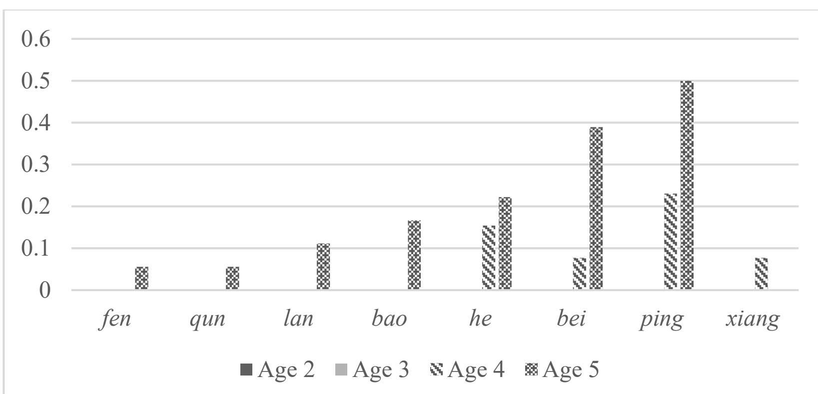


Figure 2. The distribution of mensural classifiers across the age groups

As shown in Table 3, the number of C/Ms used by the children increased with age. The two-year-olds used only *ge*, unaware of the (in)compatibility of ge^5 (个) with the noun in question. The two-year-olds sometimes also used no C/M at all when required. Most of their productions are technically generalizations, and thus the correct use of ge^5 (个) may turn out to be accidental. Some of them even failed to provide any response, though they could name the objects in the picture.

The three-year-olds used Cs besides *ge5* (个), including zhi^1 (只, for animals), *tai*^{2} (台, for machines), *ke*^{1} (颗, for small round objects), and *jie*^{2} (节, for objects in segments). However, each of these Cs was used only once by a different child.[7] Most of the children also used *ge*^{5} (个) to quantify the objects, and this was a typical overgeneralization. Unlike the two-year-olds, the three-year-olds almost always quantified a noun with a C, but they also overgeneralized *ge*^{5} (个) in cases where a different C or an M is required.

The four-year-olds used *ge*^{5} (个) and other Cs, including *ke*^{1} (颗) for round objects, *duo*^{3} (朵) for flowers, and *ding*^{3} (顶) for hats, though the latter two appeared only sporadically, as indicated in Figure 1. However, two of the Cs, *jie*^{2} (节) and *tai*^{2} (台), used by the three-year-olds were not found in this group. The four-year-olds also used several Ms, including *ping*^{2} (瓶) 'bottle', *bei*^{1} (杯) 'cup/glass', *he*^{2} (盒) 'box', and *xiang*^{1} (箱) 'carton'. Such use of Ms was hardly observed in the two younger groups. The four-year-olds nonetheless overgeneralized in some trials, particularly those involving an M_2 in Her, Chen, and Yen's (2017) classification. For example, they referred to flowers with the general classifier *ge*^{5} (个), when *duo*^{3} (朵) should be used, and produced *shi*^{2}-**ge*^{5}-*hua*^{1} (十个花). They referred to three flocks of sheep by counting them individually and produced *er*^{4}-*shi*^{2}-*si*^{4} **ge*^{5} *mian*^{2}*yang*^{2} (二十四个绵羊) 'twenty-four sheep', instead of *san*^{1} *qun*^{2} *mian*^{2}*yang*^{2} (三群绵羊) 'three flocks of sheep'. Note also that they used *ge*^{5} for sheep, not the intended C *zhi*^{1} (只).[8]

Finally, the five-year-olds used the widest variety of C/Ms among the age groups. Apart from the Cs mentioned above, the children here also used the C for clothes, i.e. *jian*^{4} (件), which was not used by the younger children, and other Ms, including *bao*^{1} (包) 'pack', *lan*^{2} (篮) 'basket', *fen*^{4} 'serving', and *qun*^{2} (群) 'group'. This may suggest that the five-year-olds might have demonstrated a potential command of these C/Ms. Although the five-year-olds have had command of most of the Cs, they nevertheless struggled to quantify hats with the specific C *ding*^{3} (顶) and still used the general classifier *ge*^{5}. As to their use of Ms, the five-year-olds used most container Ms correctly, e.g., *bei*^{1} (杯) 'cup', *ping*^{2} (瓶) 'bottle', and *bao*^{1} (包) 'bag', but like the four-year-olds, they still had difficulty in using the collective Ms, e.g., *san*^{1}-*qun*^{2} *yang*^{2} (三群羊) 'three groups/flocks of sheep', and also the M for baskets, as in *si*^{4}-*lan*^{2} *shui*^{3}*guo*^{3} (四篮水果) 'four baskets of fruit'. The addition of Ms and the expansion of Cs can also impose some challenges on the children, since they need to distinguish not only Ms from Cs but different types of Cs (in terms of their semantic compatibility) and in particular Ms (in terms of their mathematical values). This can explain why some five-year-olds performed below the average during the task, and that is why the mean score of the five-year-olds appears to be lower than that of the four-year-olds. This may appear counterintuitive. This study, however, has intended to disclose the overall trend of the children's use of C/Ms. Although there appears to be a decrease in the mean core of correct C/M from age 4 to 5, this decrease may not have distorted the overall trend to a great extent. In addition, in language development, the decrease of a certain acquired form is not rare, and it is found in some acquisitional patterns due to increased overgeneralization. Based on this acquisition pattern, we believe that the children observed have demonstrated a similar pattern and the decrease can be an indicator of their overgeneralization of the use of C/Ms during this age period.

Moreover, we also devised a survey to elicit adult responses to these pictures.[9] In the survey, the adult respondents mostly used *ge*^{5} (个) for such nouns as bread and cakes, and this is commonly acceptable here in Taiwan. Other cases of *ge*^{5} (个) were also found in the adult response, but they were generally less than 10% of all responses to each picture. The results of adult responses can further support the argument that the children's use of the general classifier *ge*^{5} (个) should be considered overgeneralization of *ge*^{5} (个).

6. DISCUSSIONS

6.1. Acquisition of Cs and Ms

The results reported in the previous section indicate that Mandarin-speaking children's use of Cs and Ms develops with age and they acquire Cs before Ms. An awareness of the required C occurs by the age of three, and Ms appear by the age of five, thus completing the [Num C/M N] construction. These findings are consistent with the study by Chen and Her (2018) based on CHILDES corpora and the psycholinguistic study by Her, Chen, and Yen (2017), where Cs are processed faster and more accurately by adults (Her, Chen, and Yen 2017). Such a convenience in processing should have implications in child language acquisition. Given that Cs are fixed with the numerical value 1, Mandarin-speaking children should acquire Cs earlier than Ms, which come in various types of fixed and non-fixed values.

Chen and Her's (2018) study based on CHILDES corpora found that Mandarin-speaking children tend to produce Cs before Ms, and Ms were not observed before the age of five. The children before the age of four tend to primarily use the general C, *ge*^{5}. Although the four-year-olds were found to use several Ms correctly, such uses appear sporadic and limited to particular types of Ms. In contrast, the five-year-olds were found to use Ms more consistently and systematically, and their production of Ms also contains different types of Ms. Therefore, Mandarin-speaking children do seem to acquire Cs before Ms; Cs may be acquired by age three, and Ms, by age five.

The experiment results in the current study accord with the findings in the previous studies and indicate that the use of the general C *ge* may emerge at the age of two, since several two-year-olds were found to use it during the experiment, though not consistently. The use of the general C by the three-year-olds, on the other hand, reveals that the children may have acquired the syntactic understanding of the [Num C/M N] constituent and the grammatical requirement of a C. Therefore, as pointed out in several previous studies (e.g., Erbaugh 1984; 1986; Fang 1985; Hu 1993a; 1993b), before they are able to use a wider range of C/Ms, Mandarin-speaking children use the general C *ge*[5] to hold the syntactic position of C/M in the [Num C/M N] constituent.

6.2 Acquisition of different types of Ms

The findings seem to partially support the theory of Her, Chen, and Yen (2017), where numeral classifiers are categorized into five types. The findings in this study indicate that before the age of four, children are able to use Cs and by the age of five, they are able to use Ms. The four- and five-year-olds produced the following Ms: *ping*[2] (瓶), *bei*[1] (杯), *he*[2] (盒), *xiang*[1] (箱), *lan*[1] (篮), *bao*[1] (包), *fen*[4] (份), *kuai*[4] (块) and *qun*[2] (群), all of the type M_4, thus with non-numerical and variable values, except for *qun*[2] (群), which is an M_2, whose value is variable and numerical. Those M_4 were found to be used by children before the age of four, while the M_2 was found at the age of five. However, whether a natural order exists among the four types of Ms is a subject for future research.

6.3 The acquisition of the semantics of C/Ms

Given the cross-sectional nature of this study, we do not know the acquisition order of C/Ms that appeared within an age group; however, the children's overall performances across the four age groups do offer some indications. As shown in Table 3, the very first C acquired is *ge*[5] (个), which is the general classifier and, crucially, also the predominant C for humans in the language. Other human-specific Cs must understandably come much later, as sociolinguistically *wei*[4] (位) has an honorific connotation and *ming*[2] (名) and *yuan*[2] (员) are somewhat archaic and used more often in formal or literary contexts. Among the Cs appearing after *ge*[5] (个), with distributional patterns taken into account, the following pattern seems to appear: *zhi*[1] (只) > *ke*[1] (颗) > *tai*[2] (台) > *duo*[3] (朵)/*ding*[3] (顶) > *liang*[4] (輛)> *jian*[4] (件). Children thus seem to first acquire the C for humans and general objects, followed by the C for animals, and then a shape C (i.e., *ke*[1] (颗), small and round) and a function C (i.e., *tai*[2] (台), machines). Note that the latest one in the sequence is *jian*[4] (件), a function C for clothing as well as for abstract concepts such as matters and affairs. This pattern thus largely conforms to the Numeral Classifier Accessibility Hierarchy, shown in (4) (Croft 1994; Hansen and Chen 2001).

(8) Animate human > Animate non-human > Shape > Function

In a very recent study, Ma et al. (2023), while revealing a marginally significant age effect, also found that children performed the best with animacy classifiers, followed by vehicle and configuration and classifiers and their comprehension was reliable for animacy, shape, and vehicle classifiers but not for configuration classifiers. Their findings are thus consistent with our study, except for configuration classifiers. The reason is straightforward: because the so-called configuration classifiers such as *qun*^{2} (群) 'group, herd', *pai*^{2} (排) 'row, queue', and *shuang*^{1} (双) 'pair' are all Ms, not Cs. According to the taxonomy of C/Ms in Table 1, *shuang*^{1} (双) is M_1, given its fixed numerical value of 2, and *qun*^{2} (群) and *pai*^{2} (排) both belong to M_2, given their variable numerical value of 2 or larger.

The Ms produced by the children seem to have this order: *ping*^{2} (瓶)>*bei*^{1} (杯)>*he*^{2} (盒)>*xiang*^{1} (箱)>*lan*^{2} (篮)>*bao*^{1} (包)> *fen*^{4} (份)>*qun*^{2} (群). Among them, *ping*^{2} (瓶), *bei*^{1} (杯), *he*^{2} (盒), *xiang*^{1} (箱), *lan*^{2} (篮), and *bao*^{1} (包) are all containers, i.e., bottle, cup, box, carton, basket, and pack, respectively. They all denote the particular amount that a concrete container can hold. On the other hand, the concepts denoted by *fen*^{4} (份) and *qun*^{2} (群) are relatively more abstract conceptually. In general, the children's use of Cs suggests that they acquire animate Cs before inanimate Cs and concrete Ms before abstract ones. Future studies concerning this aspect can further investigate the role of the semantics of Cs and Ms in L1 acquisition.[10]

6.4 Acquisition of numerals, numeral bases, and C/Ms

As shown in Table 2 above, children's correct uses of C/Ms tend to increase with their abilities of numeral counting and number matching. A regression analysis found that their understanding of numerals significantly predicted the children's grasp of C/Ms and is quite robust ($R^2 = .35$, $F(1, 54) = 29.43$, $p < .001$), so are the other predictors, including use of C/Ms and correctness of block-counting and block-matching.[11] This indicates that the development of numerals and numeral bases is highly correlated with their grasp of numeral classifiers.

As to the development of numeral bases, the results in Table 2 indicate that children at the age of three may have a rudimentary concept of numeral bases, since they were able to count over twenty and up to fifty. In order for the children to count to fifty, they should have developed the knowledge of *shi*^{2} (十) 'ten' being the numeral base that serves as the multiplicand for its preceding numerals, so that they were able to produce *er*^{4}-*shi*^{2} (二十) 'twenty', *san¹-shi²* (三十), etc. Their understanding of numeral bases appears to be consolidated at the age of four. As indicated in Table 2, the four-year-olds could count up to one hundred. This shows that they understand *shi²* and *bai³* (百) 'hundred' are numeral bases and function as multiplicands, so that *qi¹-shi²* (七十) 'seventy' can be rendered as *qi¹* (七) 'seven' × *shi²* and *yi¹-bai³* (一百) 'one hundred' as *yi¹* (一) 'one' × *bai³* (百) 'hundred'.

The compositional rule of numerals, i.e., [(x × base) + y], is a key to understanding the natural number system as in learning languages. An anonymous reviewer raised the possibility that the delayed development of complex numerals may be due to adding y to the x base, but not calculating the x base. Let's use *er⁴-shi²-yi¹* (二十一) as an example. The reviewer is thus suggesting that the difficulty may be due to the addition between [*er⁴-shi²* (二十) and *yi¹* (一)], and thus not the multiplication [*er⁴* (二) × *shi²* (十)]. We offer two additional arguments to support our view. First, as shown in Table 2, the two-years-olds count to the teens only, thus simple numerals 1-10 and additive numerals 11-19, whose composition is [10 + y]. The three-years-olds continue to count to 50, thus including multiplicative numerals 20, 30, 40, and 50, whose composition is [x × 10], and also complex numerals (involving both multiplication and addition) in between the round numbers with the composition of [(x × 10) + y], e.g., [(*2* × *10*) + *1*]. The four-year-olds then count to 100. Such a sequence clearly indicates that additive numerals from 11 to 19 appear in acquisition before multiplicative numerals from 20 to 90. Thus, the appearance of the complex numeral 21, [(*2* × *10*) + *1*], predicts the appearance of both 20, [*2* × *10*], 11, [*10* + *1*], and 10, [*10*]. The acquisition of addition in numerals is a prerequisite to that of multiplication. Second, typological studies of the numeral systems of the world's languages provide equally strong evidence that "the existence of multiplication implies the existence of addition", which is precisely Generalization 9 in Greenberg's (1990, 277) seminal work 'Generalizations about Numeral Systems'. Her et al. (2023), in a recent survey of 4099 languages of the world, by far the largest of its kind, reported no exceptions to this generalization. While a small percentage of languages have additive numerals but without multiplicative numerals, no languages are the other way around. Finally, as indicated in Gould (2017), we can rule out the strategy of rote-memorizing when children can produce complex numerals above 50.

The findings indicate a significant correlation between the development of C/Ms and that of numeral bases, as the multiplicative theory predicts. In addition, a significant difference due to age is also observed, as older children are expected to be more competent in the use of numerals and measure words than younger ones. The discussion in 6.1 mentions that the three-year-olds may have developed the use of C/M in the [Num C/M N] construction and they used the general C *ge* to demonstrate this, though around three-fourths of their Cs were semantically inappropriate. Meanwhile, they may also have developed a rudimentary grasp of numeral bases, that is, the use of *shi* as a multiplicand. In addition, the four-year-olds were found to use Cs almost all the time when they were quantifying nouns and the variety of Cs they used expanded, and they were also able to use two different numeral bases, *shi* and *bai*. Given the results in this study and those indicated by the regression analysis reported above, together with Hwang's findings (2021), it is likely that the children's numeral ability facilitates their understanding and correct use of C/Ms.

This observation may seem mundane on its own, as a reviewer points out; however, what is new and significant is the correlated development between numerals, numeral bases, and numeral classifiers, as the multiplicative theory predicts. While these findings do not necessarily prove the multiplicative theory, they are consistent with the theory; otherwise, the theory would have been falsified.

In response to a comment given by an anonymous reviewer, we note that having the implicit cognitive concept of multiplication encoded linguistically does not necessarily afford an advantage in the explicit performance of the arithmetic act of multiplication. In fact, as convincingly demonstrated in Chapter Two of Butterworth (2022), speakers of languages without even the basic simple numerals, let alone multiplicative numeral bases, such as *ten* or *hundred*, have no difficulty in mastering such arithmetic skills when entering a culture where the use of money is important and there is no evidence that their language constitutes a disadvantage. Thus, arithmetical competence may be a by-product of language during evolution and an innate capacity of all humans (Chomsky 2016, 23), and typologically certain languages opt to overtly encode such functions and others do not. This nonetheless calls for further investigation to discover how the development of numeral concepts interact with the acquisition of C/Ms.

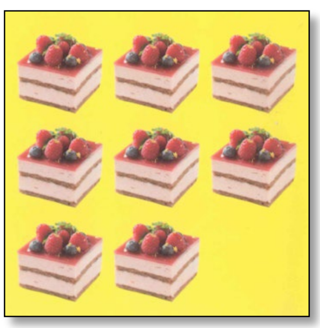
7. CONCLUSION

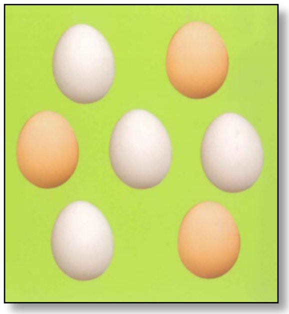
This study investigates Mandarin-speaking children's acquisition of numerals and classifiers under the mathematical view which predicts that sortal classifiers (Cs) should appear before mensural classifiers (Ms), given that Cs are mathematically and conceptually simpler than Ms, and that their acquisition of C/M should be related to their understanding of numerals, particularly numeral bases. The findings show that Cs may be acquired as early as the age of 3 and Ms before 5. Mandarin-speaking children also seem to acquire the general C *ge* first as a placeholder for C/M in the [Num C/M N] construction, as previously reported in Erbaugh (1984; 1986), Fang (1985), and Hu (1993a; 1993b). Furthermore, children before 3 may have acquired that between a numeral and a noun there should be a C/M and use the general C *ge* to demonstrate their grasp of the [Num C/M N] constituent before they acquire a fuller range of C/Ms. The mathematical view of Cs and Ms implies that children's acquisition of C/Ms should be correlated with their understanding of numeral bases. The findings indeed reveal a correlation in this regard, which, however, is not statistically significant. Future studies can further pursue this issue.

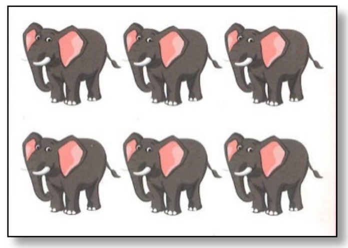
Moreover, the two-year-olds in the study were found to perform better in the number matching task than in the block counting task, while the children in the other three age groups appeared to perform otherwise. Future studies can explain such a discrepancy, which is beyond the scope of this study. Future studies can also explore the correlation between the frequencies of adult use of Cs and Ms in child-directed speech and children's language output. Last but not least, the present study mainly focuses on the distinction between Cs and Ms, while the distinction among the four types of Ms is not explored, which is nevertheless also an intriguing research topic.

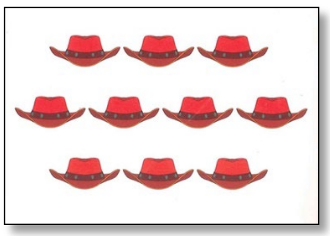
APPENDIX I:
PICTURES USED IN THE C/M MATCHING TASK

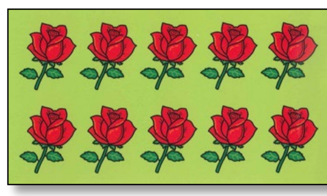
Desirable responses are sortal classifiers

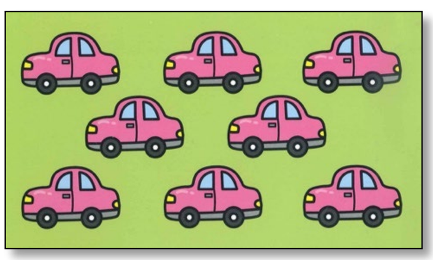


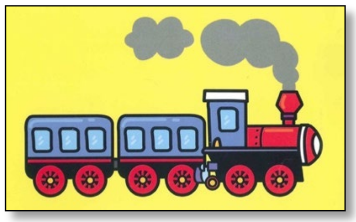


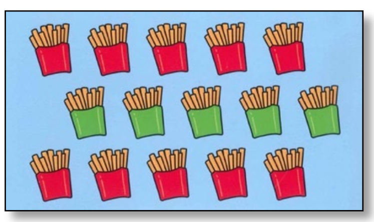


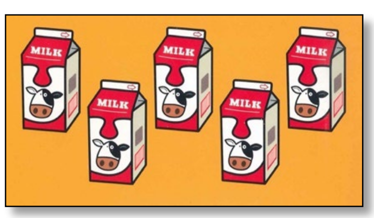


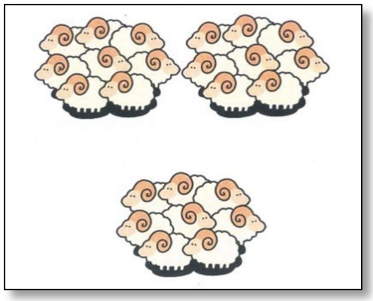


Desirable responses are mensural classifiers:









NOTES

1. This study is primarily focused on Taiwan Mandarin.
2. An informed consent form was explained to the parents and signed by them before the children participated in this experiment.
3. When we were recruiting, around 90 couples of parents were registered for the experiment. Unfortunately, during the informed consent form signing stage, about 40% of them opted out, and most of them expressed that they were concerned about signing the informed consent form, even though they were well-aware of the information in the informed consent form. They were willing to have their children participate in the study, but they would not want to sign the informed consent form.
4. Some of the data appear to be invalid, so that they are excluded for further analysis. Five out of the 19 participants of the Age 3 group and one of the Age 4 and Age 5 groups were excluded.
5. The range of rote counting numbers can be quiet variable in each of the age groups. The respective range of variation in each age group is as follows: Age 2, 1~20; Age 3, 10~100; Age 4, 19~100, and Age 5, 49~100.
6. All acceptable uses in adult speech were considered correct here.
7. In Mandarin there can be two variants of *jie*; one is a C, as what is here, and the other is an M, as illustrated in Table 3.
8. We thank the reviewer for this suggestion. As indicated in the survey on adults, only a small proportion of the adult respondents mistook the picture of five glasses of water as five glasses. Unlike the children's productions reported here, adults mostly responded to the pictures involving Ms correctly.
9. We thank an anonymous reviewer for this suggestion to enrich this study.
10. As an anonymous reviewer has keenly pointed out, an inadequacy in the materials used in the studies reported is the lack of human nouns. This should be remedied in future studies.
11. It was found that the numerals the children knew significantly predicted their block counting ability ($R^2 = .69$, $F(1, 54) = 26.25$, $p < .001$); their block matching ability ($R^2 = .655$, $F(1, 54) = 26.81$, $p < .001$); and their use of C/Ms ($R^2 = .704$, $F(1, 54) = 44.84$, $p < .001$).

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汉语儿童习得数词与量词的对等发展

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摘要

基于量词和位数词都可视为是「被乘数」的观点（Greenberg，1990：293；Her, 2012a；Her 等人，2017；2018），本文进而探究汉语儿童习得【数量名】结构时在数词、位数词和量词上的使用情形；其中量词可分为个体量词与计量量词。本研究执行了四个诱答性测试，涵盖了 2 到 5 岁的四个年龄组。与先前的研究结果一致，显示个体量词的习得先于计量量词，且在儿童能够使用不同的量词来适切地量化名词之前，「个」这个通用的个体量词往往有作为占位符的功能，这表明汉语儿童已理解了同时使用数词与量词来量化名词的必要。更重要的是，本研究发现也首次显示了位数词和量词之间的对等发展，两者之间的显著相关性意味着儿童对数词和位数词的掌握有助于他们在量词上的习得。这项研究发现也进一步支持了位数词和量词在认知上同为被乘数的观点。

关键词

量词　位数词　乘法　语言习得