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Explaining the Acquisition Order of Classifiers and Measure Words via their Mathematical Complexity

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Abstract

We provide theoretical explanation for the acquisition of numeral classifiers (sortal classifiers) and measure words (mensural classifiers) in Mandarin Chinese. Previous research in various languages separately observed that the general classifier is acquired before specific classifiers and that classifiers are acquired previous to measure words. However no theoretical discussion was fully developed and no study combined general classifier, specific classifiers and measure words in one dataset. We propose to fill these gaps by combining *semantic complexity* (Brown, 1973) and a mathematical approach (Her, 2012): given that the relative complexity of x , y and z is unknown, $x + y$ is more complex than either x or y , and $x + y + z$ is more complex than any of them. By applying the mathematical approach, it is observed that general classifier carries the mathematical value of times one, noted x , while specific classifiers possess x plus a semantic value of y , which highlights an inherent feature of the referent. Finally, measure words detain both x and y , along with a new information of quantity z . Therefore, the acquisition order is expected to start from the simplest semanticity and develop toward the most complex, i.e. general classifiers (x) > specific classifier ($x+y$) > measure word ($x+y+z$). As supporting evidence, we gathered longitudinal data from CHILDES (Child Language Data Exchange System; Zhou, 2008). The participants included 110 children from 1-6 years old, providing a total of 110 conversations of 20 minutes each with 1851 tokens of numeral classifiers and measure words. Our methodology applied the definition of acquisition from Brown (1973) and the equation of Suppliance in Obligatory Context (SOC) cross-checked with Target-Like Usage (TLU) from Pica (1983). The results demonstrated that our model generated correct prediction, serving as theoretical basis for future studies in the field of language acquisition.

Keywords numeral classifier, measure word, Mandarin Chinese, semantic complexity, child language acquisition

1. Introduction

Systems of numeral classifiers have already been discussed by linguists from various approaches, whether in terms of typology (Greenberg, 1990; Aikhenvald, 2007; Gil, 2013) or syntax (Li, 1999; Borer, 2005; Yeung, 2007; Yi, 2011; Her, 2010) among others. The so-called classifiers can generally be

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divided into two categories: *classifiers* (sortal classifiers) and *measure words* (mensural classifiers). As stated by Tai & Wang (1990:37-38): A classifier categorizes a class of nouns by picking out some salient perceptual properties, which are permanently associated with entities named by the class of nouns². An example of Mandarin Chinese is given in (1a), where the classifier 本 *ben* highlights that the following noun has the feature of a volume, e.g. a book, a magazine or a dictionary etc. On the other hand, a measure word does not categorize but denotes the quantity of the entity named by the noun, as shown in (1b) with 箱 *xiang* ‘M-box’, which points out the unit of quantity for the referent.

(1) Sample of classifiers and measure words in Mandarin Chinese

a. Classifier

三	本	書
<i>san</i>	<i>Ben</i>	<i>shu</i>
three	CLF-volume	book
‘three books’		

b. Measure word

三	箱	書
<i>san</i>	<i>xiang</i>	<i>shu</i>
three	M-box	book
‘three boxes of books’		

Various formal syntactic tests have been proposed to verify the categorization of classifiers in Mandarin Chinese, including numeral/adjectival stacking (Cheng & Sybesma, 1998:390; Tsai, 2003; Liang, 2006; Her & Hsieh, 2010: 538), *de* insertion (Chao 1968:555, Paris 1981:32, Zhu 1982:51, Tai & Wang 1990, Tai 1994, Cheng & Sybesma 1998:388 ; Tang, 2005:444; Zhang 2007:49; Her & Hsieh, 2010:541), *ge* substitution (Tai & Wang, 1990; Tai, 1994), among others. First, it is suggested that measure words block numeral and adjectival stacking but classifiers do not, i.e. measure words may accept antonymous adjectives on the classifier and the noun while classifiers cannot, e.g. 一大箱小蘋果 *yi da xiang xiao pingguo* ‘one big M-box little apple’ meaning ‘a big box of small apples’ is grammatical but *一大顆小蘋果 **yi da ke xiao pingguo* ‘one big CLF-round little apple’ is not since an apple cannot be big and small at the same time³. Second, *de* insertion stipulates that measure words can also be used with the genitive marker *de*, while classifiers cannot (Her & Hsieh, 2010:541), i.e. 一箱的書 *yi xiang de shu* ‘one M-box GEN book’ meaning ‘a box of books’ but *一本的書 **yi ben de shu* ‘one CLF-volume GEN book’. Finally, classifiers are expected to be interchangeable with the general classifier *ge* but measure words are

² Accordingly, a noun may be combined with different classifiers depending on which feature of the noun the speaker wishes to highlight, further explanation is provided in Section 1.2.

³ *yi da xiang xiao pingguo* ‘one big M-box little apple’ meaning ‘a big box of small apples’ is grammatical because the first adjective *da* ‘big’ refers to the box while the second adjective *xiao* ‘small’ refers to the apple. No contradiction occurs since the referents are different for the two antonymous adjectives. This is not the case for the classifier construction where both adjectives refer to the same noun ‘apple’.



not, e.g. 三顆蘋果 *san ke pingguo* ‘three CLF-round apple’ and 三個蘋果 *san ge pingguo* ‘three CLF-general apple’ both mean ‘three apples’, however 三箱蘋果 *san xiang pingguo* ‘three M-box apple’ would refer to ‘three boxes of apples’ instead. Even though, such tests do have their respective limitations when facing non-prototypical cases and areal variations of speakers, they still represent an overall differentiation for classifiers and measure words.

Following this distinction, studies in the field of Child language acquisition did provide numerous diachronic data applicable for how this classification is acquired by children in various languages. However it did not propose a theoretical explanation for this phenomenon. The main purpose of this paper is to combine theoretical discussion with empirical evidence and obtain a model capable of correct prediction within the field of numeral classifiers acquisition. Following this logic, Mandarin Chinese was chosen as the language of analysis since it is a rich classifier language (Tang, 2004:391), i.e. syntactically classifiers are obligatory in presence of the numeral and their inventory in Mandarin Chinese reaches nearly one-hundred classifiers (97 according to Her & Lai, 2012:88), which is relatively big compared to other existing classifier languages, e.g. Newar (Tibeto-Burman) is attested to be detaining one of the most fully developed classifier systems in Nepal (Weidert, 1984:185) but only possesses 16 numeral classifiers (Kiryu, 2009:54-55). Moreover, Mandarin Chinese is also the classifier language with the highest amount of speakers in the world as reported by Ethnologue and the database of 491 classifier languages from Professor Her’s research team at the syntax and lexicon laboratory of National Chengchi University.

1.1. Literature Review

In the literature, the acquisition of numeral classifiers has been widely discussed in different languages (Aikhenvald, 2007), including Mandarin Chinese (Erbaugh, 1986; Liu, 2008), Japanese (Sanches, 1977; Matsumoto, 1985, Naka, 1999), Cantonese (Tse et al, 2007), Vietnamese (Matsumoto, 1987; Tran, 2011) among others. Generally speaking, a common ground is attained on the fact that during the development process, children establish the syntactic structure of the classifiers, e.g. (D)-Num-CLF-(N) in Mandarin Chinese (Tang, 1990), memorize the noun-classifier pairing as a chunk and then generalize the pairing to new nouns (Erbaugh, 1986). While they reached the age of three, in terms of comprehension studies, children often correctly select unfamiliar referents on the basis of classifiers, suggesting that they have made appropriate generalizations regarding the semantics of many classifiers (Sumiya & Colunga 2006, Huang & Chen 2009, Li et al. 2010). On the other side in production, children are often more conservative, using a “default” or “general” classifier instead of the correct, specific classifier (Erbaugh 1986, Myers and Tsay 2000). As an example from Mandarin Chinese, when referring to a dog, the speaker may use the specific classifier for animals *zhi*, as in 三隻狗 *san zhi gou* ‘three CLF-animal dog’ meaning ‘three dogs’. Another option is to apply the general classifier *ge*, which does not refer to any specific feature of the following noun, and may combine to nearly every countable entity, as in 三個狗 *san ge gou* ‘three CLF-

general dog' also meaning 'three dogs'. Following this differentiation, it is actually only in later years (four to five years old) that stable and frequent production of specific classifiers then measure words (six to seven years old) would occur (Ying et al, 1983; Tse et al, 2007:512-513). Interestingly, even though replacing specific classifiers remains a strong tendency among children and adults, they do not replace measure words with the general classifier, implying that they are aware syntactically of the distinction between the two categories (Tse et al, 2007:508). To sum up, although children's classifier selection in production may not always be appropriate, they rarely omit a classifier when syntactically required, indicating that syntax of classifier is mastered earlier than classifier semantics (Erbaugh 1986, Wong 1998, Hu 1993); this would also be the main reason to have a general classifier: It is used to fulfill the syntactic obligations when the specific classifier is not acquired yet or memory fails for some reason or the other, e.g. if the noun shares few characteristics with the prototype of a specific classifier, such rule equally applying to children and adults (Myers & Tsay, 2000:87-89). As a result, the order of acquisition would be general classifier > specific classifier > measure word.

However, less consensus are reached when explaining the acquisition process obtained in previous studies. As discussed by Li & Cheung (2015): some researchers (e.g., Sanches, 1977; Uchida & Imai, 1999; Yamamoto & Keil, 2000) combined cognition development with classifier acquisition: since numeral classifiers categorize nouns by their inherent features such as animacy and shape, it was expected that the acquisition order of specific classifiers would yield evidence for the acquisition order of conceptual categories, i.e. the Sapir-Whorf hypothesis suggests that the acquisition of classifiers might influence conceptual development (Muraishi, 1983; Yamamoto & Keil, 2000:380-381). Under such claim, more salient features such as animacy should be acquired earlier if the language primarily distinguished animacy via classifiers (e.g. in Japanese) and the related classifiers were acquired earlier than other classifiers such as shape classifiers. However, further study demonstrated that concepts of salient features were already acquired by children prior to their related classifiers (Hu, 1993), implying that other factors (e.g. frequency of classifiers in the input) also influence the order of classifier acquisition. Following this observation, another theory is proposed by Myers & Tsai (2000) who combined classifier acquisition with the connectionist model (Rumelhart & McClelland's, 1986; McClelland & Cleeremans, 2009): within the connectionist model, information processing in the brain occurs via the propagation of activation among neurons organized in networks. Therefore, learning is based on interactive experience with the environment: the more frequently two items are applied together in language, the stronger their connection will be thus the more easily they will be activated. As an example, children would tend to extensively use the general classifier since it is also more frequent in the adult speech they hear, emphasizing the importance of input. Nevertheless, even if the results do support a connectionist approach, it still does not provide a direct explanation for the acquisition order of numeral classifiers. As a summary, the main gap within previous studies is that besides the converging results in terms of the order of acquisition,



divergence occurs for the theoretical explanation. This issue is the main target of this paper and is developed in the following sections: we first introduce our theory to explain the acquisition of classifiers, and then present the methodology of our experiment and its results as empirical evidence. Finally, we will provide discussion, limitation and conclusion.

1.2. *Theoretical discussion*

On the theoretical side, we combined the *semantic complexity* of Brown (1973) and the mathematical approach of Her (2012) on numeral classifiers. Brown’s theory, also named as cumulative complexity, can be defined as follow: Even if the relative complexity of elements x , y and z is unknown, it may be said that $x + y$ is more complex than either x or y , and that $x + y + z$ is more complex than any of them. This logic is applicable to different grammatical constructions in language (Carroll, 2008:288), e.g. a morpheme that entails knowledge of any element x is less complex than a morpheme that entails knowledge of x plus something else. Taking as an example the comparison between the plural, third-person present and auxiliary in English: the plural morpheme encodes the semanticity of number (x), i.e. the speakers must be able to distinguish if there is one or more of the referent. Second, the third-person present entails number and time ($x+y$), i.e. the speaker knows that there is one referent instead of more than one and he must also be able to differentiate between the present and the past. Third, the auxiliary requires both of these notions plus the concept of temporary duration that an event is currently happening ($x+y+z$), i.e. the usage of *-ing* after the auxiliary. This situation fulfills the comparison of $x + y$ being more complex than y , and $x + y + z$ being more complex than $x + y$. Therefore we can make the prediction that the plural morpheme should be acquired before the third-person singular morphemes, followed by the auxiliary. This fact is proved by the data of Brown (1973) in Table 1, with the average order of acquisition of fourteen grammatical morphemes in English.

Table 1
Order of acquisition of fourteen grammatical morphemes in English

Order	Morpheme	Sample
1	Present progressive	<i>singing, playing</i>
2/3	Prepositions	<i>in the cup, on the floor</i>
4	Plural	books, dolls
5	Irregular past tense	<i>broke, went</i>
6	Possessive	mommy’s chair, Susie’s teddy
7	Copula (uncontractible)	this <i>is</i> my book
8	Articles	<i>the</i> teddy, <i>a</i> table
9	Regular past tense	<i>walked, played</i>
10	Third-person present tense regular	he climbs, mommy cooks
11	Third-person present tense irregular	John <i>has</i> three cookies

12	Auxiliary (uncontractible)	she <i>was</i> going to school
13	Copula (contractible)	I'm happy, you <i>are</i> special
14	Auxiliary (contractible)	mommy's going shopping

This theory alone cannot explain the acquisition of numeral classifiers due to the fact that in previous studies classifiers are either viewed as purely syntactic (Gil, 2013) or bearing various semanticity which are incomparable in terms of semantic complexity (Chen, 2013). We take into consideration a mathematical approach on numeral classifiers (Her, 2010) which can be combined with Brown's *semantic complexity* and clarify the acquisition order of numeral classifiers. Enhancing previous studies proposing that languages with a classifier system tend to not have plural marking (Greenberg, 1990; Li, 1999; Borer, 2005; Yeung, 2007; Yi, 2011 among others), Her (2012) argues that numeral classifiers serve as a multiplicand on a mathematical side: their behavior is similar to the plural marker -s in English and is used to denote that the following noun is a countable unit, as opposed to mass units which are not countable. To be more precise, if classifiers and measure words are to be interpreted as having a mathematical value, then the only possible mathematical function linking the numerals with classifiers or measure words is multiplication, where the classifiers as the multiplicand are necessarily of the value 1. A sample is provided in (2a), where the classifier 朵 *duo* semantically points out that the following noun belongs to the category of flowers, and at the same time carries the mathematical value of *times one*, so that the exact quantity of roses is still the one provided by the numeral 三 *san* 'three'. Measure words, on the other hand, are semantically substantive, and mathematically must have a value that is not necessarily 1 (e.g. *times n*). As demonstrated in (2b), the measure word *da* brings the information of quantity of a dozen, mathematically being equal to *times twelve*. The total quantity referred to here is therefore *three times twelve*.

(2) Sample of classifier and measure word with mathematical approach

a. Classifier

三	朵	玫瑰	
<i>san</i>	<i>Duo</i>	<i>meigui</i>	(3 x 1 flower)
three	CLF-flower	rose	
'three roses'			

b. Measure word

三	打	玫瑰	
<i>san</i>	<i>Da</i>	<i>meigui</i>	(3 x dozen flower = 3 x 12 flower)
three	M-dozen	rose	
'three dozens of roses'			

Less prototypical measure words may carry numerical or non-numerical value, being either fixed or variable; the primary prerequisite being that only



classifiers necessarily assign the value of one⁴. As displayed in Table 2, numeral classifiers belong to the main category of necessarily fixed numeral value of one, while the measure word 打 *da* ‘M-dozen’ is annotated with the fixed numerical value of twelve. Not fulfilling the requirement of numeral classifiers with necessarily the value of one, 打 *da* ‘M-dozen’ is therefore categorized as a measure word, along with 群 *qun* ‘M-group’ which possesses instead a variable numerical value⁵. Other measure words with non-numerical value (whether fixed or variable) such as 瓶 *ping* ‘M-bottle’ and 袋 *dai* ‘M-bag’ would on the other hand denote a simple variable value, e.g. 三瓶水 *san ping shui* ‘3 M-bottle water’ meaning ‘three bottles of water’ specifies that the water is existent as the quantity of times three bottles, the exact amount depending on the type of bottle which is referred to.

Table 2
 Types of Mathematical Value in C/M (adapted from Her & Wu, 2016)

Value		Example	Type
Necessarily numerical	Fixed	1 三朵玫瑰 <i>san duo meigui</i> ‘three CLF-flower rose’	C
		三打玫瑰 <i>san da meigui</i> ‘three M-dozen rose’	M ₁
	Variable	三群人 <i>san qun ren</i> ‘three M-group people’	M ₂
Non-necessarily numerical	Fixed	三升醋 <i>san sheng cu</i> ‘three M-litre vinegar’	M ₃
	Variable	三瓶水 <i>san ping shui</i> ‘three M-bottle water’	M ₄

Beside the mathematical value, classifiers and measure words also carry an added semanticity (Hsieh, 2009; Her, 2011; Her & Lai, 2012). Following the principles of essential & accidental properties (Robertson & Atkins, 2008) and Kant's distinction between analytic & synthetic propositions (Rey, 2003), we can obtain a clarification for classifiers and measure words: classifiers refer to an essential property of the noun while measure words point at its accidental properties, e.g. the classifier 本 *ben* ‘CLF-volume’ in 三本書 *san ben shu* ‘three CLF-volume book’ highlights that the following noun has the feature of a volume, which is at the same time an essential property of a book. However, it is not the case for measure words, e.g. in 三箱書 *san xiang*

⁴ Measure words may also refer to the value of one but not necessarily, e.g. 一袋鳳梨 *yi dai fengli* ‘one M-bag pineapple’ meaning ‘a bag of pineapples’ could equal to one pineapple if the bag contains only one of it, but that is not a necessary condition since the measure word *dai* does not have a fixed value, i.e. a bag of pineapple could contain half, one, two, three, four pineapples (among other infinite possibilities).

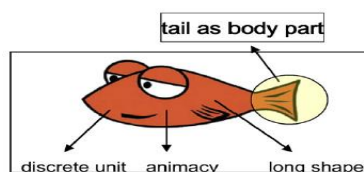
⁵ 一群人 *yi qun ren* ‘a group of people’ could include three, four, five, ten, twenty or more members, the only condition being that the value is numerical, e.g. it could not refer to three and a half people.

shu ‘three M-box book’ the measure word 箱 *xiang* implies that the following noun can be stored in boxes and counted as such unit of quantity, but the fact that books can be contained in boxes is an accidental property (books don’t obligatorily need to be storable in boxes to be accepted as books). In other words, measure words serve to quantify the noun in the phrase, as displayed in (2b) and in the following example: *dun* (M-ton) in *sanbai dun pingguo* ‘300 tons of apples’. They carry their independent semanticity and their mathematical value of *times n*. Regarding classifiers, they serve as a profiler (Fillmore, 1982; Langacker, 1987) and highlights an inherent semantic attribute of N beside their mathematical value of *times one*. By the example from Her (2012:1673-1674) in (3), different classifiers may apply on the same noun by pointing to different features of the referent, e.g. the tail of the fish(3a), its long shape(3b) or its animacy(3c), all three features being inherent properties of a fish.

(3) Sample of classifier semantics in Mandarin Chinese

a. Highlighted the *tail* feature of the fish

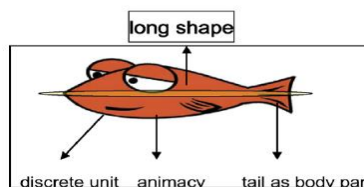
一	尾	魚
<i>yi</i>	<i>wei</i>	<i>yu</i>
1	CLF-tail	fish
‘1 fish’		



N-fish as frame and *CL*-tail as profile

b. Highlighted the *long shape* feature of the fish

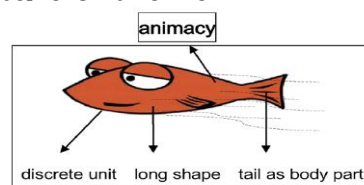
一	條	魚
<i>yi</i>	<i>tiao</i>	<i>yu</i>
1	CLF-long shape	fish
‘1 fish’		



N-fish as frame and *CL*-long shape as profile

c. Highlighted the *animacy* feature of the fish

一	隻	魚
<i>yi</i>	<i>zhi</i>	<i>yu</i>
1	CLF-animacy	fish
‘1 fish’		



N-fish as frame and *CL*-animacy as profile

By combining Brown’s semantic complexity and Her’s mathematical approach in Mandarin Chinese classifier acquisition, we generate the result in Table 3, with the different semantic complexity of general classifier, specific classifiers and measure words.



Table 3
 Semantic complexity and mathematical value of numeral classifiers

	Sample	Math	Semantic	Total
1	一個書 <i>yi ge shu</i> 'one CLF book'	x		x
2	一本書 <i>yi ben shu</i> 'one CLF-volume book'	x	y	$x + y$
3	一箱書 <i>yi xiang shu</i> 'one M-box book'	$x+z$	y	$x + y + z$

Following previous studies discussed in Section 1.1, there is a distinction between the general classifier *ge* which only carries the semanticity of countable unit (used as a syntactic filler) and more specific classifiers highlighting different features of the following noun (e.g. *zhi* with feature [+anymacy]). The same difference can be seen through semantic complexity: the general classifier *ge* only highlights the countable property of the noun (as times one), thus carry the mathematical complexity of x . Second, more specific numeral classifiers such as 本 *ben* 'CLF-volume' not only posses the same mathematical semanticity of times one (x) but also highlight an inherent feature of the following noun, e.g. *ben* highlights that the following noun has the particularity of a volume. This extra feature can be noted as y . Accordingly, we can deduce that the general classifier only has complexity of x , but the more specific numeral classifiers have $x + y$, hence the specific classifier is more complex semantically and acquired later. The same process applies with measure words, since they carry an additional semanticity of quantity z , being able to be numerical as in 打 *da* 'M-dozen' or non-numerical as in 升 *sheng* 'M-litre'. Therefore, we can considerate measure words with a complexity of $x + y + z$, expected to be acquired later than general numeral classifier and specific numeral classifiers. As a summary, we can make the prediction that general classifiers should be acquired first, then followed by specific classifiers and measure words.

Past researches already provide partial evidence for our proposal. The acquisition order between general classifier and specific classifier has been confirmed by studies in various languages, taking as an example Japanese (Sanches, 1977; Matsumoto, 1985; Naka, 1999), Mandarin Chinese (Erbaugh, 1986; Liu, 2008), Hokkien (Ng, 1989) and Cantonese (Tse et al., 2007). The largest of which is Tse et al. (2007), a study of Cantonese-speaking children between 3 and 5 years of age which also attested that classifiers are acquired before measure words. The gap in previous studies is first that they mostly focused on the age range of 3 to 5 years old in participants. Second, they did not include general classifiers, specific classifiers and measure word at the same time in their analysis. To improve this domain is the purpose of our analysis.

2. Methodology

On the empirical side: following the hypothesis developed, we ran an analysis on two combined child corpus data from Zhou (2008) in CHILDES (Child Language Data Exchange System). The selected data included in total 110 children from 1-6 years old. The children were divided by 10 as a group,

each group spaced with an average of 6 months of age. The total data contained eleven groups of ten children, respectively at 14, 20, 26, 32, 36, 42, 48, 54, 60, 66 and 72 months of age, providing a total of 110 conversations of 20 minutes, each conversation originating from a different children. The gap of only four months between 32 and 36 was due to the combination between two study programs of the same author. This data was chosen to represent the longitudinal development sequence of classifier and measure word acquisition with children. The children at each group were different participants, but the quantity of the data was estimated to be sufficiently representative. The main innovation compared with previous studies being that our dataset includes participants from a longer age period, i.e. 1-6 years old, and produce a simultaneous analysis on general classifier, specific classifier and measure word.

The cross-sectional data analyzed here was collected in preschool programs in Nanjing, China, following the design of Harvard Project in the United States (Snow et al. 1996). The participants originated from four preschool programs of the same geographical area and were selected using the criterion as below: The age difference within each of the groups was not exceeding one month and the socioeconomic and educational background of their family was controlled as middle class range, i.e. the mothers either graduated from university or finished their educational program in a technical secondary school; they were generally workings as government offices, teachers, accountants, among others. The parents and teachers confirmed the absence of hearing impairment or developmental delay. There were an equal numbers of girls and boys and all of them were the first born and only child of the family. Data was recorded using the following procedure: A laboratory was set up as a kindergarten with a remote-controlled camera in the corner to record 20 minutes interaction between each parent-child pair. The investigator was in the room but was not involved in the conversation between mother and child. Each recording started with a warm-up period of a few minutes, during which the parents and children were provided with a collection of toys to get accustomed to the setting. Afterward, the semi-structured play period would begin, involving ball play, toy play, picture drawing and book reading.

Our methodology for corpus analysis was as follow: first we checked in the transcription the occurrences of numeral classifiers & measure words and counted the total obligatory context for their occurrence. As in (4a), the numeral classifiers and measure words cannot be omitted or exchanged without an alternation in semanticity, while in (4b)-demonstrative form, (4c)-numeral form and (4d)-skipping of noun the omission of numeral classifier would lead to incorrect syntactic structure⁶.

⁶ Even though syntactic and semantic criteria are available it is observed that these parameters may be transgressed in specific discourse context, e.g. when the speaker emphasizes vagueness on unspecified nouns, a frequent strategy is to apply the general classifier or omit the classifier (Erbaugh, 2013:120-121). They were however rare in our data, therefore we did not develop this subject here.



(4) Obligatory context for classifier and measure word in data

a	三本書	<i>san ben shu</i>	‘three CLF-general book’	three books
	三箱書	<i>san xiang shu</i>	‘three M-box book’	three boxes of books
b	拿這個顏色	<i>na zhe ge yianse</i>	‘take this CLF-general color’	take this color
	*拿這顏色	<i>na zhe yianse</i>	‘take this color’	*
c	劃一個太陽	<i>hua yi ge tai yang</i>	‘draw one CLF-general sun’	draw one sun
	*劃一太陽	<i>hua yi tai yang</i>	‘draw one sun’	*
d	我要三個	<i>wo yao san ge</i>	‘I want three CLF-general’	I want three
	*我要三	<i>wo yao san</i>	‘I want three’	*

Second, the correct/incorrect usage and omission of each classifier & measure word was noted by the following criteria: if it was required syntactically as shown in (4) and if the combination with the noun was semantically appropriate, e.g. the clause *三顆人 *san ke ren* ‘3 CLF-round people’ fulfills the syntactic requirement of Num + CLF + N but it would still be noted as incorrect since the semantics of the classifier ‘round’ does not correlate with the noun ‘people’. As for the comparison between numeral classifier & measure word, we followed previous studies methodology and applied the terms of Brown (1973): we defined the acquisition as the time when the morpheme was supplied in 90 percent of its obligatory context. As a unit of measure, we relied on the calculation of Suppliance in Obligatory Context (SOC) cross-checked with Target-Like Usage (TLU) from Pica (1983), to include into our scope generalization to inappropriate contexts. Detailed equations are listed in Figure 1 and Figure 2.

$$\frac{(\text{Number of correct suppliance} * 2 + \text{number of misformations})}{\text{total obligatory contexts} * 2}$$

Figure 1. SOC (suppliance in obligatory context)

The SOC allows us to calculate if the child applied classifiers correctly when he/she had to. As an example, if the numeral classifiers should have been applied in ten occurrences in discourse, but the child only used the classifier correctly three times, the SOC score would be $(3 * 2 + 7) / 10 * 2 = 65\%$. Seeing that it did not reach the required 90%, we would estimate that the child in question did not fully acquire yet how to use classifiers. Nevertheless, this formula only tells us if the classifiers were used correctly when needed, but does not include the overused sequences. In other words, a child may over-generalize and apply classifiers in every sentence, resulting in a high SOC score while he/she actually still does not use the classifier properly. Therefore, we added a second formula to cross check, which is the Target-Like Usage (TLU) score in Figure 2.

$$\frac{\text{Number of correct suppliance in obligatory contexts}}{(\text{number of obligatory contexts} + \text{number of suppliance in nonobligatory contexts})}$$

Figure 2. TLU (target-like use)

The TLU score calculates whether a child has applied classifiers in places where it is not supposed to. As an example, if the child applied numeral classifiers correctly in ten obligatory contexts, but also used classifiers in ten other occurrences where he/she should not have. The SOC score would be $(10 \times 2 + 0) / 10 \times 2 = 100\%$, misleading us to conclude that the child fully acquired the system of classifiers. Per contra, the TLU score would be $10 / (10 + 10) = 50\%$, letting us know that the child is actually over-generalizing classifiers, thus did not completely acquire this system yet. Finally, it is necessary to point out that this methodology was not possible for the comparison between general and specific classifiers, since they are interchangeable, i.e. if the child omitted a classifier in an obligatory context, we were not able to count which of the two classifiers is receiving the penalty of points when coding because both general and specific classifiers were possible for matching, as displayed in (5). Therefore, we also followed previous studies (Erbaugh, 1986; Myers & Tsay, 2000) regarding this subject: we focused on the proportion alternation between the two classifier classes.

(5) Similar distribution of general and specific classifiers

- | | | | | |
|----|------|-----------------------|----------------------------|--------------------|
| a. | 三個書 | <i>san ge shu</i> | 'three CLF-general book' | three books |
| | 三本書 | <i>san ben shu</i> | 'three CL-book book' | three books |
| b. | 我要三個 | <i>wo yao san ge</i> | 'I want three CLF-general' | I want three books |
| | 我要三本 | <i>wo yao san ben</i> | 'I want three CLF-book' | I want three books |

3. Results

Our results can be divided in two parts, the first displays the acquisition process of numeral classifiers vs measure words. The second provides the detailed development of general classifier vs specific classifiers. For the acquisition of numeral classifiers, the results of SOC and TLU are in Table 4. Our results are similar to previous studies: between 2-3 years old, the children can already steadily produce the numeral classifiers (Erbaugh, 1986), reaching an average of SOC and TLU above 90%. The correct usage included combination with demonstrative such as 這個 *zhe ge* 'this CLF-general' 那個 *na ge* 'that CLF-general', and with numerals, e.g. 一本書 *yi ben shu* 'one CLF-volume book', 兩個蛋糕 *liang ge dangao* 'two CLF-general cake'. Their detailed distribution ratio will be discussed in the following section about general and specific numeral classifiers. The incorrect usage of numeral classifiers included omission of nouns e.g. *掉在一個 *diao zai yi ge* 'fall at one CLF-general', and incorrect mapping of numeral classifier & noun e.g. 這件小老鼠 *zhe jian xiao laoshu* 'this CLF-clothe little mouse'. It is interesting to point out that no omissions of numerals or numeral classifiers



were attested after the age of 2;⁷, even though they still made other type of errors such as incorrect combination of classifier and noun. These results are in accordance with precedent research showing that the children acquire the syntactic structure quite early and rarely omits the numeral classifier in terms of production (Erbaugh, 1986; Wong, 1998; Hu, 1993).

Table 4
 SOC and TLU score of numeral classifiers

Age	Correct use of CLF	Incorrect use of CLF	Omission of CLF	Obligatory context	SOC	TLU
1;2	0	0	0	0	0%	0%
1;8	24	2	2	28	89%	86%
2;2	180	3	6	189	96%	95%
2;8	100	9	0	109	96%	92%
3;0	191	0	0	191	100%	100%
3;6	165	3	0	168	99%	98%
4;0	159	2	0	161	99%	99%
4;6	253	1	0	254	100%	100%
5;0	225	7	0	232	98%	97%
5;6	226	5	0	231	99%	98%
6;0	222	13	0	235	97%	94%

We are aware that the numbers in our data may seem intriguing when analyzing the SOC and TLU score of the children: both scores changes from 0% to 89% & 86% between 1;2 and 1;8. This fact would seems to be a too abrupt development process, however since the period between each data gathering was 6 months, it is reasonable to assume that within the period 1;2-1;8, an analysis of the SOC and TLU score of the children would show a more gradual increase. Nevertheless, in general a brusque diffusion is still expected by the geyser effect, i.e. “when a new construction enters the child’s grammatical repertoire, we first see only a few examples, but these are followed soon after by regular use and within a few months by an explosion of examples” (Snyder, 2007:70). Moreover the fact that child speech is still limited at the age of 1;2 is also an influencing factor. As an example one of our participant from the group of 1;2 consistently replied questions of his mother using bare nouns constructions, e.g. if the mother asked: 這是什麼 *zhe shi sheme* ‘this is what?’ The child answered 球 *qiu* ‘ball’. Such construction is syntactically correct: since the numeral is absent, the classifier is not required either. This part will be discussed further in the

⁷ This observation may also be biased by the fact that children tends to first memorize classifiers as a chunk, even if they did not fully acquire the syntax of classifiers yet (Erbaugh 1986), e.g. demonstrative and general classifier: 這個 *zhe ge* ‘this CLF-general’, which has a high occurrence rate in our data, as further explained in Section 4.

Section 4. Moreover, this is still in accordance with children acquiring classifier syntax at an earlier stage: they know that a slot for numeral classifier is required in the syntactic structure, which also enhance the acquisition of a general classifier to fill the syntactic slot, while the acquisition of specific classifiers is “semantically instigated” and occur at a later stage (Tse et al, 2007:513). A more detailed analysis in terms of quantity of tokens will be provided in the Section 4.

Regarding measure words, the results are written in Table 5: the production of measure words starts to stabilize and steadily increase starting from 3-4 years old. This result also being attested with precedent researches (Tse et al, 2007). The correct usage of measure words included combination with toys such as 一盒積木 *yi he jimu* ‘one M-box lego’, and usage with imaginary food, e.g. 我要兩勺 *wo yao liang shao* ‘I want two M-big spoon’. It is also necessary to highlight that the SOC and TLU ratio gap between 0% and 100% could also be questioned, but as explained with the classifiers data, the long period between interviews should be an influencing factor. Second, based on our prediction of acquisition order, measure words follow numeral classifiers in time. It is then reasonable to propose that when the children acquire measure words, their syntactic and semantic structure already stabilized, so they do not produce errors easily. Additionally, measure words can be combined with a large inventory of nouns, making it harder to perceive an error in production.

Table 5
SOC and TLU of measure words

Age	Correct use of M	Incorrect use of M	Omission of M	Obligatory context	SOC	TLU
1;2	0	0	0	0	0%	0%
1;8	0	0	0	0	0%	0%
2;2	1	0	0	1	100%	100%
2;8	0	0	0	0	0%	0%
3;0	2	0	0	2	100%	100%
3;6	4	0	0	4	100%	100%
4;0	5	0	0	5	100%	100%
4;6	9	0	0	9	100%	100%
5;0	11	0	0	11	100%	100%
5;6	9	0	0	9	100%	100%
6;0	16	0	0	16	100%	100%

As a summary, the analysis through SOC and TLU displayed that the production of numeral classifiers stabilized between 2-3 years old, while the production of measure words occurred between 3-4 years old. Their distribution also demonstrated that in terms of productivity, numeral classifiers outperform measure words before the age of six years old: In Figure 3 with the total quantity of numeral classifiers and measure words,



between the age of 1 to 6 years, numeral classifiers production detains an average of 97%, compared to 3% with measure words. Starting from the age of 3 years old, the usage of measure words steadily increased from 2% to 7%. This distribution change being highly statistically significant in the test of one way ANOVA ($p=0.0003<0.001$), it once more supports the results of previous studies that measure words are acquired later than classifiers.

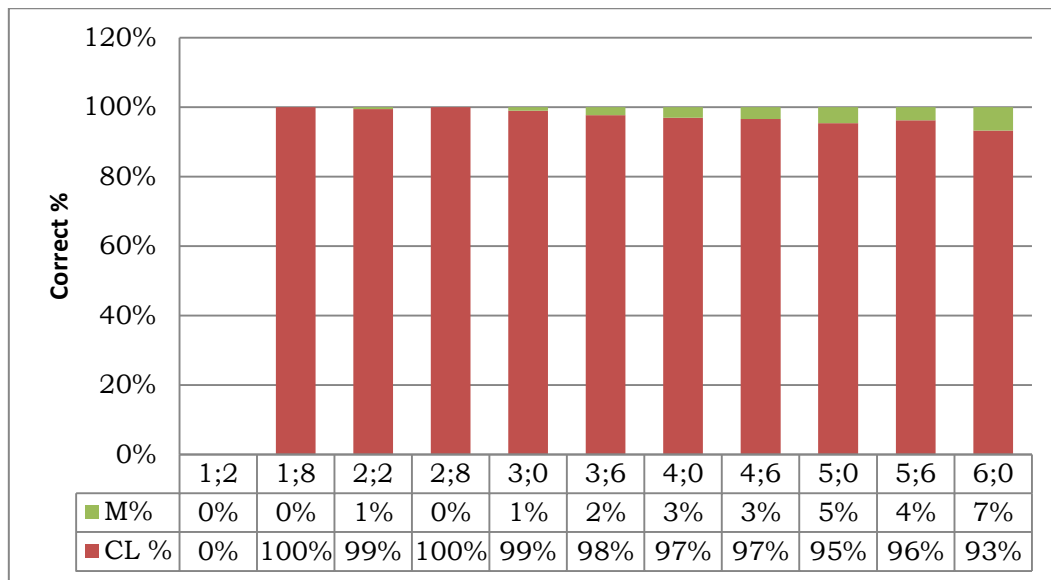


Figure 3. Production percentage of classifiers and measure words

For the comparison between general classifiers and specific classifiers, as explained in the methodology section, we were not able to rely on SOC and TLU due to interchangeability of general and specific classifiers in a clause. Therefore, we used the distribution ratio between the two classes to analyze their acquisition process. In Figure 4, general classifier usage counted as 94% vs 6% with specific classifiers before the age of 4, however after 4 years old, the specific classifiers raise to an average of 10%, reaching 15% at the time of 6 years old, demonstrating that the stable production of general classifier occurs before specific classifiers. This fact also being supported by previous studies: the syntactic structure of numeral classifiers is acquired before the semantic structure, resulting in the general classifier being used to fulfill the syntactic obligations when the specific classifier is not acquired yet or memory (e.g. for which semantic features are encoded by which classifier) fails (Myers & Tsay, 2000). It is also necessary to point out that due to the individual difference of two participants, the statistical tests were not significant for this ratio comparison, further details are explained in Section 4.

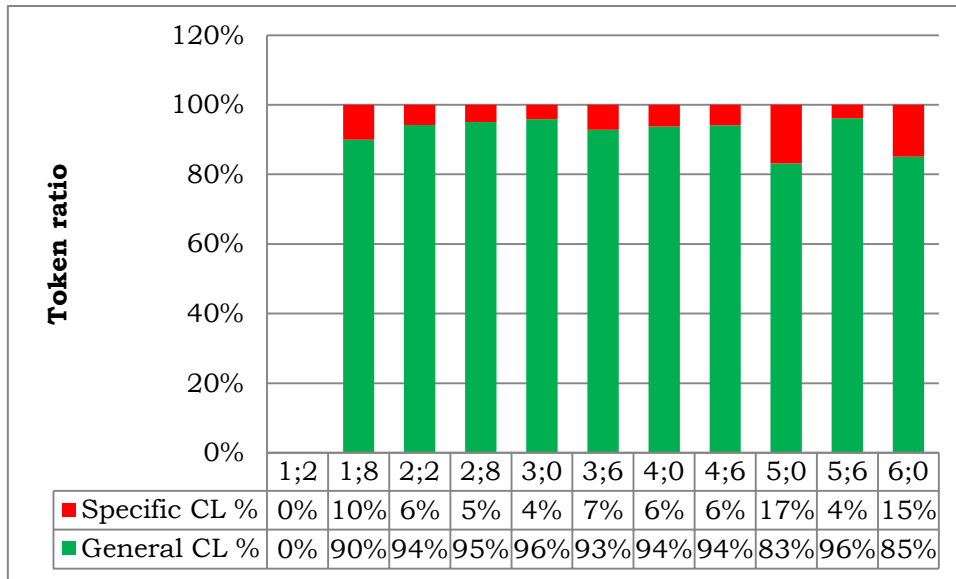


Figure 4. Production percentage of general and specific classifiers

4. Discussion

Within the results of Table 3 and 4, we observed that classifiers were acquired before measure words and in Figure 3 and 4 we demonstrated that within classifiers, the general classifier was acquired before specific classifiers. By combining the two results, we can deduce that general classifiers are acquired first, followed by specific classifiers and then measure words. This order is displayed in Figure 5: in terms of production ratio, between the age of 1-6 years old, general classifiers detain the majority within an average of 90%, followed by specific classifiers with 8% and finally by measure words with 2%. Even after 4 years old, when the measure words production increased, general classifier still retains 87%, specific classifiers 9% and measure words 4%, showing that the production of specific classifier is stabilizing before the production of measure words.

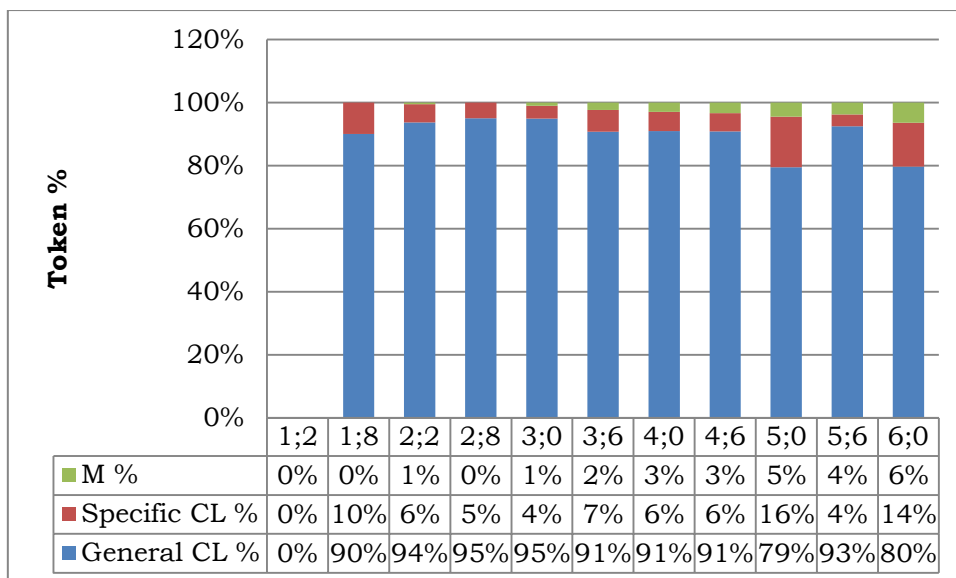


Figure 5. Production of general/ specific classifiers and measure words



In terms of quantity, the steady progression within general/ specific classifiers and measure words is even more transparent in Figure 6. The development process can be divided in three stages (by pointed lines): at 1;2-2;8, the children starts from zero production to reach an average of 7.9 classifiers per conversation of 20 minutes. Then, from 3;0-4;0, the production rate increased to an average of 17.4 classifiers. Finally between 4;6-6;0 the average reaches 23.8 classifiers, the longitudinal correlation between age and usage of classifiers being highly significant in the one way ANOVA test ($p=0.0002<0.001$). The specific classifiers usage also increases starting from stage 2, as colored in red, attaining an average of 4 tokens in stage 3. Contrastingly, measure words only reach an average of 1 per conversation at 5-6 years old. Proving once again that in terms of production, general classifiers are acquired before specific classifiers and measure words.

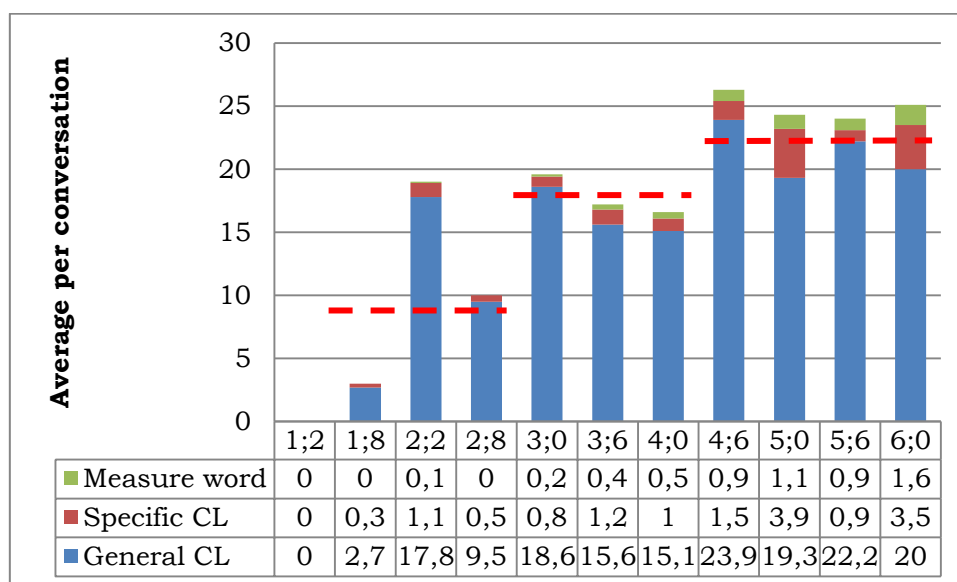


Figure 6. Average quantity of classifiers and measure words per conversation

It is necessary to highlight that the data recorded at the age of 2;2 represents an anomaly compared to the expected tendency. The average of production reached 17.8 classifiers per conversation, which is much higher than the preceding and following period of 1;8 and 2;8. This phenomenon can be explained by individual differences when analyzing the data in details: within two conversations of the group 2;2, two children used 45 and 36 classifiers during their recording. The reason for such production being an ordering of toys: the two children communicated to their mother how to put pieces of toys with different colors together, and during this process they heavily relied on demonstratives such as 這個 *zhe ge* 'this CLF-general'. After explaining this fact, we can realize that the data is following our prediction and previous studies results. Similar observations are attested in terms of total quantity, as displayed in Figure 7.

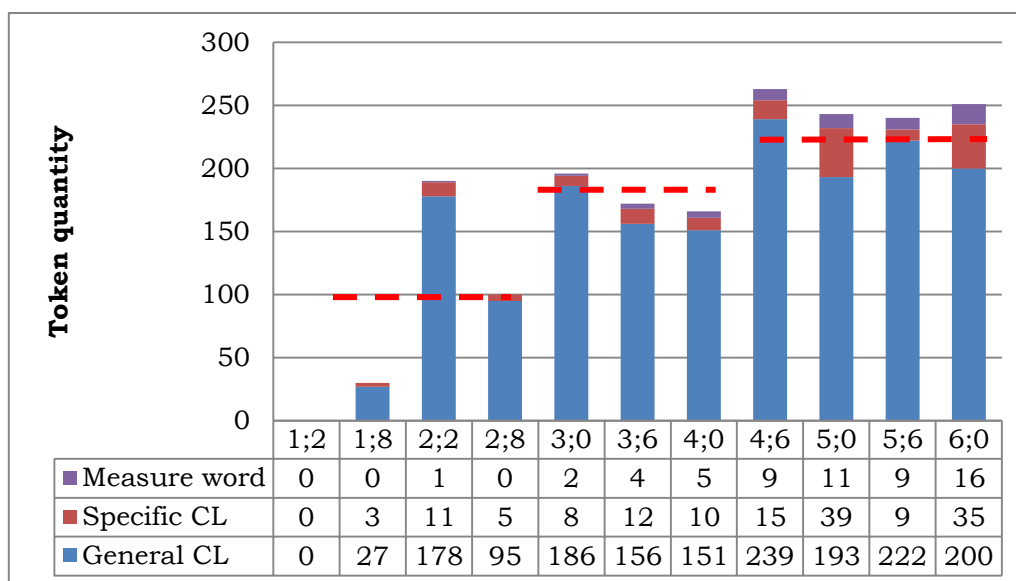


Figure 7. Total quantity of classifiers and measure words

Here also, the overall total increases, with general classifiers detaining the majority constantly. But starting from three years old, the quantity of produced specific classifiers grows steadily, while measure words productively occur starting from 4-5 years old.

5. Conclusion

As a conclusion, through the combination of semantic complexity (Brown, 1973) and mathematical approach to classifiers and measure words (Her, 2012), we provided a theoretical explanation for the development process of classifiers and measure words in child language acquisition of Mandarin Chinese, expecting that the general classifier will be acquired before specific classifiers, then followed by measure words. This order was indeed observed in previous studies (Erbaugh, 1986; Myers & Tsay, 2000; Tse et al, 2007). Moreover, through the analysis of longitudinal data toward 110 Mandarin Chinese speaking children between 1;2 and 6;0, (Zhou, 2008) the predicted acquisition order was also occurring, which provides empirical evidence for our theoretical discussion.

The limitations of our research mainly come from the data side. First, we were able to retrieve longitudinal studies between the age of 1;2 to 6;0, with different children group at each stage. It would be preferable to rely on data from the same 10 (or more) children from 1;2 to 6;0. No research actually constructed such corpora, consequently we chose the alternative option with different children groups. Our second issue lies in the interval between each recording: six months is too long to analyze the developmental sequences of classifiers and measure words. Corpus providing children spoken data between the age of 1 to 2 could be selected to verify the details of the evolution process. A possible source would be the corpus of Tardif (1993) from CHILDES, which targets data of children between 1;9-2;2. However since this part was already analyzed and proved by previous studies (Erbaugh, 1986; Myers & Tsay, 2000), we did not include it into this paper.



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Abbreviations

CLF = classifier; D = demonstrative; GEN = genitive; M = measure word; N = noun; Num = numeral

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