Wu, Jiun-Shiung and One-Soon Her. 2021. Taxonomy of numeral classifiers and measure words: A formal semantic proposal. In Chungmin Lee, Youngwha Kim, and Byeong-uk Yi (eds.), Numeral Classifiers and Classifier Languages: Chinese, Japanese, and Korean, 40-71. Routledge, 40-71.

2 Taxonomy of numeral classifiers

A formal semantic proposal

Jiun-Shiung Wu and One-Soon Her

1 Introduction

In a numeral classifier language like Chinese, when a noun (N) is quantified by a numeral (Num), a classifier (C) or measure word (M) is often needed, as in (1a) and (1b), respectively. Note that C and M appear in exactly the same syntactic position and are in complementary distribution, as shown in (2).

(1) a. *san* *tiao* *yu*
3 C fish
'3 fish'
b. *san* *xiang* *yu*
3 M-box fish
'3 boxes of fish'
(2) a.* *san* *tiao* *xiang* *yu*
b.* *san* *xiang* *tiao* *yu*

This fact suggests that C and M in a classifier language form a single syntactic category, which we shall dub 'C/M'. This C/M convergence view is shared by many linguists, for example, Hass (1942), Emeneau (1951), D. Nguyen (1957), Chao (1968), Becker (1975), Li and Thompson (1981), Huang (1982), Hundius and Kölver (1983), Craig (1994), Lin (1997), Cheng and Sybesma (1998, 1999), and Hsieh (2008), among many others, where various arguments have been constructed to support this view (see Her 2012b for a summary). Most standard dictionaries, grammar books, and language textbooks of classifier languages also do not make any formal distinction between the two. However, as likewise noted by numerous linguists, Cs and Ms are very different. This following informal characterization by Tai and Wang (1990: 38) is an often-cited example:

> A classifier categorizes a class of nouns by picking out some salient perceptual properties, either physically or functionally based, which are permanently associated with entities named by the class of nouns; a measure word does not categorize but denotes the quantity of the entity named by noun.
>
> (Tai and Wang 1990: 38)

The undeniable fact that Ms quantify the head noun, but Cs must qualify the noun in terms of certain semantic features, has compelled many researchers to claim that C and M are two distinct semantic and/or syntactic categories, for example, Greenberg (1990[1972]), Tai and Wang (1990), Tai (1994), Her and Hsieh (2010), X. Li (2011, 2012), and Zhang (2011), among many others. T. Nguyen (2004: vii), for example, is emphatic that "classifiers and measure phrases, often treated as belonging to a single category in prior literature, are shown to be fundamentally distinct". Likewise, various arguments have been constructed to support this divergence view (also see Her 2012b for a summary).

The fact that C and M seem to converge and diverge at the same time has long put linguists in a quandary. In practice, most syntactic works, especially the more recent ones in the generative framework, such as Tang (2005), Hsieh (2008), Huang *et al* (2009), Her (2012b), and A. Li (2014), to name just a few, take C and M to be a single category, some explicitly and others implicitly, even though, as H. Zhang (2007: 45) observes, "Chinese linguists generally agree that a distinction between these two kinds should be made". Wang (1994: 19–20) complains that "previous works in Chinese grammar treat classifiers and measure words on an equal footing" and proclaims that "it is essential to tell classifiers from measure words both semantically and syntactically". N. Zhang (2009) also observes that "the relation between classifiers and measure words has baffled linguists for a long time" and subsequently proposes in N. Zhang (2011, 2013) that C and M constitute two different categories in both syntactic and semantic terms. Yet, even for those who explicitly claim that C and M should be distinguished, the criteria proposed are often informal and imprecise. The quote from Tai and Wang (1990: 38) given above is a good example.

An added confusion in this already confused state of affairs is the issue of whether classifier languages like Chinese make a lexical distinction of mass and count. While many, such as Cheng and Sybesma (1998), Tang (2005), Hsieh (2008), Her and Hsieh (2010), Yi (2009, 2011a, 2011b), and Her (2012a), among others, assume such a distinction in Chinese and contend that C requires a lexical count noun but M does not, many others, such as Quine (1969), Allan (1977), Hansen (1983), Link (1991), Lucy (1992), Krifka (1995), Chierchia (1998a), Mou (1999), Toyota (2009), and Toyota *et al* (2012), insist that the fact that C/M is required for Num to quantify N means that N can only be mass in such languages.

In this chapter, we aim to accomplish three things. First, we will follow Her (2012a) in interpreting the convergence and divergence between Cs and Ms from a mathematical perspective and further argue that C/M as a single syntactic category can be classified into different subtypes in terms of their mathematical values. Thus, Her and Lin's (2015) formal taxonomy of various subtypes under C/M will be discussed and supported. Second, we shall offer a formal semantic account for the C/M unification as well as the various types in the C/M taxonomy. Third, we will demonstrate that in carrying out the above two goals, it is necessary to assume a lexical mass/count distinction in classifier languages. This position then leads to the conclusion that such a distinction is universal.

The chapter is organized into six sections. Section 2 offers a brief description of the current confused state of affairs in the study of Cs and Ms and provides some clarification. Section 3 first reviews the similarities and difference between Cs and Ms and then accounts for such convergence and divergence with a new taxonomy of C/Ms based on an insight from a mathematical perspective, where C/Ms are viewed as multiplicands with various kinds of values. Section 4 proposes a formal semantic account of Cs and various subtypes of Ms. Section 5 demonstrates that the taxonomy and the semantics proposed in this chapter are evidence for a universal mass/count distinction at the lexical level. Section 6 consists of a summary and some concluding remarks.

2 A confused state of affairs

As noted by some researchers, such as H. Zhang (2007: 45) and Her (2012a: 1669), the uncertain status of Cs and Ms is reflected in the often confusing terminology used in the literature. Terms used for C include 'classifier', 'count-classifier', 'count-noun classifier', 'individual classifier', 'qualifying classifier', and 'sortal classifier'; those for M include 'measure word', 'mass-classifier', 'mass-noun classifier', 'massifier', 'mensural classifier', 'measural classifier', and 'quantifier'. This list is not meant to be exhaustive. Furthering the confusion, many also use the term 'classifier', 'numeral classifier', or 'quantifier' for C/M as a single category, and others use the term 'measure word', 'measure', 'unit word', or 'numerative' instead for the same purpose. Most of the papers or books published in Chinese use the term 量詞 *liangci* 'measure word' to refer to the category of C/M, while a small number of them do clearly distinguish between 分類詞 *fenleici* or 類別詞 *leibieci* 'classifier' and *liangci* 'measure word'. In this chapter, we use the term 'C/M' to refer to the unified category of the elements between Num and N; the construction is referred to as [Num C/M N]. 'C' is strictly for 'classifiers' (or 'sortal classifiers') and 'M' strictly for 'measure words' (or 'mensural classifiers' or 'massifiers'). Explicit criteria for this distinction will be discussed in section 3.

Another symptom of the confused state of affairs, as noted by Her and Hsieh (2010: 528), is the drastically different inventories of 'classifiers', or *linagci*, compiled by different researchers for Mandarin Chinese, ranging from as few as 51 (Chao 1968) and several dozen (Erbaugh 2002), to 126 (Gao and Malt 2009), to 200 (Hung 1996), to 427 (Huang and Ahrens 2003), to as many as many as 600 (Hu 1993). These different numbers no doubt reflect very different ideas about what belongs to this category, and even for those who do make a clear distinction between Cs and Ms, there is confusion over what exactly counts as a C. To the best of our knowledge, Lai (2011) and Her and Lai (2012) on Mandarin, Chen (2013) and Chen *et al* (2020) on Taiwanese southern Min, and Liao (2014) on Taiwanese Hakka are the only three works in the literature that offer a comprehensive list of Cs in a classifier language that is based on explicit and testable criteria.

The problem is thus two-fold: how to precisely and insightfully distinguish C and M and yet also unify C/M at the same time. Previous accounts fall short one way or another. Accounts that treat C and M as one formal category typically lack precise or formal distinction between the two subcategories, for example, Hsieh (2008), Huang *et al* (2009), and A. Li (2014), to name just a few. Li and Thompson (1981: 106) famously claim that "any measure word can be a classifier". On the other hand, in works that do offer a distinction between C and M, the distinction is typically stated informally, and there is also a lack of accounting for C and M's formal convergence. Examples abound; here we discuss several examples from prominent works, starting with a classic, Chao (1968: 584–620), where Cs are referred to as 'classifiers', 'individual measures', or 'Mc' for short and considered one out of eight types within the category of nominal measure words.[1]

(3) Chao's (1968: 584–620) Classification of Measure Words

1 Mc (Classifiers, or Individual Measures):

for example, 一個人 *yige ren* (1 C person) 'one person'

2 Mc' (Classifiers Associated with V-O):

for example, 惹一場禍 *re yichang huo* (cause 1 C disaster) 'cause a disaster'

3 Mg (Group Measures):

for example, 一行字 *yihang zi* (1 line character) 'one line of characters'

4 Mp (Partitive Measures):

for example, 一堆土 *yidui tu* (1 pile dirt) 'one pile of dirt'

5 Mo (Container Measures):

for example, 一鍋麵 *yiguo mian* (1 pot noodle) 'one pot of noodles'

6 Mt (Temporary Measures):

for example, 一頭百髮 *yitou baifa* (1 head white-hair) 'a headful of white hairs'

7 Mm (Standard Measures):

for example, 一尺布 *yichi bu* 'one meter of cloth'

8 Mq (Quasi-Measures, or Autonomous Measures):

for example, 一釐 *yili* or 一趴 *yipa* 'one percent'

The fundamental disadvantage associated with this taxonomy is that the eight types are all disjoint and allow no intersecting natural classes. For example, a group measure, a container measure, and a quasi-measure that has a standardized value, for example, 打 *da* 'dozen', 茶匙 *chichi* 'teaspoon', and 釐 *li* '%', respectively, can of course also be seen as a standard measure. Further, any measure word of any type currently without a standardized value can easily take on a standardized value, be it permanently or temporarily, among a small population or a large population, and thus become a standard measure. The fact that the different types intersect means that having them as disjoint misses the essential purpose of taxonomy.

The same weakness is seen in Aikhenvald (2000: 115–117), a seminal work on classifiers, where she distinguishes between '(numeral) classifiers' (a term for both 'sortal classifiers' and 'measural classifiers') and 'measure words' (a term exchangeable with 'quantifiers' and 'quantifying expressions') in classifier languages based on the observation that classifiers use the unit provided by a noun, while quantifiers, or quantifying expressions, establish the unit to be counted. Under her view, 'classifiers', 'sortal' and 'mensural', must co-occur with count nouns, while 'measure words' appear with count or mass nouns. Consider the examples in (4).

(4) *san* *zhi/shuang/xiang/jin* *xie*
3 C/M-pair/M-box/M-kilo shoe
'3 shoes/3 pairs/boxes/kilos of shoes'

In spite of their identical syntactic position, *zhi* 'C', *shuang* 'pair', *xiang* 'box', and *jin* 'kilo' are seen as a sortal classifier, mensural classifier, quantifier, and quantifier, respectively. The former two are 'classifiers', but the latter two are excluded. Such exclusion misses important generalizations of C/M as a single category and is also in conflict with the view shared by most grammarians, that *shuang* 'pair', *xiang* 'box', and *jin* 'kilo' are all Ms, or mensural classifiers.

S. Huang (2013), in an important recent work on Chinese grammar, where an entire chapter is devoted to numeral classifiers, claims to follow Aikhenvald's (2000) distinction of 'sortal' and 'mensural' classifiers; furthermore, his distinction is also essentially the same as that of Tai and Wang (1990: 38):

> In the following discussion we will ignore Chao's types (7) and (8), since they do not represent what I take to be true classifiers in the strict sense of the term. I will for the time being distinguish just two basic types of NC for nominal classifiers, more or less following Aikhenvald (2000), sortal classifiers and mensural classifiers. A sortal classifier is one which individuates a referent in terms of its more inherent properties such as animacy, shape, or consistency. Mensural classifiers are used for measuring more temporary state of an object, its quantity, or the arrangement it occurs in. . . . Note that sortal classifiers and mensural classifiers are to be distinguished from ordinary measure words such as *jin* (斤) in *yijin tang*.
>
> (S. Huang 2013: 167–168)

S. Huang's (2013) rejection of Chao's type 7, or standard measures like *jin* 'catty, kilo' and 尺 *chi* 'meter', as mensural classifiers is puzzling. Standard measures, after all, occupy exactly the same syntactic position as other C/Ms, for example, *zhi* 'C', *shuang* 'pair', and *xiang* 'box' in (4), and serve the same function to measure the noun. The exclusion of Chao's type 8, that is, quasi-measures, is also unnecessary, as these are simply standard measures of portion that often appear without a head noun.

The final taxonomy we shall briefly review is found in N. Zhang (2013), where seven types of 'unit words', or C/Ms in our term, are recognized: individual (e.g., 枝 *zhi*), individuating (e.g., 滴 *di*), kind (e.g., 種 *zhong*), container (e.g., 瓶 *ping*), standard (e.g., 斤 *jin*), partitive (e.g., 段 *duan*), and collective (e.g., 群 *qun*). In spite of the apparent resemblance with Chao's taxonomy, there are several noteworthy differences. First, N. Zhang rightly ignores Chao's type 2, classifiers associated with V-O, as such classifiers easily appear in non-object positions, and

Chao's type 8, quasi-measures, which, as shown earlier, can be seen as standard measures. Second, N. Zhang (2013: 212) contends that Chao's type 6, or temporary measures, can be seen as container measures or nouns. Third, N. Zhang includes kind classifiers as a separate type, which is rather reasonable. The fourth difference is more important: Chao's type 4, partitive measures, is divided into two types, partitive and individuating. An individuating unit word must select nouns that are not delimitable, but a partitive unit word can select either delimitable or undelimitable nouns. A delimitable noun is atomic, while an undelimitable noun has no intrinsic shape, size, or boundaries.

Note that N. Zhang makes an extraordinary, and likely to be controversial, claim that container, standard, partitive, and collective unit words have a left-branching structure, but individual, individuating, and kind unit words have a right-branching structure. The seven types thus in effect form two formally distinct categories, as shown in Table 2.1.

This dichotomy has serious implications. Assigning the individual Cs and the individuating Cs to the same category is inconsistent with the fact that the former requires delimitable nouns and the latter undelimitable nouns. On the other hand, assigning the individual Cs and collective Ms to two different categories misses the generalization that they both require delimitable nouns. More importantly, this dichotomy predicts that the left-branching measures and right-branching classifiers need not follow the same word order in a language. We should thus expect to find that the two distinct categories deviate in word order in some languages. Yet, Greenberg (1990[1975]: 228) claims that Cs and Ms do not deviate in word order in any classifier language. In an ongoing research project headed by the second author, in a database of over 500 classifier languages, no evidence is found that Cs and Ms differ in word order in any of them. In addition, in all these languages, in a nominal phrase that consists of a Num and an N, either a C or an M is used, never both. C and M are always in complimentary distribution. These facts are disconfirming to N. Zhang's dichotomy and suggest strongly that C and M belong to the same category and occupy the same structural position.[2]

Last but not least, it is crucial to distinguish between the formal syntactic category of C/M, as defined by the construction [Num C/M N], and the function they serve, for there is unfortunately a prevailing confusion over whether certain types of Cs or Ms are in fact universally available in all languages. The simple fact is that

Table 2.1 Taxonomy of C/Ms derived from Zhang (2013)

Category	*Type*	*Examples*
Measures (left-branching)	Container	瓶 *ping*, 箱 *xiang*
	Standard	斤 *jin*, 尺 *chi*
	Partitive	段 *duan*, 節 *jie*
	Collective	群 *qun*, 打 *da*
Classifiers (right-branching)	Individual	枝 *zhi*, 朵 *duo*
	Individuating	滴 *di*, 灘 *tan*
	Kind	種 *zhong*, 類 *lei*

classifier languages like Chinese employ C/M as a syntactic category, while non-classifier languages like English have the functional equivalent of such words but do not distinguish a C/M category formally. Many linguists make the misleading claim that measure words, or mass-classifiers, are a mundane part of all natural languages, and only sortal classifiers, or count-classifiers, are unique to classifier languages like Chinese and Japanese and are not a part of English grammar except in rare cases such as *five head of lettuce* (e.g., Allan 1977: 285–286; Croft 1994: 151–152; Tai 1994: 481; Wang 1994: 1; Aikhenvald 2000: 115; Her and Hsieh 2010: 528, among many others). N. Zhang (2013: 246) and Croft (1994: 151–152) claim specifically that standard measures (e.g., *kilo* in *five kilos of apples*), container measures (e.g., *bottle* in *three bottles of milk*), kind CL (*kind* in *three kinds of chocolate*), partitive CLs (e.g., *section* in *three sections of orange*), and collective CLs (e.g., *group* in *three groups of students*) are universally available, but individuating CLs and individual CLs exist only in classifier languages. Such a view seriously confuses function with form. Worse still is Toyota's (2009: 120) use of the term *classifier* in his claim that English has numerous classifiers. In the following quote, PDE stands for present-day English.[3]

> The use of classifiers with the mass noun is quite common in PDE, as in *a piece of furniture*, *an item of clothing*, etc. There may be numerous classifies in PDE, but typical examples used for the analysis in this paper are listed in (5).
>
> (5) an article of clothing; a blade of grass; a block of ice; a bit of information; a bunch of grapes; a cake of soap; a cut of meat; a drop of water; an ear of corn; a grain of corn; an item of clothing; a leaf of sage; a loaf of bread; a lot of water; a piece of information; a sheet of paper; a slice of bacon; a speck of dust; a stick of chalk; a strip of land; a suit of clothing. (Toyota 2009: 120)

None of the words of measure in the above quote is the Chinese-style M or C. In a non-classifier language, there can of course be words of measure, for example, *kilo*, *bottle*, *section*, *group*, and so on in English, which have the semantic function identical to that of Ms in a classifier language, for example, the corresponding *jin*, *ping*, *jie*, *qun*, and so on in Chinese (e.g., Lyons 1977: 464; Croft 1994: 152; Löbel 2000: 223). However, formally, since there is no (overt) structural position for C in English or other non-classifier languages, there can be no such position for M.[4] There can thus be no Ms in English, not in the same formal sense as in Chinese or other classifier languages. Words of measure in English in fact behave as Ns, and nothing like Ms in Chinese (e.g., Lehrer 1986; Van Riemsdijk 1998; Aikhenvald 2000; Löbel 2000; Borer 2005; Kayne 2005). As shown in (5), the word of measure *box* must pluralize like a noun, and its complement must be introduced by a PP, not a bare NP. Its syntactic category and structural position in (5) are exactly identical to those in (6) and (7), where *box* behaves as a mundane common noun.

(5) a. *three boxes of chocolate*
b.* *three box of chocolate*
c.* *three boxes chocolate*

(6) a. *three boxes of excellent quality*
b.* *three box of excellent quality*
c.* *three boxes excellent quality*

(7) a. *three boxes of theirs*
b.* *three box of theirs*
c.* *three boxes theirs*

In short, while a classifier language typically has both Cs and Ms,[5] a non-classifier language has neither, though it does have a class of words that share the same semantic function as Ms in classifier languages.

3 A math-based taxonomy of C/M

Any characterization of C and M must reconcile the dilemma that the two converge structurally in [Num C/M N] and yet diverge semantically. A long-neglected mathematical perspective offers a unique insight to the relation between Num and C/M, as well as the precise distinction between C and M. The earliest source of such a view we know of is Greenberg (1990[1972]: 172), where he states with unmistakable clarity that "all the classifiers are from the referential point of view merely so many ways of saying 'one', or more accurately, 'times one'". Thus, *san tiao yu* [three C fish] of (1a) is seen as [[*3* × *1*] fish].

Seeing sortal classifiers as a multiplicand with the numerical value of 'one' implies the entity being quantified must have natural boundaries and thus appear as single units (Croft 1994: 148; Bisang 1999: 113–121). This view has been pursued in some of the more recent works, for example, Bender and Beller (2006), Au Yeung (2005, 2007), and Yi (2009). Her (2012a) takes this view most seriously in coming up with a precise formulation for the unification of, and distinction between, C and M.

(8) C/M Distinction in Mathematical Terms (Her 2012a: 1679)

[Num × N] = [[Num × X] N], where X = C iff X = 1, otherwise X = M.

Under this precise formulation, C and M *converge* in entering the same multiplicative relation as the multiplicand, with Num as the multiplier. Thus, crucially, while Cs and Ms converge in denoting *one unit*, the one unit denoted by Cs has the precise numerical value of *one*, but the one unit denoted by Ms does not, for example, *da* 'dozen' denotes the precise numerical value of *twelve*. C/M as a multiplicand denoting *one unit* thus is naturally identically coded structurally in a language. This convergence explains why C/M consists of a single syntactic category and in many respects behaves in a uniform manner. Yet C and M also *diverge* in their respective values: all Cs as the multiplicand must necessarily have the exact numerical value *1*, while an M's value can be anything except 1 and can thus be numerical or non-numerical. More simply, an M's value is never necessarily *1*. This divergence in mathematical value accounts for the semantic differences and consequent behavioral differences observed between Cs and Ms.

The most significant difference is M is semantically substantive, but C is semantically redundant, in the sense that M does, but C does not, contribute additional information to the head noun (e.g., Greenberg 1990[1974]: 201; W. Li 2000: 1117). Her and Hsieh (2010) apply Aristotle's essential vs. accidental property to C/M's semantic distinction:[6] while a C denotes one or more essential properties of the head noun, an M denotes accidental properties. This means that a C is semantically redundant in the nominal expression, but an M is not. For example, the following three expressions, 三隻魚 *san zhi yu*, 三條魚 *san tiao yu*, and 三尾魚 *san wei yu*, have exactly the same connotation, that is, *3 fish*, in spite of the different Cs; yet, if the three different Cs are replaced with three different Ms, then each expression will have a different connotation, for example, 三磅魚 *san bang yu* '3 pounds of fish', 三箱魚 *san xiang yu* '3 boxes of fish', and 三籃魚 *san lan yu* '3 baskets of fish'.

This difference between C and M also receives a plausible explanation in the multiplicative theory: a multiplicand in a multiplicative relation is redundant if and only if its value is *1*; a C is thus redundant in a nominal expression, but M is not (Her 2012a). Such redundancy also manifests itself in C's being transparent to adjectival modification. Thus, (9a) and (9b) have the same meaning, but (10a) and (10b) do not.

(9) a. 一**大**顆蘋果 = b. 一顆**大**蘋果 (Her and Hsieh 2010 (13a))
yi ***da*** *ke pingguo* = *yi ke* ***da*** *pingguo*
one big C apple — one C big apple
'one big apple' — 'one big apple'

(10) a. 一**大**箱蘋果 ≠ b. 一箱**大**蘋果 (Her and Hsieh 2010 (13a))
yi ***da*** *xiang pingguo* ≠ *yi xiang* ***da*** *pingguo*
one big M-box apple — one M-box big apple
'one big box of apples' — 'one box of big apples'

Note that an M can, of course, be represented *redundantly* as *1*M; however, crucially, the value of *1*M is entirely different from the numerical value of any C, which is exactly *1*. For example, *san da* [*3*×dozen] can be expressed *redundantly* as [*3*×*1*dozen]; however, both expressions are different from [*3*×*1*]. Such a misunderstanding is found in N. Zhang (2013: 37), where she claims that Greenberg's 'times one' interpretation of all Cs is true of all measure words as well:

> Greenberg (1972: 10) points out that "all the classifiers are from the referential point of view merely so many ways of saying . . . 'times one'." This is also true of all measure words. All types of CLs and measure words are used in counting, telling us what counts as one in the context, i.e., the unit of counting. (see Croft 1994: 152 and Allan 1977: 293). (N. Zhang (2013: 37)

Importantly, in Greenberg's works on numeral classifiers (Greenberg 1972, 1974, 1975), he has consistently made the distinction between the classifier construction and the measure construction. It is thus clear that Greenberg only intends for the 'times one' interpretation to apply to Cs, not Ms. In fact, in the same passage, Greenberg (1990[1972]: 172) further applies multiplication to two instances of measure words, *two dozen* and *twelve pairs*, and acknowledges that their 'identity of final numerical result', which is unmistakably 36, is drastically different from the result of [2×1] or [12×1]. C/Ms are indeed all units of counting, but the crucial difference between C and M is their inherent mathematical value.

There is thus another caveat to heed: the actual value of an M may *accidentally* be precisely *1*, but that is not the same as *necessarily 1*. For example, *san bang yu* 'three pounds of fish' may just happen to be exactly three fish, each weighing exactly one pound. This sheer accident does not make *pound* a C, not even temporarily. However precise or imprecise the value of an M, be it number, weight, volume, size, time, height, length, or monetary value, the crucial point is that as a multiplicand, its mathematical value is *not necessarily 1*. The value of a C is *necessarily 1*, but it can also have an accidental non-numerical value. For example, *san tiao yu* '3 fish' may just happen to be exactly three pounds of fish, again each weighing exactly one pound. This sheer accident likewise does not make *tiao* an M, not even temporarily.

C thus acknowledges a single unit of an entity with natural boundaries, whereas M creates boundaries for an entity which may or may not have natural boundaries. Some Ms thus also encode numerical values, such as *2*, *12*, or a vague number, and create boundaries for entities with natural boundaries only. Other Ms thus encode non-numerical values and create boundaries for all entities. Her and Lin (2015) thus put forth the innovative concept that a insightful taxonomy of C/M types can be achieved according to the different types of mathematical values encoded by C/M, as shown in Table 2.2.

The two most important criteria for this classification scheme are: first, whether the value is exactly *1* and, second, whether the underlying mathematical value of a C/M as a multiplicand is numerical. The first criterion is crucial because a multiplicand is redundant only when its value is *1*; this unique property sets Cs apart from Ms. The second criterion is crucial because C/Ms with a numerical value must select nouns that are delimitable, or atomic, and thus countable, while those with a non-numerical value can appear with either delimitable or undelimitable nouns. Non-numerical measure words thus come in various subtypes, for example, volume, container, weight, length, area, time, money, portion, and so on.

Any C/M with a fixed or standardized value can be seen as standard, thus including C, M_1, and M_3. It is thus possible for a C/M to be crossed-listed, if its value is ambiguous; for example, 茶匙 *chachi* 'teaspoon' in Chinese can be used as a formal standard measure in cookbooks as well as a causal container elsewhere

Table 2.2 Types of C/M based on mathematical value

Numerical or not	*Fixed or not*	*Examples*		*C/M Type*
Numerical	**Fixed**	***1***	個 *ge*, 隻 *zhi*, 條 *tiao*, 本 *ben*, 朵 *duo*	**C**
		*¬**1***	*2* 雙 *shuang*, 對 dui; *6* 手 *shou*; *12* 打 *da*	$\mathbf{M_1}$
	Variable	*>**1** (¬**1**)*	排 *pai* 'row, 群 *qun* 'group, 幫 *bang* 'gang'	$\mathbf{M_2}$
Non-Numerical	**Fixed**	*¬n(¬**1**)*	斤 *jin* 'catty', 升 *sheng* 'liter', 碼 *ma* 'yard'	$\mathbf{M_3}$
	Variable	*¬n(¬**1**)*	滴 *di* 'drop', 節 *jie* 'section', 杯 *bei* 'cup'	$\mathbf{M_4}$

without a fixed value. It is thus possible for a container measure to be M_1, if its value is numerically fixed, for example, the container measure 籠 *long* 'steamer, cage', when referring to the small steamed pork buns in a Chinese restaurant specializing in northern cuisine, has a standardized value of 10. However, elsewhere, it is an M_2 or less commonly M_4, with a numerical or non-numerical but variable value. The so-called partitive measure, and also what Zhang (2013) calls 'individuating' unit words, are now part of M_3 and M_4, depending on whether the value is fixed, for example, 半 *ban* 'half', or variable, for example, 節 *jie* 'section'. A collective measure is now part of M_1 and M_2, again depending on whether its value is fixed, for example, 打 *da* 'dozen', or variable, for example, 群 *qun* 'group, herd'.

Some linguists also consider event classifiers, for example, 場 *chang*, a separate type among C/Ms. For example, Huang and Ahrens (2003) distinguish three types: individual, event, and kind. However, an event, by definition, is delimitable and must have a beginning and an end. Event classifiers are thus merely a subtype of Cs (Lai 2011; Her and Lai 2013). Finally, we treat the kind unit words, for example, 種 *zhong*, 類 *lei*, 樣 *yan*g, and 式 *shi*, as measure words, more specifically as a subtype of the non-numerical M_4. This classification is confirmed by a process of elimination. A kind unit word is not restricted to delimitable nouns, which means it can only be an M_3 or M_4. Given that what constitutes a kind is hardly standardized or fixed, it cannot be an M3. The C/M taxonomy thus offers comprehensive coverage of all the elements that appear as C/M in the constituent formed by Num, C/M, and N.

4 A formal semantic account

In this section, we shall first briefly review several important accounts of formal semantics, Chierchia (1998a, 1998b), Krifka (1995), Jiang (2012), X. Li (2011), and Rothstein (2010), and demonstrate that they cannot model the semantic distinction between C and M argued for in Section 3, before we propose our own formal semantic account.

4.1 Review of previous accounts

The semantics of a C/M is closely related to that of the head noun, as a fundamental criterion for identifying different types of C/M is the semantics of the nouns they select. Since Chinese nouns are not marked for plurality, there are two potential theoretical hypotheses for the semantics of Chinese nouns. The first is that Chinese nouns denote kind, referred to as 'kind analysis' in this chapter, for example, in Chierchi (1998a), Krifka (1995), and so on, and the other is that Chinese nouns denote mass, that is, the famous mass noun hypothesis, for example, in Chierchia (1998b), Hansen (1976), and so on.

We start from the kind analysis. Carlson (1980), observing that bare plurals in English can denote kind, proposes that kind is a (special type of) individual, which is distinguished from an individual described a singular count noun, and that kind can be mapped to object (i.e., individual), which, in turn, can be mapped to stage (Carlson 1980: 69). McNally (2017) looks into the semantics of kind from another perspective, based on the idea that common nouns denote distributional representations. However, McNally also proposes a type shifter KO' to achieve the same purpose of mapping kind to an object.

There is another type of research on the semantics of nouns that seems relevant here. Grimm (2012) examines nouns in languages such as Welsh or Maltese and describes a third distinction among nouns, in addition to singular/plural and count/mass, that is, collective/entity. Nouns in these languages thus have singular and plural morphological markings, demonstrate the count-mass distinction, and also denote collectivity and entity. Morphologically, collective nouns are not marked, but they are marked when denoting an entity of that collective (Grimm 2012: 53). Grimm (2012: 68) proposes a hierarchy of individualization: substances < granular aggregates < collectives < individual entities and suggests that the grammatical number system for nouns relies on different parts of the hierarchy; for example, languages that have a collective/entity distinction use the middle part of the hierarchy.

Chierchia (1998a: 354) explicitly proposes that nouns denote kind in Chinese. Chierchia bases his idea on the fact that a bare noun can appear in an argument position in Chinese. A constituent that can appear in an argument position must be of type *e*. If Chinese nouns were of type <*e*, *t*>, like English count nouns, then it would be difficult to explain why a constituent of type <*e*, *t*> can appear in a position where a constituent of type *e* is required. Although not providing formal details, Chierchia (*ibid.*) identifies as one of the distinctive features for languages whose nouns are of type *e* that such languages utilize classifiers.

If Chinese nouns denote kind, then some device is required to map kind to countable objects, that is, individuals, so that such nouns can be quantitized. Krifka (1995) proposes that classifiers perform type-shifting, in a sense similar to Carlson (1980) and McNally (2017), and maps a kind to countable objects. For example, *xiong* 'bear' is a name referring to kind, that is, Ursus, and the other usages, including *san zhi xiong* [three C bear], are derived from the kind reading. To account for the [Num C/M N] construction, Krifka proposes an operator that takes a noun denoting a kind and returns the number of specimens of that kind. See the following example.

(11) a. $[\![\text{zhi}]\!] = \lambda n \lambda y \lambda i \lambda x[RT_i(x, y) \wedge OU_i(y)(x) = n]$
b. $[\![\text{san zhi}]\!] = \lambda y \lambda i \lambda x[RT_i(x, y) \wedge OU_i(y)(x) = 3]$
c. $[\![\text{san zhi xiong}]\!] = \lambda i \lambda x[RT_i(x, \text{Ursus}) \wedge OU_i(\text{Ursus})(x) = n]$
(Krifka 1995: 401)

In (11), RT applies to a kind and gives us the property of being a specimen or a subspecies of the kind. OU, object unit, is a function that takes a noun expressing a kind and gives back the number of the specimens of that kind. The subscripted *i* represents a possible world. The number *san* 'three' instantiates the *n* argument of the classifier *zhi*, that is, OU specifies that the number of the specimens of a kind is three. The semantics of *xiong* is Ursus, a kind, which instantiates the *y* argument in the semantics of *san zhi* 'three C'. Therefore, the semantics of *san zhi xiong* 'three CL Ursus' is: RT maps the kind, Ursus, to specimens, OU counts the specimens of the kind Ursus, and the number of the specimens is three.

For *san qun xiong* [three herd Ursus], Krifka analyzes *qun* as a counterpart of English *herd* and its semantics is: $\lambda n\lambda y\lambda i\lambda x[RT_i(x, y) \wedge herd_i(x) = n]$. For *san zhong xiong* 'three kind Ursus', the semantics of *zhong* is $\lambda n\lambda y\lambda i\lambda x[RT_i(x, y) \wedge KU_i(y)(x) = n]$. As can be seen from the semantics of *zhi* and *qun*, the difference is that *qun* does not require an OU operator because its core semantics is *herd*. On the other hand, the semantic difference between *zhi* and *zhong* is that the former takes an OU operator, which returns the number of specimens of a kind, while the latter has a KU (kind unit) operator, which gives back the number of kind.

The kind analysis of nouns cannot apply to Chinese nouns for two reasons.[7] First, under Krifka's (1995) idea that a classifier serves as a type shifter that maps a kind to an individual, a noun without a classifier should receive a kind reading. While Chierchia (1998a) does not discuss the function of classifiers, in this chapter, Chinese nouns are proposed to express kind. But, standing alone without a classifier, a Chinese noun does not (necessarily) express kind. For example, the phrase *wu bing er yu* (five loaf two fish), gets an individual reading only, that is, *five loaves and two fish*. In examples without a numeral, such as *shu*, *wo dou nianwan le* 'book, I all read-finish Pfv', *shu* 'book' here does not refer to kind as well, since it is impossible to finish reading *books* as a kind.

Second, it is unclear how exactly the type shifter can pick out a coherent individual from a kind. While it seems natural to think of a kind as consisting of individuals, Carlson's (1980) theory treats kind as a type of individual. Then, the question is how the type shifter can identify a discrete, natural or man-made unit from a kind, for example, a *banana*, a *car*, and a *trillion*. This question has not been addressed in works that support the kind-to-individual theory.[8] To resolve this problem, one may think of Grimm's (2012: 134) definition of 'wholes', "any two parts that make up the whole of *x* [that thing] are connected to each other." Yet this definition is too restrictive for classifiers in Chinese. For example, in the phrase *yi ben zhilipuosui de shu* 'one C in-tatters book', the classifier and *zhilipuosui* 'in tatters' are still compatible. Such examples suggest that Grimm's definition of wholes cannot be applied to Chinese classifiers. Hence, the second problem remains.

On the other hand, Chierchia (2010) suggests that classifiers, which are of type $<k, <e, t>>$, are needed to type shift kind (of type k) to type $<e, t>$ so that numbers, which are of type $<<e, t>, <e, t>>$, can go with such a noun. He (1998a: 349) further proposes that kind is a function from worlds w to pluralities. Chierchia (1998b, 2010) suggests that the semantics of a plural is the set of all the atoms and of all the possible sum individuals of the atoms and that the semantics of mass equals that of plurals, except that the boundaries among the atoms for mass are vague. Chierchia (1998b: 74) further suggests that classifiers map a mass noun to atoms. Therefore, while technically a classifier can shift the semantic type of a kind (or mass), it is not clear how the vague boundaries of atoms for a mass noun can be made distinctive so that individual atoms can be separated from each other. That is, even with Chierchia's (1998a, 1998b, 2010) ideas, the second problem is still in effect.

Next, let's look at the mass noun hypothesis. Hansen (1976) suggests that Chinese nouns are mass. Chierchia (1998b) also has a similar proposal.[9] As pointed out above, Chierchia (1998b, 2010) proposes that the semantics of a plural is the set of all the atoms and all the sum individuals of the atoms and that the semantics of a mass noun is like that of a plural, except that the boundaries between the atoms for a mass noun are vague. Rothstein (2010), on the other hand, proposes the following semantics for mass nouns, count singular nouns, and count plural nouns, based on a complete atomic Boolean algebra M:

(12) a. Root nouns: $N_{root} \subseteq M$: Root nouns denote a Boolean algebra of mass entities, the closure of a set of atoms in M under the sum operations $\sqcup_M$.
b. Mass nouns: $N_{mass} = N_{root}$
c. Singular count nouns: $COUNT_k(N_{root})$: A singular count noun denotes a set of ordered pairs of which the first projection is $N_{root} \cap k$, a subset of N_{root} whose members do not (generally) overlap, and the second projection is the context k.
d. Plural count nouns: in a default context k, $PL(N_k) \subseteq M \times \{k\}$, where the first projection is the closure of $N_{root} \cap k$ under sum and the second project is k.

$COUNT_k$ takes the root noun meaning and gives back entities which, in the given context k, are qualified as atoms and thus can be counted. Based on the semantics in (12), Rothstein also assumes that C/Ms in Chinese are the overt realization of the $COUNT_k$ operator, which applies to the root meaning (= the mass meaning) of a noun.

X. Li's (2011) formal semantic analysis of C/Ms is based on Rothstein's (2010) idea. He first distinguishes four types: (a) counting classifiers, which identify the natural counting unit inherent to sets of discrete entities; (b) classifiers with a measuring reading, which "simply measure the quantity of entities along a certain dimension, for example weight, length" (X. Li 2011: 126); (c) classifiers with both counting and measuring readings; and (4) kind classifiers. Note that X. Li uses the term 'classifiers' for all C/Ms. He also assumes that Chinese nouns are mass. The semantics of the four types are shown in (13) and the semantics of numbers in (14):

(13) a. **[**duo**]** = $\lambda\mathbf{k}\lambda x.\pi_1(x)\epsilon(^{\cup}\mathbf{k}\cap k)$^Blossom-form$(\pi_1(x))$^$\pi_2(x) = k$
b. **[**ping**]** = $\lambda\mathbf{k}\lambda x.\pi_1(x)\epsilon(\text{BOTTLE}\cap k)^CONTAIN(\pi_1(x), \mathbf{k})$^$p_2(x)=k$
c. **[**jin**]** = $\lambda n\lambda\mathbf{k}\lambda x.x\epsilon^{\cup}\mathbf{k}$ ^ POUND$(x) = n$
d. The kind classifier is an overt lexical realization of the operator $\bigsqcup$, which takes a kind and gives back the set of subkinds according to a partition.

(14) a. **[**wu**]** = $\lambda P\lambda x.P(x)$^$|\pi_1(x)|_k = 5$
b. **[**yi**]** = 1

(13b) is an instance of C/Ms with both counting and measuring readings. Since in phrases such as *yi ping shui* 'one bottle water', the number expresses the quantity of *bottle*, the atom, $\pi_1(x)$, is a member of the intersection of *bottle* and the context variable *k*. CONTAIN is a relation for containers on the counting reading. (13c) is an example of standard measures with a measuring reading. The first lambda-bound variable of (13c) is different from those of (13a) and (13b) because X. Li (2011: 151) claims that a C/M with a measuring reading forms a constituent with Num first, while those with a count reading, such as (13a) and (13b), merge with a kind N first. (13d) should be self evident.

The semantics of numbers in (14) are proposed in X. Li (2011: 149–151). It is important to note that numbers have different semantics for different readings: on the one hand, there are C/Ms with a measure reading only, and on the other hand, there are those with a count reading and those with both count and measure readings. Let's see the diverse semantic derivations below.

(15) a. [yun] = $^{\cap}$CLOUD
b. [duo yun] = $\lambda x.\pi_1(x)\hat{I}(^{\cup\cap}\text{CLOUD}\cap k)$^Blossom-form$(\pi_1(x))$^$\pi_2(x)$=k
c. [wu duo yun] = lx.$\pi_1(x)\epsilon*(^{\cup\cap}\text{CLOUD}\cap k)$^*Blossom-form$(\pi_1(x))$^$|\pi_1(x)|_k$=5 ^$\pi_2(x)$=k

(16) a. [shui] = $^{\cap}$WATER
b. [wu ping shui] = x.$p_1(x)\epsilon$(BOTTLE$\cap$k) ^ CONTAIN$(\pi_1(x), {}^{\cap}\text{WATER})$ Ù$|\pi_1(x)|$=5 ^$\pi_2(x)$=k

(17) a. [yi jin] = $\lambda\mathbf{k}\lambda x.x\epsilon^{\cup}\mathbf{k}$^POUND(x)=1
b. [mi] = $^{\cap}$RICE
c. [yi jin mi] = $\lambda x.x\epsilon^{\cup\cap}$RICE^POUND(x)=1

As shown in (15)–(17), numbers play different roles and hence have different semantics. In (15) and (17), *wu* 'five' takes the phrase consisting of a C/M and a kind noun as its argument, while in (17), *yi* 'one' instantiates the *n* argument in *jin* 'pound', and the phrase composed of *yi* and *jin* takes a noun as its argument.

Jiang (2012) also adopts the idea that Chinese nouns are kind-referring and a C/M transforms a kind-denoting noun into a set, that is, <e, t>, so that the atoms in this set can be dealt with. She claims that this provides a unified account for C/Ms in Chinese because

> standard measures classifiers, like *bang* 'pound', measure parts under sum; kind classifiers, like *zhong* 'kind, measure sub-kinds; container classifiers, like *wan* bowl', measure parts via a fill-in-relation with respect to the noun; group classifier like *qun* 'group' measure sets formed as groups; partitive classifiers, such as *ceng* 'layer' measure partitions.
>
> (Jiang 2012: 139)

Note that Jiang also uses the term 'classifiers' for all C/Ms.

While all of the works above are enlightening in deciphering the semantics of C/Ms in Chinese, they face some challenges. First, they all assume that Chinese nouns are either kind or mass. As pointed out above, Chinese nouns cannot express kind, because, standing alone without a classifier or as a bare noun, a Chinese noun does not (necessarily) have a kind interpretation. Moreover, the hypothesis that Chinese nouns are mass has been seriously challenged. For example, Yi (2009, 2011a, 2011b), adopting a similar mathematical perspective on C/Ms as we do, argues specifically that a lexical distinction of mass/count is needed in Chinese, as well as other classifier languages. Kuo and Wu (2010) propose specific syntactic tests for mass/count distinction in Chinese.[10]

Particularly, Yi (Unpublished) argues against what he refers to as a (revised) individualizer theory, where classifiers are considered some type of 'individualizer', which functions to 'individualize' a kind or mass and transforms the kind/mass to atoms, because such an analysis leads to inconsistencies in both linguistic facts and the syntactic interactions between numeral, classifiers, and head nouns.

Furthermore, Her and Hsieh (2010) and Her (2012a, b) demonstrate that it is not possible for a C to serve as an 'individualizer', and thus that count nouns must be recognized lexically. Her and Hsieh (2010: 533) use *yi gen xiangjiao* 'one C banana' as an example and argue that:

> Under this view [all Chinese nouns are mass], *xiangjiao* 'banana' can only refer to the banana mass, and the reading of a natural unit of banana with peel is only accidental and due to the classifier *gēn*, which 'carves out' an elongated discrete unit. This view thus predicts that (5) [*yì gēn xiangjiao* 'one C banana'], besides this natural reading, can also mean an elongated unit of bits or pieces of the banana substance or mashed banana. Such a reading is simply impossible.

The second challenge is related to the first. Krifka (1995) utilizes an OU to take a kind as an input and the specimens of the kind as output. Rothstein (2010) uses a $^{\cup}$ operator for a similar purpose. Chierchia (2010) suggests that classifiers perform such a function. Yet it is not clear how these operators can distinguish nouns that allow this operation from those that do not. There are nouns in Chinese that behave in a way parallel to mass nouns in English, for example, *shui* 'water' and *mianfen* 'flour', in that they do not have atoms in their semantics. Obviously, OU or $^{\cup}$ cannot apply to such nouns, as no Cs can go with such nouns, which allow Ms only.

In X. Li's (2011) account, numbers come in two different semantics, depending on the different readings of a [Num C/M N] expression. A unified semantics for numbers is, of course, preferred, which is the case under our proposal for the semantics of C/Ms.

In order to capture the semantic distinction between C and M that we have argued for, we utilize Link's (2003[1983]) semantics of mass nouns and plural nouns,[11] where the semantics of a singular count noun is a set of entities denoted by the noun. He proposes a * operator, which takes a set of entities and produces all of the individual sums of the entities. The sum operation is represented as ⊕. If α is an individual and β is another individual, then α⊕β is also an individual (i.e., individual sum) composed of α and β, which can be considered a plural individual. Here is an example.

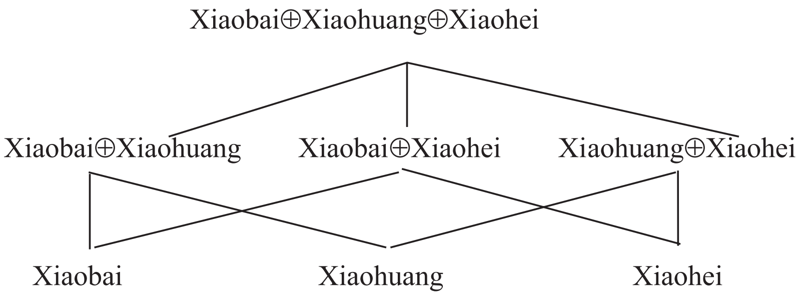
(18) a. ⟦gou⟧ = {Xiaobái, Xiaohuáng, Xiaohēi}

b. Xiǎobái⊕Xiǎohuáng⊕Xiǎohēi

Xiǎobái⊕Xiǎohuáng Xiǎobái⊕Xiǎohēi Xiǎohuáng⊕Xiǎohēi

(18a) is a set of three dogs: Xiaobai, Xiaohuang, and Xiaohei. This is the semantics of singular count noun *gou* 'dog'. The * operator applies to *gou* 'dog' and forms the semantics of plural *gou*: all of the individual sums of the three dogs, that is, (18b). Under this definition, the starred noun now has the same cumulative property as a mass noun. A plural noun and a mass noun are both closed under sum formation. Any sum of parts of a plural noun is again the plural noun, and any sum of a mass noun is again the mass noun. In (18), for example, if we perform sum operation on Xiaobai⊕Xiaohuang and Xiaobai⊕Xiaohei, we get Xiaobai⊕Xiaohuang⊕ Xiaobai⊕Xiaohei, reducible to Xiaobai⊕Xiaohuang⊕Xiaohei. If we execute sum operation on Xiaohuang⊕Xiaohei and Xiaobai⊕Xiaohuang⊕Xiaohei, we get Xiaohuang⊕Xiaohei⊕ Xiaobai⊕Xiaohuang⊕Xiaohei, which, again, can be reduced to Xiaobai⊕Xiaohuang⊕Xiaohei. Pick any two individuals in (18b) and perform sum operation, you get an individual in (18b). This is the cumulative property for plural nouns and mass nouns. Combining (18a) and (18b), we get (19):

(19)



In (19), the bottom level is the atomic level, where the elements in this level are atoms, that is, individual dogs. The other levels are non-atomic individual (sum) level, where the elements in these levels are plural individuals, that is, an individual composed of two or three dogs.

Based on (19) and following Krifka (1998), suppose that ⟦gou⟧ is the semantics of singular *gou* 'dog' and GOU represents singular *gou* and plural *gou*. Then GOU can be defined as follows:

(20) a. GOU is the smallest function that satisfies the following conditions:

(i) $\forall x \in D_e\ [⟦gou⟧(x) \rightarrow \text{GOU}(x)]$

(ii) $\forall x, y \in D_e\ [(\text{GOU}(x) \wedge \text{GOU}(y)) \rightarrow \text{GOU}(x \oplus y)]$

b. $⟦{*}gou⟧ = \lambda x \in (D_e - A)\ [\text{GOU}(x)]$

(20a) is the definition for a lattice for *gou* 'dog', singular and plural, in Chinese, represented as GOU. (20a-i) is the baseline. All singular ⟦gou⟧ is GOU. (20a-ii) is a recursive definition for GOU. If *x* is GOU and y is GOU, then *x*⊕*y* is also GOU. Hence, if both *x* and *y* are singular ⟦gou⟧, then *x*⊕*y* is GOU. If *z* is also singular ⟦gou⟧, then *x*⊕*y*⊕*z* is gou, as well. We can build (19) if there are three dogs. We can build a more complicated lattice if we have more than three dogs.

(20b) is the semantics of plural ⟦gou⟧, that is, ⟦*gou⟧ in Link's (2003[1983]) terms. *A* represents the atomic level of a lattice. A lattice is type e because everything in a lattice is an individual – either an atomic individual or an individual sum. $D_e - A$ stands for a lattice except for the bottom (atomic) level. (20b) says that the semantics of plural *gou* is one of the individual sums in the lattice for GOU.

Furthermore, according to Link's idea, the semantics of a plural count noun is the same as that of a mass noun; that is, the semantics of a mass noun such as *shui* 'water', *tu* 'earth', *mianfen* 'flour', and so on, is a lattice like (19) without the bottom (atomic) level.

4.2 Proposal of a formal semantic account

Given the semantics of a singular count noun, a plural count noun, and a mass noun as discussed above, we can provide semantics for the taxonomy of C/Ms proposed in section 3:

(21) a. Numerical – Fixed – × 1:

$[\![\text{C}]\!] = \lambda n \epsilon R^+ \; \lambda P \epsilon D_{<e,\, t>} \; \lambda x \hat{I}(D_A \text{ or } D_e{-}D_A) \; [P(x) \wedge \text{ATOM}(x) = n \times C]$, where C = 1 and C profiles the head noun *P* in the sense of Her (2012a).[12]

b. Numerical – fixed – × *m* (where *m* is a positive real number, which is fixed and greater than 1):

$[\![\text{M}_1]\!] = \lambda n \epsilon R^+ \; \lambda P \epsilon D_{<e,\, t>} \; \lambda x \epsilon \; D_e{-}D_A \; [P(x) \text{ Ù } \text{ATOM} \; (x) = n \times m]$, where *m* stands for fixed number greater than 1, and M_1 has selectional restrictions on the head noun *P*.

c. Numerical – variable – × *m* (where *m* is a positive real number):

$[\![\text{M}_2]\!] = \lambda n \epsilon R^+ \; \lambda P \epsilon D_{<e,\, t>} \; \lambda x \epsilon \; D_e{-}D_A \; [P(x) \text{ Ù } \text{ATOM} \; (x) = n \times m \wedge m > 1]$, where M_2 has selectional restrictions on the head noun *P*.

d. Non-numerical – Fixed:

$[\![\text{M}_3]\!] = \lambda n \epsilon R^+ \; \lambda P \epsilon D_{<e,\, t>} \; \lambda x \epsilon (D_e{-}D_A) \; [P(x) \text{ Ù } M_3(x) = n]$, where M_3 represents a specific measure of *P*.

e. Non-numerical – Variable:

$[\![\text{M}_4]\!] = \lambda n \epsilon R^+ \; \lambda P \epsilon D_{<e,\, t>} \; \lambda x \epsilon (D_e{-}D_A) \; [P(x) \text{ Ù } M_4(x) = n]$, where M_4 stands for a vague measure of *P*.

f. $\forall x \epsilon D_e$, $\text{ATOM}(x) = \#\{y | y \leq x\}$ (Krifka 1998)

g. $y \leq x$ iff $y \oplus x = x$, $\forall x, y \epsilon D_e$

An explanation for the notations in (21) is needed. R^+ represents a positive real number. A lattice such as (19) is of type <e, t>. D_A stands for the atomic level of a lattice such as (19). $D_e{-}D_A$ represents the parts of a lattice that stand for the semantics of a plural noun or of a mass noun.

Following Krifka (1998), ATOM returns the number of all of the atoms that are parts of *x*. If *x* itself is an atom, ATOM(x) = 1, because by definition, an atom is a part of itself. If x is an individual sum, for example, $u \oplus v \oplus w$, then $\text{ATOM}(u \oplus v \oplus w) = 3$. The definition of 'part of' ($\leq$) is given in (21g). M is an operator that gives back the number of a certain measurement.

(21a) is the semantics of C as defined in this chapter, such as *zhi* (C for animals), *zhang* (C for objects with a flat surface), *tiáo* (C for entities with a long shape), *ben* (C for bound printed volumes), and so on. C's in our definition refer to *one* complete, discrete atom of a count noun. The exact number of atoms expressed by a nominal phrase is determined by the number in the phrase. Because the atom of the noun that goes with C can be 1 or greater than 1, *x* is either a member of the atomic level, that is, D_A, or a member of individual sum levels, that is, D_e–A.

(21b) is the semantics of M_1, including *shuang* 'pair', *duì* 'pair', *da* 'dozen', *dao* '100 sheets (of paper)', and so on. These measure words give us the exact number of atoms of the count noun they select, but the number must be greater than one: *shuang* and *duì* denote two, *da* expresses twelve, and *dao* means one hundred. Let's look at the semantic derivations of *shi ke pingguo* [ten C apple], *shi shuang kuaizi* [ten M-pair chopsticks] and *shi da meigui* [ten M-dozen rose] below.

(22) a. $[\![\text{shi}]\!] = 10$
b. $[\![\text{shi ke}]\!]$

$= [\![\text{ke}]\!]\ ([\![\text{shi}]\!])$
$= \lambda n{\in}R^+\ \lambda P{\in}D_{<e,\ t>}\ \lambda x{\in}D_e{-}D_A\ [P(x)\ \wedge\ \text{ATOM}(x) = n \times 1]\ (10)$
$= \lambda P{\in}D_{<e,\ t>}\ \lambda x{\in}\ D_e{-}D_A\ [P(x)\ \wedge\ \text{ATOM}(x) = 10 \times 1]$

c. $[\![\text{shi ke pingguo}]\!]$

$= [\![\text{shi ke}]\!]\ ([\![\text{pingguo}]\!])$
$= \lambda P{\in}D_{<e,\ t>}\ \lambda x{\in}\ D_e{-}D_A\ [P(x)\ \wedge\ \text{ATOM}(x) = 10 \times 1]\ ([\![\text{APPLE}]\!])$
$= \lambda x{\in}\ D_e{-}D_A\ [[\![\text{APPLE}]\!](x)\ \wedge\ \text{ATOM}(x) = 10 \times 1]$
$= \lambda x{\in}\ D_e{-}D_A\ [[\![\text{APPLE}]\!](x)\ \wedge\ \text{ATOM}(x) = 10]$

In (22), because *ke* is a C, when it combines with the number 10, we get 10 × 1. Then, it goes with $[\![\text{APPLE}]\!]$, a cover term for singular *apple* and for plural *apple*, just like (20a). Then, we get the number of the atoms of $[\![\text{APPLE}]\!]$ as 10. Here, *x* is a member of D_e–D_A because the number 10 rules out the possibility that the atomic level of the semantics of APPLE.

Next, let's look at the semantic derivation of *shi shuang kuaizi* [ten M chopsticks].

(23) a. $[\![\text{shi shuang}]\!]$

$= [\![\text{shuang}]\!]([\![\text{shi}]\!])$
$= \lambda n{\in}R^+\ \lambda P{\in}D_{<e,\ t>}\ \lambda x{\in}\ D_e{-}D_A\ [P(x)\ \wedge\ \text{ATOM}\ (x) = n \times 2]\ (10)$
$= \lambda P{\in}D_{<e,\ t>}\ \lambda x{\in}D_e{-}D_A\ [P(x)\ \wedge\ \text{ATOM}\ (x) = 10 \times 2]$

b. $[\![\text{shi shuang kuaizi}]\!]$

$= [\![\text{shi shuang}]\!]\ ([\![\text{kuaizi}]\!])$
$= \lambda P{\in}D_{<e,\ t>}\ \lambda x{\in}\ D_e{-}D_A\ [P(x)\ \wedge\ \text{ATOM}\ (x) = 10 \times 2]\ ([\![\text{CHOPSTICKS}]\!])$
$= \lambda x{\in}\ D_e{-}D_A\ [[\![\text{CHOPSTICKS}]\!](x)\ \wedge\ \text{ATOM}\ (x) = 10 \times 2]$
$= \lambda x{\in}\ D_e{-}D_A\ [[\![\text{CHOPSTICKS}]\!](x)\ \wedge\ \text{ATOM}\ (x) = 20]$

Shuang in (23) is a numerical M with a fixed value 2. The semantic derivation here is very similar to that in (22), except that *ke* represents 1 but *shuang* 2. Because *shuang* denotes a fixed number 2, the atom of CHOPSTICKS is 20.

Finally, let's look at the semantic computation of *shi da meigui* [ten M rose].

(24) ⟦shi da meigui⟧

$= ⟦\text{shi da}⟧ (⟦\text{meigui}⟧)$
$= \lambda P \epsilon D_{<e,\, t>}\ \lambda x \epsilon\ D_e – D_A\ [P(x) \wedge \textsc{atom}\ (x) = 10 \times 12]\ (⟦\textsc{rose}⟧)$
$= \lambda x \epsilon\ D_e – D_A\ [⟦\textsc{rose}⟧(x) \wedge \textsc{atom}\ (x) = 10 \times 12]$
$= \lambda x \epsilon\ D_e – D_A\ [⟦\textsc{rose}⟧(x) \wedge \textsc{atom}\ (x) = 120]$

(24) is just like (23), except that *da* expresses the numerical value of 12. This is why we get the reading where the number of the atoms of ROSE is 120.

The "times one" in the semantic of a classifier may seem vacuous. However, the semantic derivations of *shi ke pingguo* [ten C apple], *shi shuang kuaizi* [ten M-pair chopsticks] and *shi da meigui* [ten M-dozen rose] in (22), (23), and (24) prove that this semantics is not vacuous but significant. While *ke*, *shuang*, and *da* refer to the number of atoms, *ke* itself simply means 1, while *shuang* denotes 2 and *da* 12. This is why *shi ke pinguo* [ten C apple] refers to ten (ten times one) apples, whereas *shi shuang kuaizi* [ten M chopsticks] describes twenty (ten times two) chopsticks, and *shi da meigui* [ten M rose] one hundred and twenty (ten times twelve) roses.

$\textsc{m}_1$ has selectional restrictions on the head nouns it takes. For example, *yi da meiguo* 'a dozen roses', *san da beizi* 'three dozen glasses', and *wu da qianbi* 'five dozen pencils' are good, but *yi da xuesheng* 'one dozen student' and *liang da gongche siji* 'two dozen bus driver' are not good. It seems that *da* prefers inanimate nouns. Of course, this observation is not fine grained enough and can be further refined. But these examples show the selectional restriction of *da*. *Shuang* 'pair' is similar. It goes only with entities that come in pairs, such as gloves, footwear, and so on. But *yi shuang xuesheng* 'one pair students' is very bad and hard to make sense of. We will not go into the details of the selectional restrictions between $\textsc{m}_1$ and its head noun and leave this issue for future studies.

(21c) is the semantics of $\textsc{m}_2$ as defined in section 3, for example *pai*, *lie*, *wo*, and so on. This type of measure words goes with count nouns and gives us an unspecified number of the atoms of the nouns. Let's take *san wo xiaogou* [three M-nest puppy] as an example. *Wo* does not denote a specific number, unlike *ke*, *shuang*, or *da*. But this phrase does refer to the number of atoms of *xiaogou* 'puppy', although the number is not specified. The semantic derivation of this phrase is as follows:

(25) ⟦san wo xiaogou⟧

$= ⟦\text{san wo}⟧ (⟦\text{xiaogou}⟧)$
$= \lambda P \epsilon D_{<e,\, t>}\ \lambda x \epsilon D_e – D_A\ [P(x) \wedge \textsc{atom}(x) = 3 \times m \wedge m > 1]\ (⟦\textsc{puppy}⟧)$
$= \lambda x \epsilon D_e – D_A\ [⟦\textsc{puppy}⟧(x) \wedge \textsc{atom}(x) = 3 \times m \wedge m > 1]$

$\textsc{m}_2$, just like $\textsc{m}_1$, has selectional restrictions on the head noun it takes. For example, *yi wo shitou* 'one nestful stones' and *liang wo shu* 'two nestful trees' are bad. So, *wo* is not compatible with inanimate entities or plants. But *yi wo laoshi* 'one nestful teachers' and *san wo junren* 'three nestful soldiers' are not good either. We will not go into the details of the selectional restrictions in this chapter. But it should be apparent that there are selectional restrictions between $\textsc{m}_2$ and its head noun.

These three types discussed above are referred to as numerical because these words themselves express a (specified or unspecified) number of atoms. The number in the nominal phrase multiplies the number indicated by the C/M, and this multiplication yields the total number of atoms expressed.

The reason C, M_1, and M_2, as in (21a), (21b), and (21c), respectively, access the atoms of a count noun is that nominal phrases, such as *shi ke pingguo* [ten C apple], *shi shuang kuaizi* [ten M_1 chopsticks], and *san wo xiaogou* [three M_3 puppy], refer to a discrete entity as a whole. Moltmann (1997: 20) states that "singular count nouns differ from mass nouns in that they characterize an entity as an integrated whole. . . . Then, singular count nouns, but not mass nouns, must express whole-properties as part of their lexical meaning." Since in Link's analysis, plural nouns and mass nouns have the same type of semantics, Moltmann's statement also applies to plural nouns. This is why the semantics of C, M_1, and M_2 rely on the atomic level of the semantics of a count noun.

(21d) is the semantics of M_3, measure words that go with either a count noun or a mass noun and which themselves express a specific quantity of a certain unit of measurement, for example, *jin* 'catty or kilo', *chi* 'meter', *miao* 'second', *nian* 'year', and so on. Let's compare *san jin weiyu* [three M tuna] and *san jin shadingyu* [three M sardine]. These two nominal phrases do not access the atoms of tuna or sardine. *San jin weiyu* [three M tuna] is actually only a small part of a whole tuna, but *san jin shadingyu* [three M sardine] refers to a (possibly large) number of sardines. This is why in (21d), the variable *x* is a member of D_e–A, to exclude the atomic level of the lattice for *weiyu* 'tuna' and *shadingyu* 'sardine'. Let's perform the semantic derivation for these two nominal phrases.

(26) a. ⟦san jin weiyu⟧

$$= ⟦\text{san jin}⟧\,(⟦\text{weiyu}⟧)$$
$$= \lambda P\epsilon D_{<e,\,t>}\ \lambda x\epsilon D_e\text{–}D_A\ [P(x) \wedge \textsc{jin}(x) = 3]\ (⟦\textsc{tuna}⟧)$$
$$= \lambda x\epsilon D_e\text{–}D_A\ [⟦\textsc{tuna}⟧(x) \wedge \textsc{jin}(x) = 3]$$

b. ⟦san jin shadingyu⟧

$$= ⟦\text{san jin}⟧\,(⟦\text{shadingyu}⟧)$$
$$= \lambda P\epsilon D_{<e,\,t>}\ \lambda x\epsilon D_e\text{–}D_A\ [P(x) \wedge \textsc{jin}(x) = 3]\ (⟦\textsc{sardine}⟧)$$
$$= \lambda P\epsilon D_{<e,\,t>}\ \lambda x\epsilon D_e\text{–}D_A\ [⟦\textsc{sardine}⟧(x) \wedge \textsc{jin}(x) = 3]$$

In (26), *weiyu* 'tuna' and *shadingyu* 'sardine' are guaranteed to be plural or mass because they apply to *x*, a variable which is of the type D_e–D_A. *san jin weiyu* [3 M tuna] and *san jin shadingyu* [3 M sardine] refer to the weight (*jin* here) of tuna or sardines but do not access the atoms. Hence, this phrase does not refer to *tuna* or *sardines* as a whole.

Finally, (21e) is the semantics of M_4, measure words that go with a count noun or a mass noun but which themselves do not denote a specific quantity of a measurement, for example, *di* 'drop', *dai* 'bag', *bei* 'glass/cup', and so on. *wu di shui* 'five drops of water' expresses quantity of water, but the quantity is not specific. And this phrase measures the quantity of water in terms of *di* 'drop' but does not refer to the number of atoms. Let's see how (21e) works.

(27) a. **[**wu di**]**

$= [\![\text{di}]\!]([\![\text{wu}]\!])$
$= \lambda n \epsilon R^{+}\ \lambda P \epsilon D_{<e,\,t>}\ \lambda x \epsilon\ D_e\text{–}D_A\ [P(x) \wedge \textsc{di}(x) = 5]\ (5)$
$= \lambda P \epsilon D_{<e,\,t>}\ \lambda x \epsilon D_e\text{–}D_A\ [P(x) \wedge \textsc{di}(x) = 5]$

b. **[**wu di shui**]**

$= [\![\text{wu di}]\!]([\![\textsc{shui}]\!])$
$= \lambda P \epsilon D_{<e,\,t>}\ \lambda x \epsilon D_e\text{–}D_A\ [P(x) \wedge \textsc{di}(x) = 5]\ ([\![\textsc{water}]\!])$
$= \lambda x \epsilon D_e\text{–}D_A\ [[\![\textsc{water}]\!](x) \wedge \textsc{di}(x) = 5]$

The five semantics in (21) can be reduced to two, one for C/Ms with a numerical value and the other for those with a non-numerical value:

(28) a. $[\![\textsc{c/m}]\!] = \lambda n \epsilon R^{+}\ \lambda P \epsilon D_{<e,\,t>}\ \lambda x\ \epsilon(D_A \text{ or } D_e\text{–}D_A)\ [P(x) \wedge \textsc{atom}(x) = n \times m\ (\wedge\ m > 1)]$, where C/M is distinguished whether *m* stands for a fixed number and, if it does, whether it equals or is greater than 1 and where C/M either profiles the head noun or has selectional restrictions on the head noun.

b. $[\![\textsc{m}]\!] = \lambda n \epsilon R^{+}\ \lambda P \epsilon D_{<e,\,t>}\ \lambda x\hat{I} D_e\text{–}D_A\ [P(x) \wedge M(x) = n]$, where M represents a certain unit of measurement. M_3 and M_4 are distinguished in terms of whether M is a specific or vague measurement.

The semantics of C/Ms proposed here avoid all the problems in the formal semantic accounts reviewed earlier and enjoy several advantages. First, it does not assume that all nouns in Chinese are mass, an assumption that has been seriously challenged. Second, whether a particular type of C/M accesses the atoms in the semantics of a noun is made explicitly clear. Third, numerals receive a unified semantics.

In addition, the semantics proposed in (21) and reduced in (28) capture the significant semantic distinctions among the C/M proposed in this chapter. Numerical C/M, that is, C and $\textsc{m}_1$, both deal with the number of atoms of a noun, and this is why they subcategorize for a count noun. On the other hand, non-numerical M's, that is, $\textsc{m}_3$ and $\textsc{m}_4$, do not address the number of atoms, and instead they simply provide a (fixed or variable) measurement for a noun. This is why $\textsc{m}_3$ and $\textsc{m}_4$ can go with either a count noun or a mass noun.

5 Implications of the mass/count distinction

The mainstream view in the literature on the mass/count distinction and numeral classifiers is the mass noun hypothesis, that is, classifier languages do not make this distinction in the lexicon (e.g., Yi 2009, 2011a, 2011b). Yet an important implication of the taxonomy and its semantics we have proposed in the chapter is that a lexical mass/count distinction is necessary in classifier languages, much the same as in non-classifier languages. A number of researchers have reached the same conclusion that the dominant view is mistaken, for example, Cheng and Sybesma (1998, 1999), Tang (2005), Watanabe (2006), Hsieh (2008), Yi (2009, 2011a, 2011b), Kuo and Wu (2010), Her and Hsieh (2010), Her (2012a), and N. Zhang (2013). We will discuss some of the arguments put forth in such works and offer an additional piece of evidence derived from the often-overlooked fact that Cs may be optional, but Ms are obligatory in *all* classifier languages.

An important motivation for the mass noun hypothesis is that the use of a C is *obligatory* in Chinese for putative count nouns to be quantified by Num. This misconception is very common in the literature (Her 2012a: 1686), as seen in the examples below, most quoted from prominent works on Chinese.

> To a speaker of English, one of the most striking features of the Mandarin noun phrase is the classifier. A *classifier* is a word that *must* occur with a number . . . and/or a demonstrative . . ., or certain quantifiers . . . before the noun.
>
> (Li and Thompson 1981: 104, *emphasis* in original)

> While the use of a measure word is occasionally required in English, its presence is *obligatory at all times* in Chinese when a number is placed before a noun.
>
> (Zhang *et al* 2002: 59–60, *emphasis* added)

> In counting, *all* concrete nouns in standard Chinese *must* be used with a numeral classifier construction.
>
> (Sun 2006: 164, *emphasis* added)

> In Chinese, it is *not possible* to directly quantify a noun through the addition of a numeral. Instead, a classifier *must* intervene between the numeral and the noun to be quantified, whether the noun is conceptually a count or mass noun.
>
> (S. Huang 2013: 164, *emphasis* added)

> Chinese nouns behave like mass nouns in the Indo-European languages, as they *always require* the presence of classifiers in the enumeration.
>
> (Cheung 2016: 243, *emphasis* added)

A depiction closer to the real picture is found in N. Zhang's (2013) book devoted to Mandarin classifiers, where, in spite of the use of the word *obligatory*, several exceptions are recognized.

> Mandarin Chinese is a typical CL language. This is because, first, in a numerical expression . . . the occurrence of a CL is obligatory in the language (except in idiomatic expressions, compounds, or certain list contexts).
>
> (N. Zhang 2013: 1)

The environments where the use of a C is optional in the language certainly go far beyond idiomatic expressions, compounds, and list contexts. To start with, Cs are often allowed to be omitted, motivated by economy or prosody (e.g., Wei 2000: 213). The extent of optional Cs also varies in terms of genres and discourse purposes (e.g., Ding 2005; Yang 2009). For example, in a study of a 1.67-million-character corpus of science textbooks, Chu (1994) finds a whopping 1731 instances of nouns quantified directly by a numeral. As pointed out in Her (2012a: 1680), though largely overlooked in the formalist literature, optional Cs have been duly noted by some pedagogical grammarians. Here are two examples.

> 因為個體量詞不表量，故可省略，"一個杯子"="一杯子"
> *yinwei getiliangci bu biao liang, gu ke shenglue, "yi ge beizi"="yi beizi"* (because classifiers do not express quantity, they can be omitted, "1 C cup"="1 cup") (Ma 2011)
> 個體量詞：一張床（一床）、一頭牛（一牛）、一個人（一人），省略後語意不變。
>
> *Getiliangci: yi zhang chuang (yi chuang), yi tou niu (yi niu), yi ge ren (yi ren), shenglue hou yuyi bu bian*. (Classifiers: 1 C bed (1 bed), 1 C ox (1 ox), 1 C person (1 person), C can be omitted without any change in meaning.)
> (Wang 2004: 113)

It has been noted (e.g., Yue 2003: 85) that the Sinitic languages in the south tend to use more classifiers than those in the north. Conforming to a similar pattern, Mandarin dialects likewise exhibit different degrees of optional Cs. Beijing Mandarin thus uses fewer Cs and allows C to be dropped much more freely than Taiwan Mandarin. In Her and Chen's (2013) survey of the dialogues in the popular movie from China, 非誠勿擾 *Fei Cheng Wu Rao* (English title: *If You Are the One*) and its sequel, out of 282 noun phrases where a C is required prescriptively, more than a quarter, or 74 tokens, to be precise, are without Cs.

This misconception of obligatory Cs is certainly not restricted to Chinese. Burling (1965: 244) claims that "In many languages of Southeast Asia, a number is never used without being accompanied by one of the special morphemes known as classifiers". Greenberg (1990[1972]: 168) thus complains "On such a view, it is not excessive to state that there are no numeral classifier languages". He offers four observations. First, there are certain classes of nouns, for example, units of time and money, which universally do not require Cs.[13] Second, some classifier languages, for example, Vietnamese, allow more extensive classes of such nouns. Third, in some languages, Cs do not occur with certain kinds of numerals, for example, in Khasi, Cs do not occur with the numeral *1*, and it is common for Cs not to occur with multiples of *10* or *20*, depending on whether their numeral system is decimal or vigesimal. Noonan (2003: 321) observes that in Chantyal, the human classifier is dropped in casual speech, while the non-human numeral classifier occurs only with the numbers *1* and *2*. Finally, there are languages, for example, Khmer, where the use of Cs is entirely optional. In a survey of 140 classifier languages, Gil (2013) identifies 78 as having *obligatory* Cs, while he fully acknowledges the concessions noted above in using the rather loosely defined term 'obligatory'. With that understanding, the existence of 62 languages of *optional* Cs in the survey is highly significant.

We can thus conclude with confidence that classifier languages universally allow a noun to be directly quantified by a numeral under certain circumstances. This in turn means a mass/count distinction must be made in classifier languages, just like non-classifier languages. Specific to our account, where C/Ms are seen as multiplicands, is the fact that Cs' redundancy and optionality are consequences of Cs having the value of *1*, as a multiplicand is redundant and thus optional if and only if its value is *1*. This is important because our account also requires a lexical mass/count distinction, as not only Cs, but also Ms with numerical values, must select count nouns. If our account is on the right track, then so is the lexical mass/count distinction in classifier languages and *vice versa*.

Given the conventional view that a lexical distinction of mass/count is made in non-classifier languages that mark plurality, such as English and French, now we only need to establish this distinction in languages with neither Cs nor plural markers (PMs hereafter) in order to claim the universality of this distinction. According to Her and Chen (2013), out of the 114 languages covered by both Gil's (2013) survey of 400 languages for Cs and Haspelmath's (2013) survey of 291 languages for PMs, only 8 have neither Cs nor PMs: Chimariko (an indigenous language of California, now extinct), Imonda (Papuan), Kombai (Papuan), Mapudungun (Araucanian), Pirahã (Amazonian isolate), Salt-Yui (Papuan), Yidiny (Australian, nearly extinct), and Yingkarta (Australian).

We offer two arguments for the mass/count distinction in such languages. Our first argument is logically oriented. Recall that the conventional rationale for the mass/count distinction is whether a noun is quantified by numerals directly or indirectly by means of a C. Note that there are plural-marking languages that allow only the singular form of N in [Num N] when the value of Num is above one, for example, Georgian (Karen Chung, *p.c.*), Finnish (Chierchia 2010: 104), Hungarian (Csirmaz and Dékány 2014: 154), Welsh (Mittendorf and Sadler 2005: 7), and Turkish (Ionin and Matushansky 2006: 326). Thus, if the [Num N] construction with PMs on N is seen as direct quantification of N by numerals, then surely the same [Num N] construction in PM-less and C-less languages must be seen as such as well. In other words, regardless of whether the noun is marked for plurality, only count nouns are selected by numerals for direct quantification.

Our second argument is empirically oriented, as there is evidence in linguistic facts. We shall use Pirahã as an example, which is anumeric and thus without exact numerals and also does not mark plurality (Everett 2005). Behavioral experiments demonstrate that monolingual Pirahã speakers are unable to conceptualize exact numerical quantity larger than three (Gordon 2004; Everett and Madora 2012). However, Pirahã has two distinct quantifiers for larger quantities, which manifest a mass/count distinction (Nevins *et al* 2009).

(29) a. *xaíbái* 'many' (used with putative count nouns only)
b. *xapagí* 'much' (used with putative mass nouns only)

Extending the view that the concept of count only requires the notion of *individual*, or *one* (e.g., Yi 2009; Her 2012a), we contend that the latter notion is both a necessary condition and a sufficient condition for the former. The concept of *individual*, or *one*, is universal in human cognition, as even pre-linguistic infants have been shown to be capable of representing small but precise numbers (1–3) (Feigenson *et al* 2004). A similar view is found in Watanabe's (2006) syntactic account, where a #P is suggested for all noun phrases, and the feature [number] in the # head is the universal locus of the mass/count distinction: "The # head is [+number] in the case of count nouns, whereas it is [-number] in the case of mass nouns" Watanabe (2006: 271). The lack of (the concept of) exact numerals above three is therefore inconsequential to the mass/count distinction, and so is the (lack of) overt marking of plurality. Given the arguments put forth, we contend that a lexical mass/count distinction is made in all human languages.

6 Conclusion

In this chapter, based on the clear distinction between classifiers (Cs) and measures (Ms) in classifier languages like Chinese, we re-classify such unit words into two types: numerical and non-numerical, according to the mathematical value they denote. The numerical type addresses the number of atoms in the semantics of a noun, while the non-numerical type offers a measurement for a noun rather than referring to the number of atoms.

For the numerical type, one subtype represents a fixed number and the other a variable number. The fixed numerical type is further divided into two groups, depending on whether the value is precisely *1*. The ones that have a numerical value of *1*, in addition to profiling a noun in the sense, as discussed in Her (2012a), for example 隻 *zhi*, 條 *tiao*, 本 *ben*, and so on, are grouped under C (classifier). Note that M (measure word) stands for all those unit words whose value is not *1*. Those that have a precise, fixed numerical value greater than *1*, for example 雙 *shuang* 'pair',對 *dui* 'pair', 打 *da* 'dozen', and so on, are referred to as M_1. The subtype referred to as M_2 consists of those with numerical values that are not precise or fixed, for example 排 *pai* 'row', 群 *qun* 'group', 幫 *bang* 'gang', and so on.

The non-numerical type comes in two subtypes. One subtype represents a measurement of fixed quantity, including 斤 *jin* 'catty', 升 *sheng* 'litter', 碼 *ma* 'yard', and so on. *Jin* represents a measurement of fixed weight and *sheng* a measurement of fixed volume of liquid. *Ma* represents a measurement of fixed length. This subtype is called M_3. The other subtype, M_4, refers to those with a measurement of variable quantity, for example 滴 *di* 'drop', 節 *jie* 'section', 杯 *bei* 'cup', and so on.

Formally, the semantics of numerical C/M is distinguished from that of non-numerical C/M in the following way: the former addresses the number of atoms in the semantics of a noun, while the latter describes a measurement of a noun rather than referring to the number of atoms. Moreover, numerical C/M either profiles or has selectional restrictions on the noun it goes with, but non-numerical C/M does not.

One of the most interesting implications of our study is that the distinction between numerical C/M and non-numerical C/M relies on the mass/count distinction in the lexicon. We further contend that the mass/count distinction is universal.

Acknowledgments

We thank the anonymous reviewers for their constructive comments, which made this chapter better. We are also grateful to the editors for their hard work. Moreover, the second author, O.-S. Her, gratefully acknowledges the financial support of the two MOST research grants, 104-2410-H-004-164-MY3 and 106-2410-H-004-106-MY3. Remaining errors are ours.

Notes

1 One more type is recognized, that is, Mv, or measures for verbs of action, which are usually referred to as 'verbal classifiers'. These are very different from nominal classifiers and are excluded from discussion in this chapter.
2 This means that X. Li's (2011: 118) proposal that C/M involves both left- and right-branching structures, the former needed for the quantity reading and the latter the counting reading, is likewise problematic.
3 Ironically, Toyota (2009) concludes, rather reasonably, that PDE is not a non-classifier language due to the common use of such words of measure with mass nouns and not count nouns, while earlier English is a classifier language, since such words of measure are scarce and thus a strict mass/count distinction is not made.
4 Some researchers view plural markers in non-classifier languages like English and Cs in classifier languages like Chinese as identical grammatical elements, formally and functionally (e.g., Borer 2005; Her and Chen 2013). However, even under such a view, words of measure in non-classifier languages cannot be seen formally as Cs or plural markers. In English, for examples, they must be nouns in the formal sense.
5 There are rare cases where a language has Chinese-style Ms but has no Chinese-style Cs. Canglo Monpa, a Tibeto-Burman language in Tibet (Jiang 2006: 50), and Hindi (e.g., McGregor 1995: 69–70) are two examples.
6 According to Robertson (2008), this distinction is characterized as follows: "*P* is an essential property of an object *o* just in case it is necessary that *o* has *P*, whereas *P* is an accidental property of an object *o* just in case *o* has *P* but it is possible that *o* lacks *P*".
7 In the sense of Grimm (2012), a kind can also be seen as a collective.
8 The same criticism applies to the mass noun hypothesis, as pointed out by Her and Hsieh (2010: 533).
9 Please note that, while Chierchia (1998a) suggests that Chinese nouns denote kind, he (ibid: 353) also states that all Chinese nouns are mass.
10 Please note that Chierchia (2010: 355) says that "[. . .] saying that all members of category NP are mass-like does not mean saying that something resembling the mass/count distinction cannot be found in such languages [. . .]." We are not certain whether Chierchia is talking about the grammar of Chinese here. It would be contradictory to claim that in the grammar of Chinese all nouns are mass and at the same time suggest that in the same grammar count/mass are distinguished.
11 Please note that, although we use Link's (2003[1983]) proposal, the semantics of C/M proposed in this chapter can be easily stated in terms of Chierchia's (1998a, b) and Rothstein's (2010) semantics of mass/count nouns, with minor modification.
12 The semantics presented here assumes a left-branching structure, where that Num and C/M form a constituent first, which then merges with N. The best evidence for the left-branching account is the fact that N never comes in between Num and C/M cross-linguistically (e.g., Greenberg 1990[1975]: 227). Also see Her (2012b) for more evidence.
13 Adopting Her and Tsai's (2015) framework that allows silent elements in syntax, Her *et al* (2015) demonstrate that some of such nouns are in fact Ms which select a silent noun.

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