Allomorphy of numerals 'one' and 'two' in Mandarin Chinese

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1. Introduction

It has been observed that cross-linguistically, numerals have two main functions (Greenberg 1978; Bultinck 2005; Rothstein 2013, 2017; Wągiel & Caha 2021): what I call *enumerating* (equivalent to Greenberg's terminology *concrete-counting* and Wągiel & Caha's *object-counting*), which enumerates entities designated by the noun (1a-c); and *abstract* (equivalent to Rothstein's terminology *singular term* and Greenberg's and Wągiel & Caha's *abstract-counting*), which refers to an abstract mathematical entity that can enter arithmetical relations (2a-b).

(1)*Enumerating use of numerals*
   a. Two cats were in the garden.
   b. The two girls cooked a wonderful meal.
   c. The guests were two girls. (Rothstein 2013:179)

(2)*Abstract use of numerals*
   a. Two plus two is four.
   b. Two is the only even prime number. (Rothstein 2013:179)

While in English the numeral in these two uses has the same morphological form, some languages distinguish them morphologically. One example is Chuvash, a Turkic language (Greenberg 1978; Róna-Tas 1999). I call the form for enumerating use *the contextual form*, and the form for abstract use *the absolute form*, following Greenberg's (1978) terminology.

(3)*Chuvash numerals that distinguish contextual and absolute forms morphologically*

Contextual	Absolute
1. pĕr	pĕrre
2. ik, ikĕ	ikkĕ
3. vis, višĕ	viššĕ
4. tăvat, tăvată	tăvattă
5. pilək	pillək
6. ult, ultă	ulttă
7. šič, šičĕ	šiččĕ
8. sakăr	sakkăr
9. tăxár	tăxxăr
10. vun, vună	vunnă
50. al, ala	alla
80. sakărvun, sakărvună	sakărvunnă

(Róna-Tas 1999:2-3)

Like these Chuvash numerals, the numeral '2' in Mandarin Chinese also has two forms–the contextual form *liǎng*, which is used for enumerating, and the absolute form *èr*, which is abstract.

The Mandarin examples corresponding to the English enumerating examples (1a-c) all use the contextual form *liǎng*:

(4)*Enumerating use of '2'*

a. Huāyuán lǐ yǒu **{liǎng/*èr}** zhī māo.
garden in have **2.CONT/2.ABS** CL cat
'There are two cats in the garden.'

b. Nà {**liǎng/*èr}** gè nǚhái shāo-le měiwèi de fàn.
that **2.CONT/2.ABS** CL girl cook-PRF delicious DE meal
'Those two girls cooked a delicious meal.'

c. Kèrén shì **{liǎng/*èr}** gè nǚhái.
guest COP **2.CONT/2.ABS** CL girl
'The guests were two girls.'

In contrast, the abstract numeral '2' always appears in the absolute form, as in counting (5a), arithmetic (5b), room numbers (5c), decimal numbers (5d), years (5e), phone numbers, fractions, etc.

(5)a. *Counting numbers*
yī **{*liǎng/èr}** sān sì…
one **2.CONT/2.ABS** three four
'One, two, three, four…'

b. *Arithmetic*
Shí chúyǐ **{*liǎng/èr}** shì wǔ.
ten divide.by **2.CONT/2.ABS** COP five
'Ten divided by two is five.'

c. *Room number*
{*liǎng/èr} líng **{*liǎng/èr}** (shì)
2.CONT/2.ABS zero **2.CONT/2.ABS** room
'Room 202'

d. *Decimal number*
{*liǎng/èr} diǎn líng **{*liǎng/èr}**
2.CONT/2.ABS point zero **2.CONT/2.ABS**
'2.02'

e. *Year number*
{*liǎng/èr} líng **{*liǎng/èr}** sān nián
2.CONT/2.ABS zero **2.CONT/2.ABS** three year
'2023'

Greenberg (1978) made many universal generalizations about numeral systems across languages, among which generalization #51 was about absolute and contextual forms and based on languages like Chuvash and Gã: "The existence of a separate absolute form for a particular numerical value implies its existence for the next lower value." He then mentioned Mandarin Chinese as an exception to this generalization because while '2' has two forms, he thinks that the lower number '1' doesn't.

In Mandarin the numeral *yi* '1' can surface in three different tones. Greenberg followed the common view that one of those tones is the citation form, which undergoes two-way tone sandhi (*yi-sandhi*) depending on the morphophonological context (Chao 1970; Zhang 1988; Wang 2014; He 2015).

This paper re-analyzes *yi*-sandhi, and argues that *yi* actually has two forms just like '2'–the contextual form and the absolute form, despite their segmental identity (6). *Yī* represents the first tone (i.e. high-level tone), *yí* the second tone (i.e. rising tone) and *yì* the fourth tone (i.e. falling tone).

(6)

	absolute form	contextual form
'1'	yī	yì/yí
'2'	èr	liǎng

The two forms of '1' can be distinguished by whether they undergo tone sandhi–the contextual form does (7), while the absolute form does not. Under this new view of *yi*, Mandarin is not an exception to Greenberg's generalization #51 because both '1' and '2' have the absolute and contextual forms.

(7)*Tone sandhi of the contextual form of '1'*
/yì/ → [yí] /__ σ̀

Furthermore, this paper will also discuss expressions that are derived from the numerals but are neither enumerating nor abstract. These expressions nevertheless still show the contextual-absolute alternation, which depends on the morphophonological context. Thus, I will argue that the two forms of '1' and '2' are not distinguished by use as Greenberg claimed for '2', but rather by the morphophonological context: the contextual form appears when linearly followed by its sister (and this sister must be overt), otherwise the absolute form appears. This generalization, together with key assumptions about how vocabulary insertion proceeds, leads to a structure for enumerating numerals like *liǎng gè nǚhái* 'two girls', where the Cardinal *liǎng* 'two' takes the Classifier Phrase *gè nǚhái* as its complement, and projects to a Cardinal Phrase.

My generalization is apparently challenged by some cases, where the contextual form does not surface even when linearly followed by its overt sister. I will argue that this is because the contextual form is a free-standing word, while the absolute form is a bound morpheme. This constrains where they can and cannot occur, because some positions cannot fit a free-standing word, but only a bound morpheme. In those positions, the absolute form will surface instead of the contextual form, even when linearly followed by its sister. Following is the allomorphy rule that this paper argues governs the alternation of the contextual and absolute forms.

(8)*Allomorphy rule*
a. numeral → #contextual form# / __ sister
b. numeral → -absolute.form-

Section 2 argues that '1' has two forms just like '2', and section 3 presents a uniform analysis of '1' and '2' by arguing that their contextual form and absolute form are allomorphs. Section 4 shows that the alternation of the two forms is not governed by use as Greenberg claimed, but rather by the morphophonological context as in (8). Section 5 argues that the contextual form is a free-standing word, while the absolute form is a bound morpheme. This further constrains where they can and cannot occur because some positions cannot fit a free-standing word, but only a bound morpheme. Section 6 addresses alternative analyses and their problems. Section 7 concludes the paper, and the Appendix provides novel evidence for the syntactic structure of multi-digit enumerating cardinals.

2. '1' has the absolute form and the contextual form

This section begins by showing that the distribution of the various forms of '1' parallels that of the two forms of '2', and thus motivates the analysis that '1' has two forms just like '2'. After that, I discuss He (2015), the dominant alternative analysis of two-way *yi*-sandhi, and show that it has problems that the current analysis does not have.

Yi '1' can surface in three different tones–the first tone *yī*, the second tone *yí* and the fourth tone *yì*. Only *yī* can surface in the abstract use:

(9)a. *Counting numbers*
{*yì/*yí/yī} èr sān sì…
one 2.ABS three four
'One, two, three, four…'

b. *Arithmetic*
shí chúyǐ **{*yì/*yí/yī}** shì shí.
ten divide.by one COP ten
'Ten divided by one is ten.'

c. *Room number*
{*yì/*yí/yī} líng **{*yì/*yí/yī}** (shì)
one zero one room
'Room 101'

d. *Decimal number*
{*yì/*yí/yī} diǎn líng **{*yì/*yí/yī}**
one point zero one
'1.01'

e. *Year number*
{*yì/*yí/yī} jiǔ liù wǔ nián
one nine six five year
'1965'

In contrast, *yí* and *yì* can surface in the enumerating use, but not *yī*. In the enumerating use, *yì* surfaces unless when immediately followed by another fourth tone syllable, in which case *yì* turns into *yí*:

(10) *Enumerating use of '1'*

a. Huāyuán lǐ yǒu **{yì/*yí/*yī}** zhī māo.
garden in have one CL cat
'There is a cat in the garden.'

b. Nà **{*yì/yí/*yī}** wèi nǚhái shāo-le měiwèi de fàn.
that one CL girl cook-PRF delicious DE meal
'That girl cooked a delicious meal.'

c. Kèrén shì **{*yì/yí/*yī}** wèi nǚhái.
guest COP one CL girl
'The guest was a girl.'

Given the complementary distribution of *yi*'s various forms in abstract and enumerating uses and the fact that the distribution of *yi*'s forms parallel that of '2''s forms, I argue that the numerals '1' and '2' each have an absolute form and a contextual form as in (6). *Yi*'s contextual form further undergoes tone sandhi in (7).

This analysis differs from the common analysis in the literature that posits a two-way tone sandhi process for *yi*. Consider He's (2015) analysis for concreteness, who proposed that *yi*'s citation tone is the first tone *yī*. *Yī* changes to *yí* when immediately followed by a fourth-tone syllable σ̀ in the same word (11a); *yī* changes to *yì* when the immediately following syllable in the same word has non-fourth tone (11b); *yī* stays in its citation tone otherwise (i.e. if it is the last syllable of a word).

(11) *He's (2015) morphophonological rule of* yi-*sandhi*

a. /yī/ → [yí] / __ σ̀]$_{word}$
b. /yī/ → [yì] / __ σ (non-falling tone)]$_{word}$

This characterization of *yi*-sandhi is less economical than the current analysis because two-way *yi*-sandhi does not fit well with the other tone sandhi processes in the language and related dialects. There is no other tone sandhi process like (11a&b) in the language, but there is a series of tone sandhi processes that parallel (7).

First, there is no tone sandhi process like (11b) anywhere else in the language, where a syllable changes to the fourth tone when followed by a non-fourth tone. Second, while we do see a variant of He's tone sandhi rule (11a) occur with other lexical items, those items may have tone sandhi in all morphological contexts, regardless of whether they are in the same word as the following syllable.

Those lexical items are *bù* 'not' in Mandarin Chinese, and *sān* 'three', *qī* 'seven', *bā* 'eight', *biè* 'don't' and *mèi* 'not.PERF' in Northeastern Mandarin (and Beijing Mandarin of the previous generation; Zhang 1988; Wei 2020). This general tone sandhi process has therefore been called the *yi-bu-qi-ba rule*. These lexical items have different underlying tones, but they all surface in the second tone when immediately followed by a fourth tone:

(12) a. *bu-sandhi in Mandarin Chinese*
bù → bú / __ σ̀
b. *san/qi/ba-sandhi in Northeastern and old Beijing Mandarin*
sān/qī/bā → sán/qí/bá / __ σ̀
c. *bie-sandhi in Northeastern and old Beijing Mandarin*
biè/mèi→ bié/méi/ __ σ̀

Following are some examples illustrating *qī*- and *bā*-sandhi in Northeastern Mandarin:

(13) a. Zhuō shàngyǒu **{qī/*qí/bā/*bá}** běn shū.
desk on have seven/eight CL book
'There are seven/eight books on the desk.'

b. Shù shàngyǒu **{qí/bá}** gè hóuzi.
tree on have seven/eight CL monkey
'There are seven/eight monkeys on the tree.'

Crucially, *qī* 'seven' and *bā* 'eight' can undergo tone sandhi in a wider range of contexts than *yi* 'one', such as in room numbers:[1,2]

[1] I am grateful to Lu Jin for providing the judgments of Northeast Mandarin in this section.
[2] *Qī* 'seven' and *bā* 'eight' do not undergo sandhi in all the abstract-use contexts. For example, they don't have sandhi in counting numbers, year numbers and phone numbers:

(i) a. *Counting numbers*
{qī/*qí} liù wǔ sì sān èr yī
seven six five four three 2.ABS 1.ABS
'Seven, six, five, four, three, two, one'

b. *Year number*
yī jiǔ **{qī/*qí/bā/*bá}** liù nián
one nine seven/eight six year
'1976 / 1986'

c. *Phone number*
Wǒ de shǒujī zuìhòu sì wèi shì **{qī/*qí}** liù {**bā/*bá}** èr.
I DE mobile final four digit COP seven six eight 2.ABS
'The last four digits of my mobile number is 7682.'

Also, for my consultant, the contexts where *sān* '3' can undergo sandhi are more limited than those for *qī* 'seven' and *bā* 'eight': *sān* '3' cannot have sandhi in counting numbers, year numbers, phone numbers or room numbers. I suspect there is interference from Standard Mandarin because in the cases where there can be *san-qi-ba*-sandhi, sandhi is always optional for my consultant. There is more to understand about *san-qi-ba*-sandhi, which I leave to future research, but just want to point out that at least *qi*- and *ba*-sandhi occurs in more contexts than *yi*-sandhi.

(14) yī líng **{qí/bá}** shì
1.ABS zero seven/eight room
'Room 107 / 108'

One reason why He posited the word boundary in (11a) was because of ordinal numbers, which are derived from the cardinal numbers by merging with the '-th' morpheme *dì*. *Yi* '1' in the ordinal form always has the first tone, and '2' always appears in the absolute form:

(15) dì **{*yí/yī/*liǎng/èr}** gè xuéshēng
-th **1.CONT/1.ABS/2.CONT/2.ABS** CL student
'the first/second student'

The '-th' morpheme can be silent, but *yi* still has the first tone:

(16) a. Ø **{*yì/yī/*liǎng/èr}** lóu
-th **1.CONT/1.ABS/2.CONT/2.ABS** floor
'the second floor

b. Ø **{*yì/yī/*liǎng/èr}** bān
-th **1.CONT/1.ABS/2.CONT/2.ABS** class.section
'the second class section'

c. Ø **{*yí/yī/*liǎng/èr}** hào
-th **1.CONT/1.ABS/2.CONT/2.ABS** number
'No. 1'

He claimed that *yi* '1' in the ordinal form has the citation tone because it is a constituent with the preceding '-th' morpheme, and does not form a word with the following syllable, and is thus not subject to the tone sandhi rule in (11a). In contrast to *yi*, the ordinal forms of *qī* 'seven' and *bā* 'eight' can still undergo tone sandhi, suggesting that their tone sandhi rule does not have the same-word condition like in (11a).

(17) a. Ø **{qí/bá}** lù jūn
-th seven/eight route army
'The Seventh/Eighth Route Army'

b. Ø **{qí/bá}** hào
-th seven/eight number
'No. 7/8'

Therefore, He's (2015) *yi*-sandhi analysis is not the same as the tone sandhi processes undergone by the other lexical items in the *yi-bu-qi-ba* rule. If we want to uphold He's analysis, we would need to say that *yi* is the odd one out in the *yi-bu-qi-ba* rule in that the *yi*-sandhi process (11a) requires a word boundary, and that *yi* undergoes an additional sandhi process (11b) that is not attested anywhere else in the language.

My analysis is more economical and avoids these issues because the tone sandhi process I proposed (7) fits well into the *yi-bu-qi-ba* rule, which can be described in (18). The *yi-bu-qi-ba* rule changes a syllable (regardless of its underlying tone) into the second tone before a fourth-tone syllable, possibly to dissimilate because the second tone contrasts with the fourth tone the most:

(18) *Yi-bu-qi-ba rule*
/σ/ → [σ́] /__ σ̀
Applies to *bù* 'not' and *yì*, the contextual form of '1' in Mandarin Chinese, and *sān* 'three', *qī* 'seven', *bā* 'eight', *biè* 'don't' and *mèi* 'not.PERF' in Northeastern Mandarin

The reason why *yi*'s ordinal form appears in the first tone is because that is its absolute form. Room numbers and ordinal forms involving *qī* and *bā* have tone sandhi because *qī* and *bā* do not have the absolute form. This is consistent with Greenberg's (1978) generalization that not all numbers necessarily have the absolute form, and the higher a number, the less likely it is to have an absolute form.

This section has shown that '1' has two forms, and their distribution parallels the two forms of '2'. This view is more economical than the dominant view of two-way *yi*-sandhi because it subsumes the contextual form of '1' under a larger group of lexical items in the *yi-bu-qi-ba* rule.

3. The two forms of '1' and '2' are allomorphs

Having argued that Mandarin '1' and '2' each have the contextual form and the absolute form, this section argues that these two forms are allomorphs rather than different lexical items. The data so far support this because the contextual form and the absolute form have complementary distribution. However, the literature has not taken this view: the only works that I know of that discuss '1' and '2' together (i.e. Chao 1970; He 2015) nevertheless assume that '1' and '2' have different distribution, and He also said explicitly that the forms of '2' are different lexical items rather than allomorphs.

3.1. Conjoined numerals must both have the contextual form or both have the absolute form, but not mix-and-match

In all the constructions discussed so far and to be discussed in this paper, the contextual forms of '1' and '2' occur in the same contexts, and so do their absolute forms. I support this with another piece of evidence from approximate expressions, a construction that puts two numerals in sequence. For example, when '1' and '2' occur in sequence, it means 'one to two':

(19) **yì** **liǎng** gè xuéshēng
1.CONT **2.CONT** CL student
'One to two students'

I assume that approximate expressions involve coordination of two numerals by a covert coordinator Conj^0 meaning 'to' (e.g. [yì Conj^0 liǎng] gè xuéshēng).[3] I also assume that when two elements are coordinated, the conjuncts must have the same morphological form.

If the contextual forms of '1' and '2' have the same morphological status, and so do their absolute forms, then we may expect that when '1' and '2' are coordinated in approximate expressions, they must both appear in the absolute form, or both in the contextual form, but not mix-and-match. I will show that this is true even in contexts that usually allow either the absolute form or the contextual form. Specifically, I will discuss two such contexts–basic mass-classifiers and numeral bases.

Before getting to the actual data involving basic mass-classifiers, I first introduce some background information on numeral and classifier constructions in Mandarin. In Mandarin the enumerating numeral is always followed by a classifier. In this construction a single-digit cardinal (i.e. a number between 1 and 9, which I call *simplex cardinal*) mostly surfaces in the contextual form, though rarely it can also surface in the absolute form, if the following classifier is a specific type (as was observed by Chao 1970:580). According to Cheng & Sybesma (2012), classifiers in Mandarin Chinese fall into two categories: (a) *count-classifiers* (20a), which name the discrete unit in which the entity denoted by the noun naturally occurs; and (b) *mass-classifiers*, which create a unit of measure. Mass-classifiers were further divided into two types–basic ones like *kilo* and *jīn* 'catty' (20c) and container ones like *tǒng* 'a bucket of' (20b). When the simplex cardinal is followed by a count-classifier or a container mass-classifier, the numeral must appear in the contextual form (20a-b). A simplex cardinal that is followed by a basic mass-classifier often has to appear in the contextual form as well, but the absolute form may also be possible when the basic mass-classifier is one with long standing in the language (e.g. *jīn* as in (20c))[4]. The absolute form in (20c) has a formal scientific connotation.

(20) a. *Simplex cardinals before count-classifiers must appear in the contextual form*
{yí/*yī/liǎng/*èr} gè xuéshēng
1.CONT/1.ABS/2.CONT/2.ABS CL student
'One/two students'

b. *Simplex cardinals before container mass-classifiers must appear in the contextual form*
{yì/*yī/liǎng/*èr} tǒng mǐ
1.CONT/1.ABS/2.CONT/2.ABS bucket rice
'One/two buckets of rice'

c. *Simplex cardinals before basic mass-classifiers may appear in either form*
{yì/?yī/liǎng/?èr} jīn mǐ
1.CONT/1.ABS/2.CONT/2.ABS catty rice
'One/two catties of rice = 0.5/1 kg of rice'

[3] Approximate expressions like (19) cannot be derived by backward ellipsis, as in *yì ~~gè xuéshēng~~ liǎng gè xuéshēng*, because it is generally not possible to elided a classifier and an NP in Mandarin Chinese. This is argued for in the Appendix.

[4] Only a small number of basic mass-classifiers can combine with the absolute form. Most basic mass-classifiers cannot, such as time mass-classifiers: **èr {miǎo/fēnzhōng/tiān/zhōu/yuè/nián}* 'two seconds/minutes/days/weeks/months/years'.

Having introduced the background information on the simplex cardinal plus classifier, now I show that '1' and '2' must occur in the same form in approximate expressions, even before the basic mass-classifier *jīn*, which normally allow either form of the numeral:

(21) a. *Simplex cardinals before count-classifiers must appear in the contextual form*
{yì/*yī} **{liǎng/*èr}** gè xuéshēng
1.CONT/1.ABS **2.CONT/2.ABS** CL student
'One to two students'

b. *Simplex cardinals before container mass-classifiers must appear in the contextual form*
{yì/*yī} **{liǎng/*èr}** tǒng mǐ
1.CONT/1.ABS **2.CONT/2.ABS** bucket rice
'One to two buckets of rice'

c. *Before basic mass-classifier* jīn*, if the first numeral is contextual, so must the second*
yì **{liǎng/*èr}** jīn mǐ
1.CONT **2.CONT/2.ABS** catty rice
'One to two catties of rice'

d. *Before basic mass-classifier* jīn*, if the first numeral is absolute, so must the second*
yī **{*liǎng/èr}** jīn mǐ
1.ABS **2.CONT/2.ABS** catty rice
'One to two catties of rice'

There is another context that allows either the contextual or the absolute form–multiplier of numeral bases. Like English, Mandarin Chinese constructs multi-digit cardinals (i.e., numbers larger than 9, which I call *complex cardinals*) using additive coordination of multiplier-base combinations.

(22) a. two hundred and twenty-two *English*
b. èr bǎi èr shí èr *Mandarin Chinese*
2.ABS hundred 2.ABS ten 2.ABS
'222'

Before getting to approximate expressions involving complex cardinals, I introduce some terminology that I will use throughout this paper. In the multiplicative structure I call the multiplicands *hundred* and *-ty* in (22a) the *base*; *two* and *twen-* the *multiplier* because they multiply by the respective base. Likewise in (22b), *bǎi* 'hundred' and *shí* 'ten' are bases, and *èr* 'two' is their multiplier. We might also posit a null ones base in (22a-b), for which the multipliers are two and *èr* 'two'. Complex cardinals can combine with NPs, as in (23a-b).

(23) a. two hundred and twenty-two students *English*
b. èr bǎi èr shí èr gè xuéshēng *Mandarin Chinese*
2.ABS hundred 2.ABS ten 2.ABS CL student
'222 students'

In complex cardinals, the multiplier may appear in the contextual or absolute form depending on the base. For example, the multiplier of base 100 can be contextual or absolute. Section 5 will focus on this fact.

(24) liǎng qiān **{yì/yī/liǎng/èr}** bǎi
2.CONT thousand **1.CONT/1.ABS/2.CONT/2.ABS** hundred '2100/2200'

In approximate expressions, the multiplier numerals must have the same form, but not mix-and-match:

(25) a. *Before a base, if the first numeral is contextual, so must the second*
liǎng qiān **yì** **{liǎng/*èr}** bǎi
2.CONT thousand **1.CONT** **2.CONT/2.ABS** hundred
'2100 to 2200'

b. *Before a base, if the first numeral is absolute, so must the second*
liǎng qiān **yī** **{*liǎng/èr}** bǎi
2.CONT thousand **1.ABS** **2.CONT/2.ABS** hundred
'2100 to 2200'

3.2. The two forms of '1' and '2' are allomorphs

Having shown using approximate expressions that the forms of '1' and '2' occur in the same contexts, I will now show that the two forms of '2' are allomorphs because when one form can't surface for independent reasons, the other form surfaces, a behavior typical of allomorphs. If the forms of '2' are allomorphs, and they occur in the same contexts as the forms of '1', then the forms of '1' must also be allomorphs.

There is a unit of weight that is a homonym to *liǎng*, the contextual form of '2'. It is not possible to use the contextual form of '2' with this unit of measure because it would lead to two adjacent identical syllables.[5] Thus, the absolute form of '2' is used instead to express the meaning:

(26) **{*liǎng/èr}** **liǎng** mǐ
2.CONT/2.ABS liang rice
'Two liangs of rice ≈ 76 grams of rice'

Crucially, the use of the absolute form *èr* in (26) is completely fine (and the only way to express this meaning), better than its use with *jīn* in (20c), and does not have the scientific connotation that (20c) has. This suggests that *èr* appears in (26) not because it may occasionally occur with some basic mass-classifiers, but because it is the elsewhere form when *liǎng* is not allowed here.

Since the absolute form of '2' surfaces when the contextual form is independently banned, and furthermore these two forms have different segments, I will assume that they are allomorphs.

[5] The string *liǎng liǎng* is possible, but it reduplicates the contextual form of '2' and means 'in pairs'.

Because the forms of '1' occur in the same contexts as those of '2',[6] I will also infer that the two forms of '1' are also allomorphs.

4. Allomorphy rule for '1' and '2'

So far I have assumed Greenberg's (1978) view that the morphological form of the numeral depends on its use–the enumerating numeral has the contextual form, while the abstract numeral has the absolute form. This section presents novel data suggesting that the two forms are not really distinguished by use, but rather by the morphophonological context. These data lead to the preliminary empirical generalization in (27): the contextual form occurs if the syntactic sister of the numeral is pronounced and linearly follows it; otherwise the absolute form occurs.

(27) *Preliminary empirical generalization*
   a. numeral → contextual form / __ sister
   b. numeral → absolute form

Under this view, the enumerating use and the abstract use differ in their morphophonological contexts. Subsections 4.1–4.6 presents six pieces of evidence for (27). The first piece of evidence contrasts complex cardinals (i.e. numbers larger than 10) with simplex cardinals (i.e. numbers between 1 and 9), which the previous sections have focused on. I show that enumerating complex cardinals contrast with simplex cardinals in their morphological form, a fact that is due to their different morphosyntactic structures. Then I discuss four types of derived use of numerals. It is hard to say if these derived numerals are enumerating or abstract, but they nevertheless still show the contextual-absolute alternation which depends on their morphophonological contexts. Specifically, the conditional head 'once' and ordinal numbers are both derived from the numeral, but the former always has the contextual form, and the latter the absolute form. Furthermore, numerals can form other words and proverbial compounds, and their morphological form depends on their position in these words. After that, I show evidence based on silent bases that the syntactic sister of the contextual form must be pronounced; if the sister of the numeral is silent, then the absolute form surfaces. Then subsection 4.7 discusses abstract numerals briefly, which have a different morphosyntactic structure than enumerating numerals under the current view.

The generalization in (27) has consequences for the syntactic structure of numeral phrases because it entails that the morphological form of the numeral depends on the phonology of its sister. This means that when the contextual form of the numeral is selected, the numeral's sister must have already been exponed, so that the numeral's sister's phonology may condition the allomorphy of the numeral. Assuming vocabulary insertion proceeds bottom-up in the syntactic structure (e.g., Anderson 1982, 1992; Kiparsky 2000; Bobaljik 2000; Paster 2006; Embick 2010), this implies that the numeral's sister should be syntactically more embedded than the numeral in the cases where the numeral's contextual form is selected. Subsection 4.8 shows that this supports one particular structure for enumerating numerals.

As a reader goes through the evidence for (27) in this section, they may hold alternative generalizations in mind that are not based on the morphophonological context, but on the syntactic

[6] There are two exceptions to this generalization that I know of. First, the contextual form can occur with the unit of weight *liǎng* because *yì liǎng mǐ* 'one liang of rice' does not involve adjacent identical syllables. Second, the absolute form of '1' occurs in *{yī/*yì/} diǎn* 'one o'clock' but the contextual form of '2' occurs in *{liǎng/*èr} diǎn* 'two o'clock' (Fulang Chen, p.c.). I do not have an account of the second fact, other than a suggestion that

category of the numeral or the prosodic structure. Section 66 discusses those alternatives and their problems.

4.1. Complex cardinals in the enumerating use

The previous sections have shown that the enumerating simplex cardinal generally appears in the contextual form. For example, I repeat (20a) below.

(20) a. *Simplex cardinals before count-classifiers must appear in the contextual form*
{yí/liǎng/*yī/*èr} gè xuéshēng
1.CONT/2.CONT/1.ABS/2.ABS CL student
'One/two students'

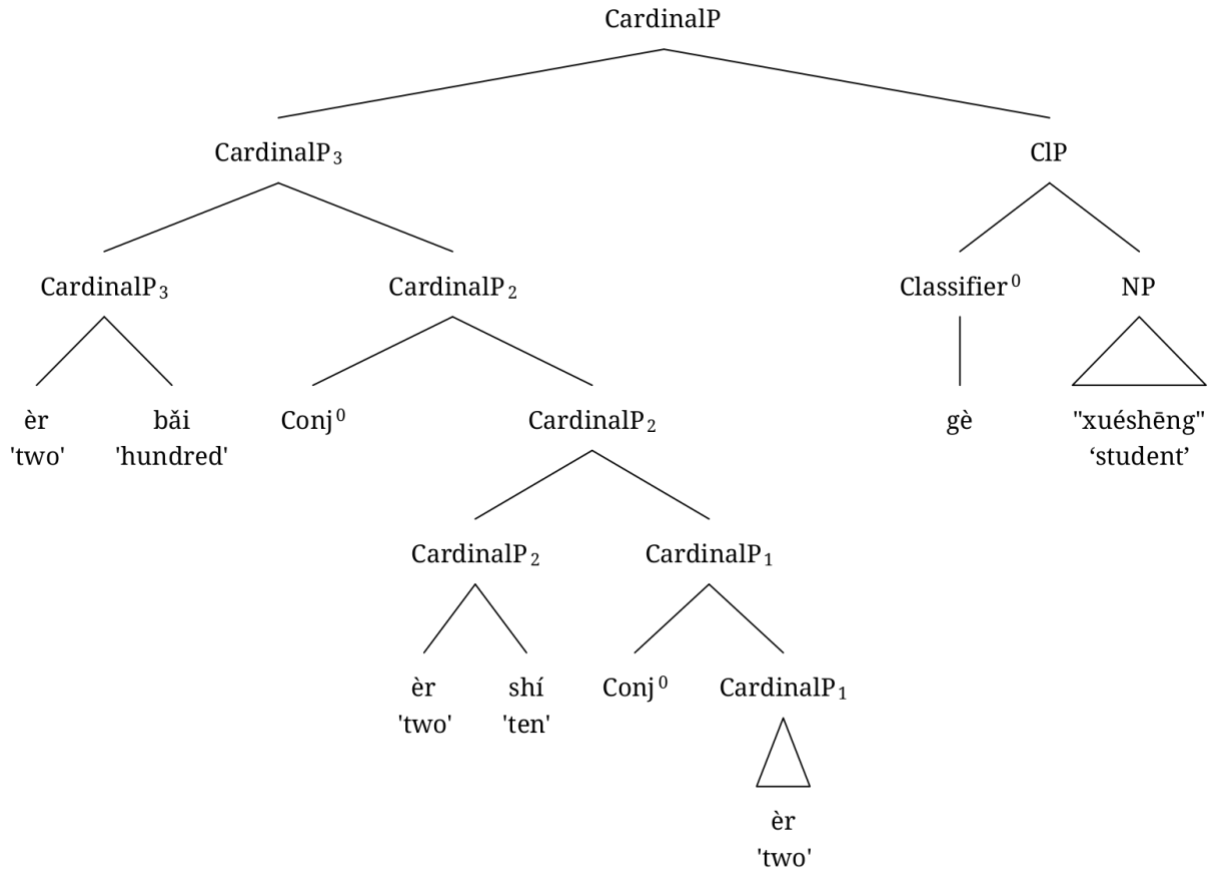
In contrast, the last digit of an enumerating complex cardinal always appears in the absolute form:

(28) *Last digit of a complex cardinal must appear in the absolute form*
{yì/liǎng/yī/èr} bǎi {*yì/*liǎng/yī/èr} shí
1.CONT/2.CONT/1.ABS/2.ABS hundred 1.CONT/2.CONT/1.ABS/2.ABS ten
{*yí/*liǎng/yī/èr} gè xuéshēng
1.CONT/2.CONT/1.ABS/2.ABS CL student
'111/222 students'

In order to understand this contrast between simplex and complex cardinals, we first need to understand the syntactic structure of enumerating cardinals. There are two competing analyses of NPs that contain complex cardinals in the literature: what I call the *CardP-conjunction approach* and the *NP-conjunction-plus-ellipsis approach*. The CardP-conjunction approach was based on Hurford's (1975) traditional view of complex cardinals–they are constituents that combine with NPs. He (2015) made this proposal explicit for Mandarin Chinese: NPs containing complex cardinals involve additive coordination of multiplier-base CardPs linked by silent coordinators $Conj^0$. The maximal CardP then combines with the Classifier and the NP.

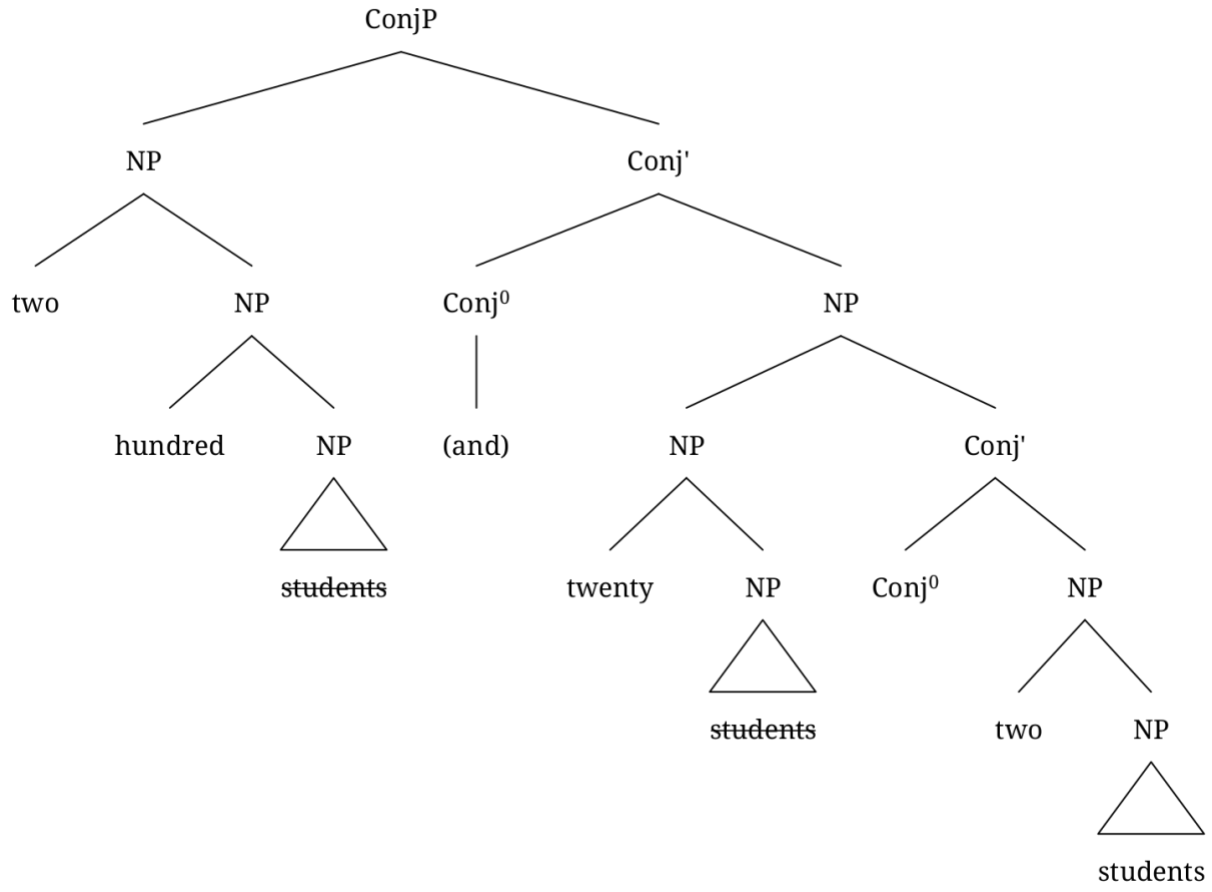
The tree below shows how He's CardP-conjunction approach would analyze (23b), but with some differences from He's original proposal. He focused on the structure internal to CardP-conjunction, and did not argue for exactly how the CardP merges with the Classifier and the NP, but just assumed that the CardP is the complement to the Classifier head (Cl^0), and the Classifier Phrase (ClP) the specifier of the NP. Cheng & Sybesma (1998) provided good evidence that Cl^0 first merges with the NP, and the ClP then merges with the CardP, thus I adopt it here. However, my structures here also differ from Cheng & Sybesma in an important way: while they assumed that CardP is the specifier of ClP, I will assume that CardP projects its label to the mother node. Subsection 4.8 will provide an argument for making this assumption.

(29) *CardP-conjunction analysis of (23b)*



Ionin & Matushansky (2006, 2018, henceforth I&M) argued based on Bantu, Biblical Hebrew, Biblical Welsh and Russian that NPs containing complex cardinals involve additive coordination of multiplier-base-NPs plus backward NP-ellipsis. Each multiplier-base-NP has an internal right-branching structure, where the NP combines with the base and then the multiplier.

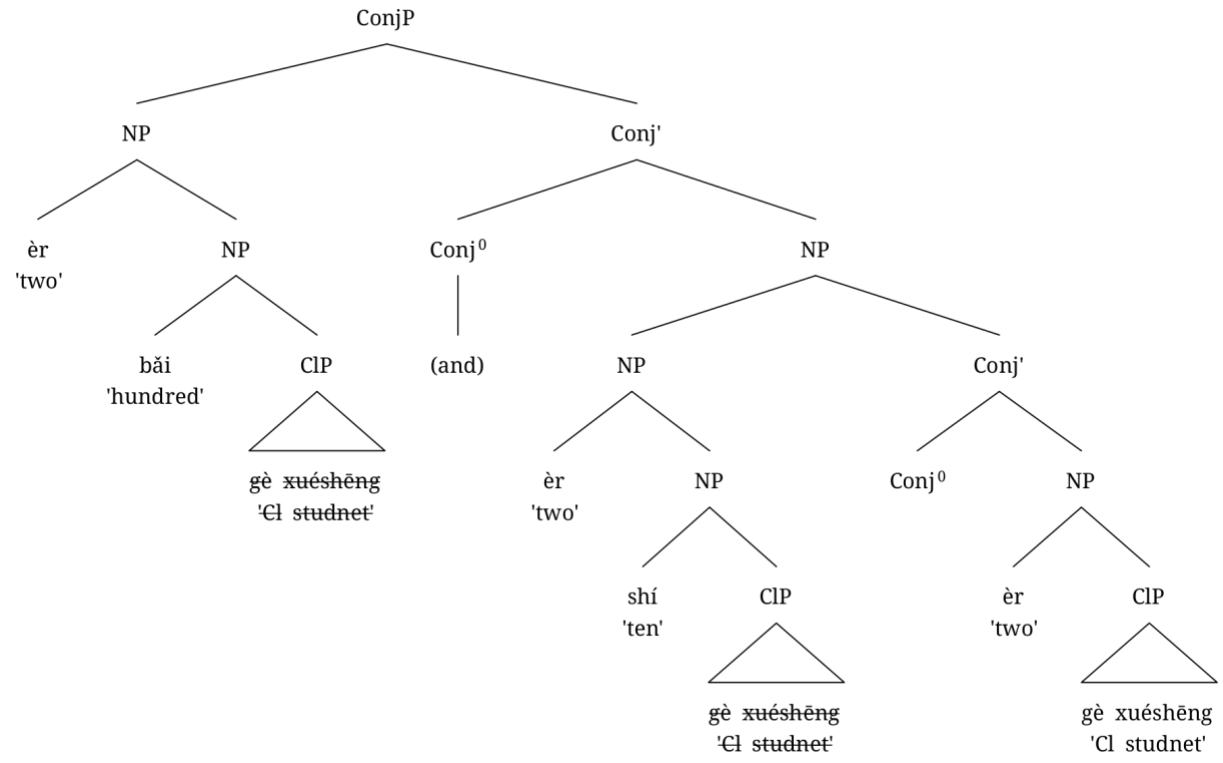
(30) *NP-conjunction-plus-ellipsis analysis of (23a)*



The key difference between these two approaches is whether the complex cardinals involve conjunction of NPs with hidden NP-structure, or conjunction of CardPs. He (2015) has made a series of arguments for the CardP-conjunction approach based on Mandarin Chinese. The Appendix adds two novel arguments that challenge I&M's approach.

One of He's arguments was precisely the morphological form of the numeral in simplex and complex cardinals. Following would be I&M's NP-conjunction-plus ellipsis analysis of the enumerating complex cardinal (28):

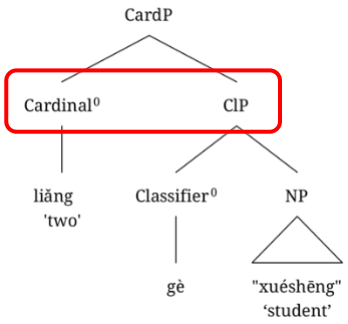
(31) *NP-conjunction-plus-ellipsis analysis of (28)*



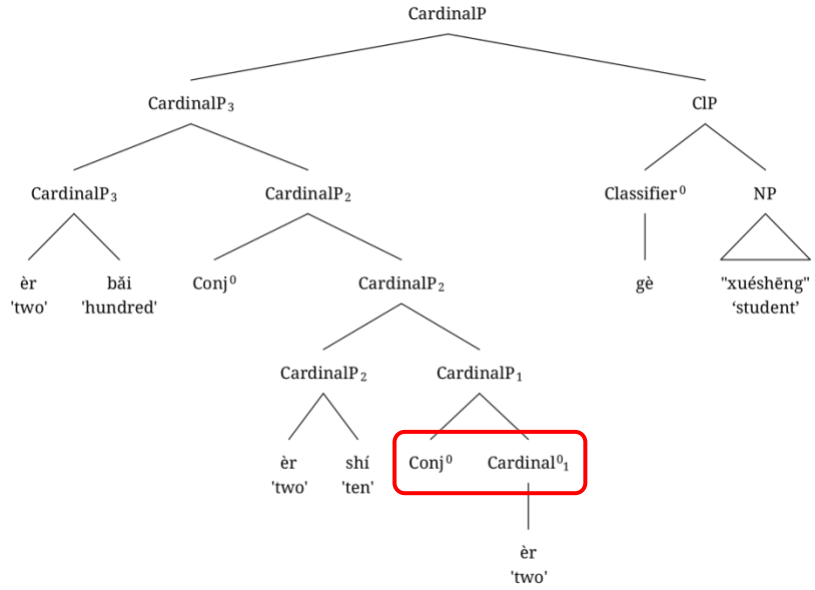
Since '2' appears in the contextual form *liǎng* in '2 students' (20a), if (28) involves additive conjunction of '200 ~~students~~ + 20 ~~students~~ + 2 students' as I&M claimed, we should expect the last digit '2' in (28) to appear in the contextual form, contrary to fact.

He's CardP-conjunction approach together with the preliminary allomorphy rule in (27) can account for the contrast between simplex and complex cardinals. Below are my analyses of (20a) and (28) following He's CardP-conjunction approach.

(32) a. *Structure of (20a)*



b. *Structure of (28)*



In (20a), the numeral merges with Cl', which follows it. Thus, the numeral has the contextual form. In contrast, in (28) the numeral merges with the preceding null Conj^0, and thus has the absolute form.

It is worth mentioning that while all the trees in this paper follow the conventions of the X-bar theory, the structures in (32a-b) may be an argument for adopting Bare Phrase Structure instead. If we follow the X-bar theory strictly, then the ClP is a complement to the simplex cardinal in (32a) but a specifier to the complex cardinal in (32b). It is not clear why the ClP's syntactic role should change according to whether the cardinal is simplex or complex. But if we adopt Bare Phrase Structure, then there is no distinction between Cardinal^0 and CardinalP. (32a&b) can have the same configuration where the Classifier merges with the Cardinal, and the Cardinal projects its label to the mother node. That being said, all the trees in this paper still follow the X-bar theory for clarity and consistency.

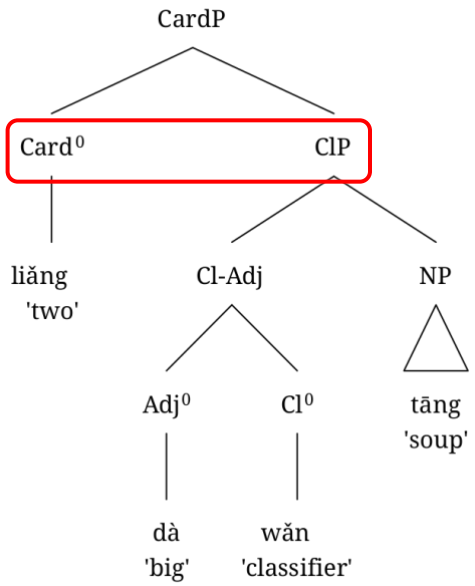
It has been observed that container mass-classifiers can be modified by a small class of adjectives like *dà* 'big' and *xiǎo* 'small' (e.g. Tang 1990). The numeral appears in the same form as they would with non-modified classifiers:

(33) a. {liǎng/*èr} dà wǎn tāng
2.CONT/2.ABS big CL soup
'two whole bowls of soup'

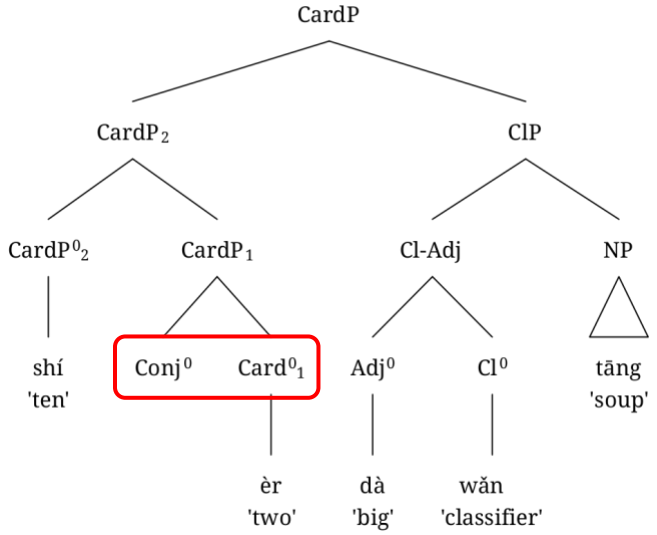
b. shí {*liǎng/èr} dà wǎn tāng
ten 2.CONT/2.ABS big CL soup
'twelve whole bowls of soup'

I adopt Cheng & Sybesma's (1998) analysis of modified classifiers, where the Cl^0 merges with the modifier:

(34) a. *Structure of (33a)*



b. *Structure of (33b)*



The modified Cl^0 does not affect the linear order of the numeral and its sister, and thus leads to the same result as with unmodified classifiers. In (33a), the numeral's sister ClP follows the numeral, leading to the contextual form, while in (33b), the numeral's sister null $Conj^0$ precedes the numeral, leading to the absolute form.

Having shown how the preliminary rule in (27) manages to account for the key contrast between simplex cardinals and complex ones, I will provide five more types of evidence supporting the allomorphy rule in (27). The first four pieces of evidence involve derived numerals that are not clearly enumerating or abstract (i.e. ordinal numbers, conditional head 'once', disyllabic words and proverbs), but they nevertheless show the contextual-absolute alternation subject to the allomorphy rule in (27). The last piece of evidence suggests that the sister of the contextual form must be pronounced. After that, I will discuss abstract numbers.

4.2. Ordinal numbers

Ordinal numbers always appear in the absolute form because their sister is the preceding '-th' morpheme *dì*:

(35) [dì èr] gè xuéshēng
-th 2.ABS CL student
'the second student'

Even when the '-th' morpheme is silent, the numeral still appears in the absolute form because it is not followed by its sister:

(36) a. [Ø èr] lóu
2.ABS floor
'the second floor

b. [Ø èr] bān
2.ABS class.section
'the second class section'

4.3. 'Once'

Like in English, the conditional head 'once' in Mandarin is derived from *yi* 'one'. There are two forms of 'once': *yídàn*, which may be decomposed into *yí* 'one' and *dàn* 'moment', and *yi*, which is identical to the contextual form of '1'. *Yídàn* can take a clause or a predicate as its sister, while *yi* can only take a predicate as its sister. In both these forms of 'once', *yi* is always in the contextual form: *yi* always has the rising tone in *yídàn* 'once' because it is followed by a falling tone, while the tone of *yi* 'once' depends on the following syllable (e.g. rising in (37a-b) and falling in (37c)). *Yi* 'once' has the contextual form because it is always followed by its sister predicate.

(37) a. Tā [$_{CondP}$ yí [$_{vP}$ shuìxǐng]], jiù kāishǐ kàn shǒujī.
She once awake PRT start look phone
'She started looking at her phone once she woke up.'

b. Tā [$_{CondP}$ yí [$_{vP}$ [$_{PP}$ zài diànhuà shàng] tīngdào māma de shēngyīn]]], jiù kū-le.
She once at phone on hear mother DE voice PRT cry-ASP
'She cried once she heard her mother's voice on the phone.'

c. Tā [$_{CondP}$ yì [$_{vP}$ tīngdào māma de shēngyīn]], jiù kū-le.
She once hear mother DE voice PRT cry-ASP
'She cried once she heard her mother's voice.'

4.4. Other disyllabic words derived from 'one'

Besides 'once', many words in Mandarin are derived from *yi* 'one'. In these disyllabic words, generally the contextual form appears when 'one' is in the first position of the word; the absolute form appears in the second position:

(38) a. yí dìng
'surely'
b. yí qiè
'every'
c. yì qǐ
'together'
d. yì zhí
'always'
e. yí zhì
'unanimously'

(39) a. tǒng yī
'unify

b. wéi yī
‘only’
c. wàn yī
‘just in case’; literally: ‘one out of ten thousand’

While these words may be considered to be frozen forms, it may not be accidental that the morphological form of *yi* varies with its position in these words in a principled way. Thus, I assign internal structure to these words just like I did to *yídàn* ‘once’, where the first syllable merges with the second. For example, just like how the English word *unify* may be decomposed into *un* and *-ify*, *tǒng yī* ‘unify’ involves merge of *tǒng* the verb ‘group’ with *yī* ‘one’.

Some other words in (38)-(39) may have less transparent internal structure, but we can still think of their meanings as being derived from ‘one’ or its extended meaning ‘total’ or ‘whole’, suggesting that they may also be created by word-internal merge. For example, *yì* ‘one’ and *qǐ*, which on its own is a verb ‘get up’, combine to create *yì qǐ* ‘together’ or ‘as one (group)’. Exactly how the morphemes compose to derive the word meaning requires an understanding of the lexical meaning of the morphemes and rules of word-internal meaning composition, which I leave to future research. I just want to point out that the lexical meaning of the morphemes in these words may not be the same as their meaning as independent words. For example, while *qǐ* on its own means ‘get up’, it may not have this precise meaning in *yì qǐ*.

Assuming that these words do have an internal binary-branching structure, then the first position numeral appears in the contextual form because it is followed by its sister, and the second position numeral has the absolute form because it is preceded by its sister.

4.5. Four-syllable proverbs

Mandarin has a lot of four-syllable proverbs *chéngyǔ* that are idiomatic and have a more rigid internal structure than typical idioms. Their internal structure cannot be altered at all, and neither can they take internal morphology. They are often derived from historical texts, stories or fables.

Numerals ‘1’ and ‘2’ occur in many four-syllable proverbs, and their morphological form is largely determined by their position in the proverb. The Corpus and Dictionary of Chinese Chéngyǔ[8] has 248 proverbs containing the numeral ‘1’ and 39 proverbs containing ‘2’. Among these proverbs, the contextual forms of ‘1’ and ‘2’ always occur in the first or third syllable, while the absolute forms always occur in the second or fourth syllable (e.g. (40a-b)).

(40) a. {yì/*yī} dāo {liǎng/*èr} duàn
1.CONT/1.ABS knife 2.CONT/2.ABS sections
‘to sever relations by one stroke; to be through with’

b. shǔ {*yì/yī} shǔ {*liǎng/èr}
rate 1.CONT/1.ABS rate 2.CONT/2.ABS
‘one of the very best; ranking very high’

There is only one exception (41), whose first and third syllables optionally occur in the contextual form or the absolute form.

[8] https://dict.idioms.moe.edu.tw/

(41) a. yì wǔ yì shí
1.CONT five 1.CONT ten
'to enumerate or to narrate in precise detail'
b. yī wǔ yī shí
1.ABS five 1.ABS ten

Because these proverbs have very rigid internal structure, I consider them compounds. While they are idiomatic, there is still internal syntactic structure to them. All the proverbs containing '1' and '2' have the binary-branching structure [σσ][σσ]:

(42) a. [yì dāo] [liǎng duàn]
1.CONT knife 2.CONT sections

b. [shǔ yī] [shǔ èr]
rate 1.ABS rate 2.ABS

c. [{yì/yī} wǔ] [{yì/yī} shí]
1.CONT/1.ABS five 1.CONT/1.ABS ten

Because the first- and third-position numerals merge with the following sister, they appear in the contextual form. The second- and fourth-position numerals have the absolute form because their sisters precede them.

Although (41) has the same binary-branching structure as the other proverbs, it may be exceptional because speakers may consider the numerals '1' to denote 'one-by-one', which always takes the absolute form.[9]

4.6. Omitted last numeral base

As we saw in (24), repeated below, the multiplier may appear in the contextual or absolute form depending on the base. For example, the multiplier of base 100 can be contextual or absolute:

(24) liǎng qiān **{yì/yī/liǎng/èr}** bǎi
2.CONT thousand **1.CONT/1.ABS/2.CONT/2.ABS** hundred '2100/2200'

The lowest base in a complex cardinal can be omitted (i.e. base 100 in (24)), in which case its multiplier must have the absolute form:

(43) liǎng qiān **{*yì/yī/*liǎng/èr}**
2.CONT thousand **1.CONT/1.ABS/2.CONT/2.ABS** '2100/2200'

[9] Originally, this proverb described the act of counting coins. Historically, five coins make a unit of counting, and thus counting by five coins and ten coins implies counting carefully. Here *yī* may denote counting one-set-by-one-set of five and ten coins. Speakers who follow a strictly synchronic analysis may give a binary-branching analysis to (41), leading to the contextual forms of the numerals.

I assume that the omitted base is still present syntactically but empty phonologically. This suggests that the sister of the contextual form must be pronounced. If it is not pronounced, then the absolute form surfaces.

This is another argument that the contextual-absolute alternation is not really correlated with whether the numeral is enumerating or abstract, but has to do with the morphophonological context. Whether the base is pronounced (24) or not (43), its multiplier should have the same use, but this multiplier has different morphological forms.

4.7. Abstract numbers

The evidence based on derived numerals and omitted numeral base suggests that what governs the contextual-absolute alternation may not be use as Greenberg (1978) originally claimed, but rather the morphophonological context as in (27). Under this view, there are two possible explanations for why simplex numerals in the abstract use appear in the absolute form. The first possibility is that they may not have any syntactic sister. For example, we could imagine that there is no internal syntactic structure to room numbers, decimal numbers and year numbers. They are just a series of digits strung together in a list-fashion, and none of the digits has a syntactic sister.

The second possibility is that the abstract numeral is created by merging the cardinal with a null morpheme. Whether this null morpheme precedes or follows the numeral does not matter. The following example shows a possible preceding morpheme:

(44) *Counting numbers*
[Ø yī] [Ø èr] [Ø sān] [Ø sì]…
1.ABS 2.ABS three four
'One, two, three, four…'

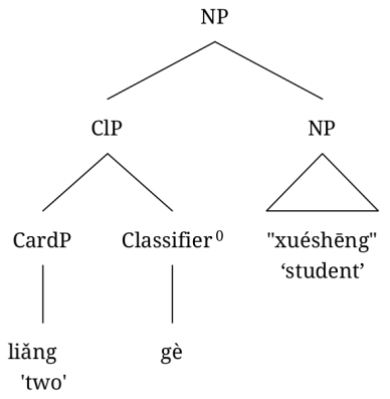
In summary in the interim, I have provided six pieces of evidence that leads to the preliminary empirical generalization in (27), where the numeral morphology depends on the linear order of the numeral's pronounced sister. This generalization can also account for the distinction between enumerating and abstract numbers.

4.8. Cardinal projects to the mother node

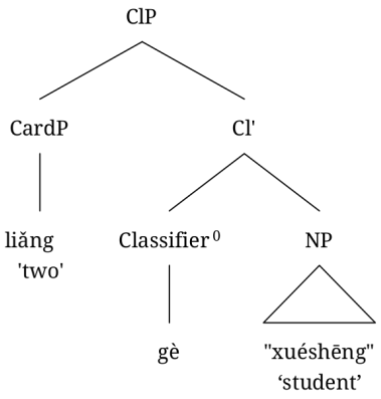
Having provided the evidence that supports the empirical generalization in (27), this subsection discusses the consequences this generalization has for the syntactic structure containing CardP. Section 4.1 focused on the internal structure of CardP, and so far I have not discussed how the CardP merges with other phrases such as ClP. This has not been the focus of the literature on Mandarin numerals because it is difficult to find evidence for one particular structure. This subsection will first present some proposals the literature has made about the CardP-ClP structure, and then argue that the empirical generalization in (27), together with key assumptions about bottom-up vocabulary insertion, supports one of the proposals.

There have been three proposals made about the CardP-ClP structure in Mandarin Chinese, which are presented in the following trees. They can be divided into two types: those where the Cardinal projects its label to the mother node ((45c), Tang 1990; Cheng & Sybesma 1999), and those where the Cardinal's sister projects ((45a-b), Cheng & Sybesma 1998; He 2015).

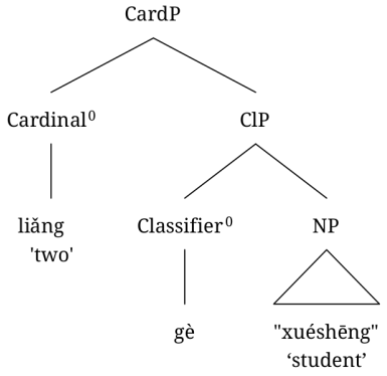
(45) a. *He (2015)*



b. *Cheng & Sybesma (1998)*



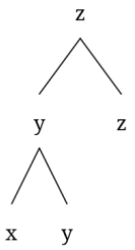
c. *Tang (1990) and Cheng & Sybesma (1999)*



The empirical generalization in (27), together with key assumptions about bottom-up vocabulary insertion, supports analyses where the Cardinal projects ((45c), Tang 1990 and Cheng & Sybesma 1999). The generalization in (27) is an example of phonologically-conditioned allomorphy because the numeral's morphological form depends on whether the numeral's sister is pronounced, and the pronounced sister's linear order to the numeral. Assuming that exponence starts from the most embedded node in the structure (e.g., Anderson 1982, 1992; Kiparsky 2000; Bobaljik 2000; Paster 2006; Embick 2010), this suggests that when the contextual form of the numeral is selected, the numeral is less embedded than its sister syntactically.

I will return to the cases where the contextual form is selected in the previous subsections to show that in those cases the numeral is indeed less embedded than its sister. But before doing so, I explain exactly what it means for a terminal node to be more embedded than another. I adopt Myler's (2017) formulation, which claims that a node x is more deeply embedded than another node y if the maximal projection of y contains x, and is categorially distinct from x. For example, in the configuration below, z is less embedded than y and x, and y is less embedded than x.

(46)



Let us apply this formulation of embeddedness to conditional sentences involving *yi* 'once' (37a-c). *Yi* is the conditional head that takes a predicate as its complement, and projects its label to the mother node, and is thus less embedded than its sister predicate. Therefore, the terminal nodes in the predicate are exponed before *yi*, which allows vocabulary insertion of *yi* to be sensitive to the phonological realization of the predicate.

Let us now turn to enumerating cardinals (e.g. *liǎng gè xuéshēng* 'two students' as in (20a)). Because the simplex cardinal has the contextual form, it needs to be able to see the phonology of its sister, and thus should be exponed later than its sister, and less embedded than its sister. Among the proposals for its structure (45a-c), (45c) is the only one where the cardinal is less embedded than the terminal nodes in its sister. Therefore, if we follow the generalization in (27) and assume bottom-up insertion, then they lead to a structure where the $Card^0$ takes the ClP as its complement and projects (45c).

5. The contextual form is a free-standing word, but the abstract form is a bound morpheme

So far we have focused on the final digit of complex cardinals, and have not looked at the higher digits. This section examines the higher digits, and suggests that the preliminary allomorphy rule in (27) is not sufficient. There is an additional insight provided by the higher digits: the contextual form is a free-standing word, while the abstract form is a bound morpheme. This further constrains where they can and cannot occur, because some positions cannot fit a free-standing word, but only a bound morpheme.

In a complex cardinal, multipliers of bases 10 and 1 must appear in the absolute form, while multipliers of higher bases have an implicational distribution: when a multiplier is in the contextual form, all the multipliers above it must also be in the contextual form (47b); when a multiplier is in the absolute form, the higher multipliers can be either absolute or contextual (47a). Although (47a-b) only exemplifies '2' and bases up to 1,000, this generalization holds for '1' and bases above 1,000 as well.

(47) a.	{**liǎng/èr**}	qiān	èr	bǎi	**{*liǎng/èr}**	shí	{*liǎng/èr}
	2.CONT/2.ABS	thousand	2.ABS	hundred	2.CONT/2.ABS	ten	2.CONT/2.ABS
	'2220'						
b.	{**liǎng/*èr**}	qiān	liǎng	bǎi	**{*liǎng/èr}**	shí	{*liǎng/èr}
	2.CONT/2.ABS	thousand	2.CONT	hundred	2.CONT/2.ABS	ten	2.CONT/2.ABS
	'2220'						

Examples (47a-b) challenge the allomorphy rule (27) proposed in the previous section in three ways. First, the multiplier of base 10 must appear in the absolute form, but according to the allomorphy rule, its sister is *shí* 'ten', which follows it. Second, the multiplier of higher bases can appear in the absolute form, but according to the allomorphy rule, their sister, the base, follows them. Finally, the allomorphy rule (27) cannot explain the implicational relationship (i.e. why the form of a multiplier would depend on the form of the multiplier of a lower base).

This section will argue for two claims that together can account for the contrast in (47a-b). They are laid out below in (48). Claim 2 is spelled out in more detail into three subclaims.

(48) **Claim 1**: The contextual form is a free-standing word, while the absolute form is a bound morpheme.

Claim 2: Each base must merge with constituents with certain morphological forms.

a. The sister of base 10 *shí* has to be a bound morpheme;
b. The sister of base 100 *bǎi* and base 1000 *qiān* has to be a bound morpheme or a free-standing word;

c. The sister of base 10,000 *wàn* and higher bases (e.g. base 100,000,000 *yì*) can be a bound morpheme, a free-standing word or a phrase.

Claims 1 and 2 together derive the fact that only the absolute form can be the sister of base 10, while the sister of higher bases can be contextual or absolute. Incorporating Claim 1 into the allomorphy rule in (27) leads to the following rule:

(49) *Allomorphy rule*
a. numeral → #contextual.form# / __ sister
b. numeral → -absolute.form-

But we still cannot derive the implicational relationship observed in (47a-b). Thus, I further propose that the $Conj^0$ that conjoins a CardP and another imposes a requirement on its conjuncts: in $CardP_x$ $Conj^0$ $CardP_y$ (e.g. '[two thousand] $Conj^0$ [two hundred]'), $CardP_x$'s multiplier $Multiplier_x$ cannot have a smaller morphological size than $CardP_y$'s multiplier $Multiplier_y$.

5.1. Indirect argument for Claim 1

Because Mandarin Chinese is a highly analytical language, there is no direct evidence for Claim 1. It is hard to find morphophonological evidence for morpheme boundedness. For example, while many affixes have the neutral tone (e.g. the continuous aspect marker *-zhe* and the perfective aspect marker *-le*), there are also affixes with lexical non-neutral tones (e.g. the perfective marker *-guò*). The absolute form and the contextual form of '1' and '2' all have non-neutral tones, but this does not indicate their morphological status. Furthermore, it is not a reliable diagnostic of morpheme boundedness whether the morpheme can be a stand-alone fragment to a question because bound morphemes can be fragment answers, as in English:

(50) Q: Was the German economy stronger pre-war or post-war?
A: Post-.

Because of the impoverished morphological marking in Mandarin Chinese, there is no direct evidence for Claim 1. Thus, I will argue for it indirectly instead. I will follow a narrower version of Greenberg's universal generalization–that is, in most languages, if not all, there is a tendency for multipliers of higher bases to have more morphological regularity than multipliers of smaller bases. Claim 1 would follow if Mandarin Chinese is subject to this generalization.

Greenberg (1978) made generalization #39 about the morphological regularity of numerals: "the degree of morphological fusion varies inversely with the size of the numerical value." Specifically, he observed that across languages, the higher the numerical value, the more regular morphology it has, and the greater predictability in morphological formation. A consequence of this generalization is the following prediction: "if a product containing a particular base is a single word, so is every product containing a smaller base."

One example given by Greenberg was Yakut, a Turkic language, whose *süürbe* '20' and *otut* '30' are opaque suppletive forms of *ikki* '2' and *üs* '3', while multiples of ten from '30' onwards are more transparent morphologically–they consist of the corresponding single digit and *uon* 'ten' (e.g. tüörduon '40' vs. tüört '4'). '40' and '50' have sandhi between the single digit and *uon*, while higher multiples don't.

I want to make a universal generalization that is part of and narrower in scope than Greenberg's generalization #39. While his generalization #39 concerns all the numbers in the language, mine concerns only multiplicative numbers. I suggest that perhaps all languages follow a monotonicity generalization, where multipliers of lower bases are less regular (e.g. suppletive, re-adjusted) than those of higher bases (e.g. analytic).[11]

To illustrate this monotonicity generalization, I use two rather familiar examples–English and French. If we consider the single digits in these languages to multiply by base 1, then their single digits are suppletive (e.g. *two* vs. *one* and *cinq* '5' vs. *un* '1'), while multipliers of base 10 are re-adjusted (e.g. *twen+ty* and *cinqu+ante* '50'). Furthermore, multipliers of base 100 and higher bases in English are analytic (e.g. *two#hundred*), and so are multipliers of 20, 100 and higher bases in French (e.g. *cinq#cents* '500').

It is worth mentioning that borrowed words may be exceptional to this generalization (e.g. Russian '40' and Belgian French '80'). If another generalization of Greenberg's (1978) is correct that higher numerals are more commonly borrowed than lower ones, and if the borrowed word is irregular, then we may find a borrowed word less regular than the multiplier of a base smaller than it, an exception to the generalization.

If most languages in the world, if not all, follow my generalization, then we may expect it likely that Mandarin Chinese follows it as well. I therefore suggest that despite its apparently impoverished morphology, the contextual forms in Mandarin Chinese are free-standing words like English *two* and French *cinq*, while the absolute form is bound like English *twen-* and French *cinqu-*.

5.2. Arguments for Claim 2

Having provided an indirect argument for Claim 1 based on a universal generalization and inference that it also applies to Mandarin Chinese, this subsection provides two direct arguments for Claim 2 using different forms for 'how many' and 'this many' and simplex and complex cardinals.

Mandarin Chinese has five bases in regular use: *shí* 'ten', *bǎi* 'hundred', *qiān* 'thousand', *wàn* 'ten thousand' and *yì* 'hundred million'. Only *wàn* 'ten thousand' and *yì* 'hundred million' can have complex cardinals as their multipliers, while the lower bases must have simplex cardinals as their multipliers. For example, the complex cardinal *sān shí* '30' can only be the multiplier of *wàn* 'ten thousand' and *yì* 'hundred million'. This is also true for related Chinese languages like Wu Chinese.

[11] We can state this generalization as *ABA, where B is less regular than A. For example, this generalization predicts that there is no English', where the multipliers of bases 10 and 1,000 are bound morphemes, but the multiplier of base 100 is a free-standing word:

	Multiplier of base 10	Multiplier of base 100	Multiplier of base 1,000
English	twen-	two	two
French	cinqu-	cinq	cinq
*English'	twen-	two	twen-

But this *ABA pattern cannot be explained by the containment analysis (e.g. Bobaljik 2012), the standard analysis of *ABA. The containment analysis would require that in English, the re-adjusted form *thir+teen* contain the suppletive form *twelve* structurally, and in French, the analytic form *quatre#vingts* '80' contain the suppletive form *cinqu+ante* '50', but this is not plausible. In contrast, a monotonicity-based approach like Graf (2019) can account for this generalization.

(51) Zhèlǐ yǒu sān shí {yì/wàn/*qiān/*bǎi/*shí} rén.
here have three ten hundred.million/ten.thousand/thousand/hundred/ten person
'There are {3,000,000,000 / 300,000 / 30,000 / 3,000 / 300} people here.'

The incompatibility of complex cardinals with bases 10, 100 and 1,000 may be accounted for by Hurford's (1975, 2007) Packing Strategy. One of the principles of the Packing Strategy is to "Go as far as you can with the resources you have", which essentially requires the sister constituent of a numeral to have the highest possible value permitted by the language. This leads to the use of the highest base possible in (51). For example, *sān shí qiān* is not possible because it competes with *sān wàn*, which wins out for its use of a higher base. Hurford argued that the maxim "Go as far as you can" is extralinguistic and a general cognitive preference. He compared this maxim to the tendency in apple-picking to fill a basket to the top before filling the next basket.

This and the next subsection provide arguments that in Mandarin and Wu Chinese, the reason for this contrast between complex and simplex cardinals is not just extralinguistic, but rooted in the morphosyntax. I will show that complex and simplex cardinals and various *wh*-expressions have different morphological statuses, which lead to their different syntactic distribution. Assuming that there is a scale of morphological size, with a bound morpheme being relatively "small", a free-standing word "medium-sized", and a phrase "large", this scale of morphological size is correlated with the bases: the sister of bases 1 and 10 must be morphologically "small" enough (i.e. a bound morpheme), while the sister of bases 100 and 1,000 can be "small" or "medium" (i.e. a bound morpheme or a word), and the sister of bases 10,000 and above can be "any size" (i.e. a bound morpheme, word or phrase). Complex cardinals are phrasal, while the absolute form of simplex cardinals is a bound morpheme. The distribution of the contextual form is in-between that of a bound morpheme and a phrase, suggesting that the contextual form is a free-standing word.

5.2.1. Argument 1 for Claim 2: tone sandhi in Shanghainese

The first argument for the morphosyntactic difference between simplex and complex cardinals comes from Shanghainese, a closely related language of Wu Chinese spoken in the Shanghai region. Shanghainese is interesting because it has more widespread tone sandhi than Mandarin, and its tone sandhi is sensitive to prosodic domains, which in turn reflect the morphosyntactic structure. Shanghainese thus provides a good diagnostic of the morphosyntax of numerals based on tone sandhi that Mandarin does not have.

Tone sandhi in Shanghainese involves spreading of the tone of the leftmost syllable to the following syllable in the same prosodic domain. For example, *bitɕ'i* 'temper' has two syllables. These two syllables *bi* and *tɕ'i* have the underlying tones LH and MH respectively. But the word *bitɕ'i* itself has the surface tone LH, which has been analyzed as deletion of the tone on *tɕ'i* and then spreading of *bi*'s second tone H to the second syllable *tɕ'i*.

Tone spreading occurs in a single word like *bitɕ'i* 'temper' but is blocked by larger prosodic boundaries. There is debate on exactly what boundaries block tone spreading (e.g. Selkik & Shen 1990; Zhang 1992; Duanmu 1992, 1995), but for our purposes we can assume that it is blocked by boundaries corresponding to a word boundary. For example, there is no tone spreading between the verb *faʔ* 'lose' and the object noun *bitɕ'i* in *faʔ bitɕ'i* 'lose one's temper' because the verb and the object are separated by a word boundary created by the noun.

Like in Mandarin, Shanghainese ordinal numbers are created by merging *di* the -th morpheme and the numeral (in its absolute form, if there is one). *Di* has the underlying tone LH. If it spreads its tone onto the following numeral, we will get LH on the entire ordinal number. If there is no tone spreading, then we would get LH on *di*, and the following numeral will have its underlying tone.

Whether there is tone spreading depends on the following numeral: if it is less than ten (i.e. a simplex numeral), the tone on *di* must spread onto the following numeral (52a); if the numeral is ten, tone spreading may be possible but dispreferred (52a-b); if the numeral is larger than ten, then tone spreading is not possible (52b). Following are the only possible ways to produce the ordinal numbers. It is not possible to spread the tone onto a complex numeral (i.e. a numeral larger than ten); neither is it possible to not spread the tone onto a simplex numeral (i.e. a numeral smaller than ten).

(52) a. di {iɪʔ / ɳi / se / sɻ / ɦŋ / loʔ / tɕ'ɪʔ / paʔ / tɕiɣ / ??zəʔ}
L H
-th 1.ABS/2.ABS/three/four/five/six/seven/eight/nine/ten
'the first/second/third/fourth/fifth/sixth/seventh/eighth/nineth/tenth'

b. di {zəʔ / zəʔ iɪʔ / zəʔ ɳi/ ɳie / se zəʔ}
LH LM / L M / L M / LM / H L
-th ten/eleven/twelve/twenty/thirty
'the tenth/eleventh/twelfth/twentieth/thirtieth'

It is worth mentioning that *zəʔ* 'ten' and *ɳie* 'twenty' are monosyllabic and monomorphemic, but they still behave differently from simplex numerals, which are also monosyllabic and monomorphemic. This suggests that the occurrence of tone sandhi here has nothing to do with the syllable number or length of the numeral, but rather its morphosyntax.

Assuming that tone spreading is blocked by word boundaries, the obligatoriness of tone spreading to simplex numerals and the impossibility of tone spreading to complex numerals suggest that simplex cardinals are bound morphemes and smaller than a word, while complex cardinals (including ten) are free-standing words. Since Shanghainese and Mandarin Chinese cardinals have nearly identical distribution, we may infer that complex cardinals are morphologically larger than simplex cardinals in Mandarin as well.

5.2.2. Argument 2 for Claim 2: 'how many' and 'this many'

Having shown that Shanghainese simplex and complex cardinals have different morphosyntactic statuses, which is reflected in their blocking of tone sandhi, this subsection will make the same claim for Mandarin simplex and complex cardinals. But because Mandarin lacks the kind of sandhi-based diagnostic that Shanghainese has, this argument will be made indirectly through *wh*-expressions that have the same distribution as the cardinals, but whose morphosyntactic status is more transparent than the cardinals.

There are two *wh*-expressions for 'how many/much' in Mandarin Chinese: *duō shǎo* and *jǐ*. *Duō shǎo* is a bimorphemic phrase consisting of *duō* 'many/much' and *shǎo* 'few', while *jǐ* is monomorphemic. They seem to have the same meaning, such as (53a&b).

(53) a. Zhuō shàngyǒu duō shǎo běn shū?
desk on have how many CL book
'How many books are there on the desk?'

b. Zhuō shàngyǒu jǐ běn shū?
desk on have how.many CL book
'How many books are there on the desk?'

Like all adjectives, *duō* 'many/much' can be turned into complex phrases by modification like *zhème duō* 'this many' and *hǎo duō* 'quite a lot'. *Zhème duō* can be used in its literal meaning (54a), or as an exclamative 'so many' with prosodic focus and/or the sentence-final particle *a* (54b).

(54) a. Zhuō shàngyǒu zhème duō běn shū.
desk on have this many CL book
'There are this many books on the desk.'

b. Zhuō shàngyǒu zhème duō běn shū a!
desk on have this many CL book SFP
'There are so many books on the desk!'

Jǐ has an additional meaning as an indefinite 'several'. In this use, *jǐ* can also be modified and turned into *hǎo-jǐ* 'quite a few'. While *hǎo duō* 'quite a lot' can refer to any large number (55a), *hǎo-jǐ* has to refer to a single-digit number (55b). This suggests that *jǐ* itself has to refer to a single-digit number.

(55) a. Zhuō shàngyǒu hǎo duō běn shū.
desk on have so many CL book
'There are many books (i.e. any number greater than one) on the desk.'

b. Zhuō shàngyǒu hǎo-jǐ běn shū.
desk on have so-several CL book
'There are quite a few (i.e. between two and nine) books on the desk.'

There is additional evidence that *jǐ* must refer to a simplex cardinal. *Jǐ* can be a *wh*-word or an indefinite in year number (56a-b) and room number (56c-d) by filling in the missing single digit. If there are two digits missing, then *jǐ* must be used twice, not once.

(56) a. *Interrogative use in year number*
Xīn Zhōngguó chénglì yú yī jiǔ jǐ *(jǐ) nián?
New China found in 1.ABS nine how.much how.much year
Literally: 'What are the X and Y s.t. P.R. China was founded in 19XY?' = 'What year in the 20th century was P.R. China founded in?'

b. *Indefinite use in year number*
Jiànqiáo Dàxué chénglì yú yī èr jǐ *(jǐ) nián.
Cambridge University found in 1.ABS 2.ABS several several year
Literally: 'Cambridge Universities was founded in 12XY.' = 'Cambridge Universities was founded in the 13th century.'

c. *Interrogative use in room number*
Nǐ zhù zài èr líng jǐ?
you live in 2.ABS zero how.much
'What is the X s.t. you live in Room 20X?'

d. *Indefinite use in room number*
Tā hǎoxiàng zhù zài èr jǐ *(jǐ).
he seem.to live in 2.ABS several several
Literally: 'He seems to live in Room 2XY.' = 'He seems to live on the 2nd floor.'

In contrast, *duō shǎo* cannot be used this way to fill in any missing digit or digits.

(57) a. *Interrogative use in year number*
*Xīn Zhōngguó chénglì yú yī jiǔ sì duō shǎo nián?
New China found in 1.ABS nine four how much year
Intended: 'What is the X s.t. P.R. China was founded in 194X?'

b. *Interrogative use in year number*
*Xīn Zhōngguó chénglì yú yī jiǔ duō shǎo nián?
New China found in 1.ABS nine how much year
Intended: 'What are the X and Y s.t. P.R. China was founded in 19XY?'

I assume that *jǐ-* 'how many/much' or 'several' and its modified form *hǎo-jǐ-* 'quite a few' are bound morphemes, while *duō shǎo* 'how many/much', *zhème duō* 'this many' and *hǎo duō* 'quite a lot' are phrasal. Now I will show that as multipliers of bases, the bound morphemes have a wider distribution than the phrases, parallel to the contrast between simplex and complex cardinals. In particular, *duō shǎo* 'how many/much', *zhème duō* 'this many' and *hǎo duō* 'quite a lot' behave like complex cardinals in only being able to attach to base 10,000 *wàn* and above:

(58) a. Zhèlǐ yǒu duō shǎo {yì/wàn/*qiān/*bǎi/*shí} rén?
here have how.many hundred.million/ten.thousand/thousand/hundred/ten person
Literally: 'What is the X s.t. there are {X00,000,000 / X0,000 / X,000 / X00 / X0} people here?' = 'How many {hundreds of million / tens of thousand / thousand / hundred / ten} people are there here?'

b. Zhèlǐ yǒu zhème duō {yì/wàn/*qiān/*bǎi/*shí} rén.
here have this many hundred.million/ten.thousand/thousand/hundred/ten person
'There are this many {hundreds of million / tens of thousand / thousand / hundred / ten} people here.'

c. Zhèlǐ yǒu hǎo duō {yì/wàn/*qiān/*bǎi/*shí} rén.
here have so many hundred.million/ten.thousand/thousand/hundred/ten person
'There are so many {hundreds of million / tens of thousand / thousand / hundred / ten} people here.'

In contrast, *jǐ* and *hǎo-jǐ* 'quite a few' can attach to any base, just like simplex cardinals:[12]

(59) a. Zhèlǐ yǒu jǐ {yì/wàn/qiān/bǎi/shí} rén?
here have how.many hundred.million/ten.thousand/thousand/hundred/ten person
Literally: 'What is the X s.t. there are {X00,000,000 / X0,000 / X,000 / X00 / X0} people here?' = 'How many {hundreds of million / tens of thousand / thousand / hundred / ten} people are there here?'

b. Zhèlǐ yǒu hǎo-jǐ {yì/wàn/qiān/bǎi/shí} rén.
here have so-several hundred.million/ten.thousand/thousand/hundred/ten person
'There are quite a few {hundreds of million / tens of thousand / thousand / hundred / ten} people here.'

c. Zhèlǐ yǒu hǎo duō {yì/wàn/*qiān/*bǎi/*shí} rén.
here have so many hundred.million/ten.thousand/thousand/hundred/ten person
'There are so many {hundreds of million / tens of thousand / thousand / hundred / ten} people here.'

It is worth mentioning that *tɕi*, the Shanghainese equivalent to Mandarin *jǐ* 'how.much', behaves like simplex cardinals in requiring tone spreading. *Tɕi* can merge with *di*, leading to *di tɕi*, which asks what is x such that it is the xth. There is obligatory tone spreading from *di* to the following *tɕi*, suggesting that *tɕi*, like simplex cardinals and *jǐ* in Mandarin, is a bound morpheme.

Hurford's (1975, 2007) maxim "Go as far as you can" cannot account for the distribution of *duō shǎo* and its variants. Take *zhème duō* 'this many' as an example. *Zhème duō wàn* 'this many tens of thousand' can refer to *jiǔ wàn* '90,000', where the multiplier of *wàn* is a simplex cardinal. If *zhème duō wàn* is possible, I do not see any principled functional explanation for why it is not possible to use *zhème duō qiān* 'this many thousand' to refer to *jiǔ qiān* '9,000'. Therefore, I will adopt a morphological approach, and argue that the distribution of the numeral expressions as multiplier has to do with their morphological size. I do not exclude the possibility that the distribution of numerical multipliers was originally governed by the Packing Strategy as Hurford claimed, but even if that's the case, this principle has now been grammaticalized and extended to non-numerical expressions that were not governed by the Packing Strategy.

[12] More generally, the absolute form of numerals and *jǐ* have almost the same distribution: they can have abstract-counting use, but the contextual form and *duōshǎo* can't. The only difference in distribution between them is that unlike the absolute form, *jǐ* can be a CardP followed by a classifier (in contrast to the impossibility of the absolute form in (28a)):

(i) jǐ gè xuéshēng
how.many CL student
'how many students'

5.3. Morphosyntactic distribution of numerals and analysis

The following tables summarize my analysis of the morphological status of the numeral expressions in Mandarin and Shanghainese and their possibility and impossibility as multiplier of each base.

The second table demonstrates an implicational relationship in the distribution of the multipliers. The higher the base, the more types of multiplier it allows. Low bases only allow multipliers of "small" morphological size (i.e. a bound morpheme), while higher bases allow "larger" multipliers (i.e. a word and a phrase).

Assuming that *duō shǎo* and its variants are phrasal, and *jǐ* and its variant bound morphemes, the implicational distribution in this table suggests that the absolute form is a bound morpheme because it has the same distribution as *jǐ*, the complex cardinal is phrasal like *duō shǎo*, and the contextual form is in between *jǐ* and *duō shǎo* because of its in-between distribution. Thus, I assume the contextual form is a word.

(60)

Phrase	• *Duō shǎo* 'how many/much', *zhème duō* 'this many' and *hǎo duō* 'quite a lot' • Complex cardinal
Free-standing word	• Simplex cardinal in contextual form
Bound morpheme	• *jǐ* 'how many/much' and *hǎo-jǐ* 'quite a few' • *tɕi* 'how many/much' • Simplex cardinal in absolute form

(61)

Multiplier	Base
✓ Phrases: *duō shǎo* 'how many/much', *zhème duō* 'this many' and *hǎo duō* 'quite a lot'; complex cardinals ✓ Free-standing words: simplex cardinals in contextual form ✓ Bound morphemes: *jǐ* 'how many/much' and *hǎo-jǐ* 'quite a few'; *tɕi* 'how many/much'; simplex cardinals in absolute form	*yì* 'hundred million'
✓ Phrases: *duō shǎo* 'how many/much', *zhème duō* 'this many' and *hǎo duō* 'quite a lot'; complex cardinals ✓ Free-standing words: simplex cardinals in contextual form ✓ Bound morphemes: *jǐ* 'how many/much' and *hǎo-jǐ* 'quite a few'; *tɕi* 'how many/much'; simplex cardinals in absolute form	*wàn* 'ten thousand'
* Phrases: *duō shǎo* 'how many/much', *zhème duō* 'this many' and *hǎo duō* 'quite a lot'; complex cardinals ✓ Free-standing words: simplex cardinals in contextual form ✓ Bound morphemes: *jǐ* 'how many/much' and *hǎo-jǐ* 'quite a few'; *tɕi* 'how many/much'; simplex cardinals in absolute form	*qiān* 'thousand'
* Phrases: *duō shǎo* 'how many/much', *zhème duō* 'this many' and *hǎo duō* 'quite a lot'; complex cardinals ✓ Free-standing words: simplex cardinals in contextual form	*bǎi* 'hundred'

✓ Bound morphemes: *jǐ* 'how many/much' and *hǎo-jǐ* 'quite a few'; *tɕi* 'how many/much'; simplex cardinals in absolute form	
* Phrases: *duō shǎo* 'how many/much', *zhème duō* 'this many' and *hǎo duō* 'quite a lot'; complex cardinals * Free-standing words: simplex cardinals in contextual form ✓ Bound morphemes: *jǐ* 'how many/much' and *hǎo-jǐ* 'quite a few'; *tɕi* 'how many/much'; simplex cardinals in absolute form	*shí* 'ten'
* Phrases: *duō shǎo* 'how many/much', *zhème duō* 'this many' and *hǎo duō* 'quite a lot'; complex cardinals * Free-standing words: simplex cardinals in contextual form ✓ Bound morphemes: *jǐ* 'how many/much' and *hǎo-jǐ* 'quite a few'; *tɕi* 'how many/much'; simplex cardinals in absolute form	base 1

Evidence in section 4 has led to the preliminary allomorphy rule (27), and the insight in section 5 so far suggests that the contextual form is free but the absolute form is bound, and there is implicational requirement on the morphological size of multipliers. To combine them, I propose (49), which is repeated below:

(49) *Allomorphy rule*
   a. numeral → #contextual.form# / __ sister
   b. numeral → -absolute.form-

Furthermore, bases require their sister to have a certain morphological shape, which is laid out in Claim 2 in (48). If all the other conditions for the contextual form are met, but the contextual form does not satisfy the requirement of the base, the absolute form will be selected instead.

The implicational distribution observed in (47a-b) suggests that the morphological size of the multiplier is flexible and for some reason depends on the size of the following CardP in a conjoined CardP structure. I propose that the $Conj^0$ that conjoins CardPs imposes the following requirement on its conjuncts: in $CardP_x$ $Conj^0$ $CardP_y$ (e.g. '[two thousand] $Conj^0$ [two hundred]'), $CardP_x$'s specifier (i.e. its multiplier) cannot have a smaller morphological size than $CardP_y$'s specifier.[13]

6. Alternative analyses and their problems

This section addresses three alternative analyses to analyze Mandarin numerals, and discusses their issues.

[13] This would incorrectly ban the configuration $CardP_x$ $Conj^0$ $CardP_y$, where $Multiplier_x$ is a word or a bound morpheme (e.g. a simplex cardinal) and $Multiplier_y$ is phrasal (e.g. a complex cardinal), such as *[liǎng] yì [liǎng qiān] wàn* '220,000,000'. To avoid this issue, we could either say that the requirement by $Conj^0$ does not apply to phrasal multipliers, or say that it applies to all multipliers, but should not ban the otherwise only way to express a numeral value. *Liǎng yì liǎng qiān wàn* is the only way to express '220,000,000' that follows Hurford's (1975, 2007) Packing Strategy.

6.1. Alternative 1: Allomorphy based on base

We may wonder if we really need the enriched allomorphy rule in (49) plus the requirements by bases on their multiplier. Instead, we could simply add two contextual rules to (27) that specify the form of the numeral when it is adjacent to certain numeral bases:

(62) *Alternative allomorphy rule for Mandarin*
- a. numeral → contextual form / __ sister
- b. numeral → absolute form
- c. numeral → contextual form / __ {yì/wàn/qiān/bǎi}
- d. numeral → absolute form / __ {shí}

Parallel rules to (62) for English numerals would be the following:

(63) *Alternative allomorphy rule for English*
- a. $\sqrt{\text{THREE}}$ → thir-/ __ {-ty/-teen}
- b. $\sqrt{\text{THREE}}$ → three

These alternative rules do not incorporate the monotonicity generalization raised in section 5.1 that multipliers of lower bases are less regular than those of higher bases. If it weren't for this generalization, nothing would prevent English' from occurring, where multipliers of higher bases are less regular than those of lower bases.

(64) *Allomorphy rule for English'*

$\sqrt{\text{THREE}}$ → thir-/ __ {million/thousand/hundred}

$\sqrt{\text{THREE}}$ → three

Also, the alternative rules in (62) cannot actually account for Mandarin Chinese, whose multipliers have the flexibility of appearing in either the absolute or the contextual form, but cannot be more irregular than the multiplier of a lower base in the same CardP-conjunction. Specifically, (62c) is not empirically true, since the multiplier of *yì, wàn, qiān and bǎi* can have the absolute form.

6.2. Alternative 2: Numerals in a certain syntactic category have the contextual form

The enumerating numeral appears to be determiner-like, and enumerating simplex cardinals always have the contextual form, which may lead us to think that the numeral has the contextual form when used as a determiner, and the absolute form otherwise. A proposal similar to this posits that the enumerating numeral is a modifier (i.e. an adjective) while the numeral in the abstract use is nominal, and the numeral has the contextual form when used as a modifier, and the absolute form when used as a nominal.

First, the numeral is unlikely to be a determiner or an adjective. There is debate about whether Mandarin Chinese has a D-layer at all, and if so, what is in it. However, no work has suggested that the numeral is the determiner. Also, pre-nominal adjectives must follow the classifier, but numerals have to precede the classifier, suggesting they have a different syntactic position from adjectives:

(65) *Adjectives and numerals have different position in the sentence*

a. Zhuō shàngyǒu yì běn hóng shū.
Desk on have 1.CONT CL red book
'There is a red book on the desk.'

b. *Zhuōshàngyǒu yì hóng běn shū.
Desk on have 1.CONT red CL book

Second, the alternative proposals are challenged by three types of data presented in the previous sections. These proposals would have to say that in disyllabic words, *yi* '1' in the first position (38) is a determiner or adjective, while *yi* in the second position (39) is non-determiner or nominal. It is not clear that this is the case – for example, that the *yì* '1' in *yì qǐ* 'together' is a determiner or adjective.

The alternative proposals are also challenged by data involving multiplier of bases – the fact that the multiplier of base 10 has to be absolute, the multiplier of higher bases can be either contextual or absolute, but its form also depends on the form of lower multipliers. The alternative proposals would need to say that the multiplier of base 10 is a non-determiner or nominal, the multiplier of higher bases can be a determiner or non-determiner, a nominal or an adjective, but its syntactic status depends on the syntactic status of lower multipliers. It is not clear why the syntactic status of the numeral would change this way.

Furthermore, these proposals also have difficulty accounting for the data involving the multiplier of a pronounced base (24) and that of an unpronounced base (43), repeated below:

(24) liǎng qiān **{yì/yī/liǎng/èr}** bǎi
2.CONT thousand **1.CONT/1.ABS/2.CONT/2.ABS** hundred '2100/2200'

(43) liǎng qiān **{*yì/yī/*liǎng/èr}**
2.CONT thousand **1.CONT/1.ABS/2.CONT/2.ABS** '2100/2200'

The alternative proposals would analyze the multiplier of the pronounced base *bǎi* 'hundred' in (24) as a determiner or an adjective, but the multiplier's syntactic status should not change when the base is not pronounced in (43). Those proposals may take a different route by not positing any base 100 at all in the syntactic structure of (43), but say instead that the final numerals *yī* and *èr* there denote 'one hundred' and 'two hundred'. These proposals would need to posit many more meanings for the numerals *yī* and *èr* such as 'ten', 'twenty', 'ten thousand' and 'two thousand' because they can have these meanings when the final base is omitted in '210', '220', '21,000', '22,000' and so on. Also, these meanings of *yī* and *èr* can only surface when a base that otherwise should be pronounced is not, and it is not clear why this is the case.

6.3. Alternative 3: Numerals first in a prosodic word have the contextual form

Wang (2014) proposed that *yi* undergoes sandhi when first in a minimal prosodic word, except in a string of digits, and a prosodic word corresponds to a compound. She further claimed that all cardinal numbers, whether simplex or complex, are compounds and therefore a single prosodic word.

This analysis is challenged by ordinal numbers whose '-th' morpheme is unpronounced such as (36) because the numeral is prosodic-word-initial, but has the absolute form. It also has

difficulty accounting for the fact that in complex cardinals, non-initial multipliers of bases higher than base 10 can have the contextual form, such as the multiplier of base 100 in '1110' and '2220', as in (47b).

This analysis also has a conceptual challenge. It only discusses *yi*-sandhi, and adopts the same view as Chao (1970) and He (2015) that *yi* undergoes two-way sandhi. But section 2 already pointed out some issues of this analysis. Furthermore, if we also take the numeral '2' into consideration as section 3 argued for, then the contextual form and the absolute form should be allomorphs rather than allophones because the contextual form of '2' has different segments from the absolute form, and is the elsewhere form. If Wang (2014) were to provide a uniform analysis of '1' and '2', she would need to say that the contextual form surfaces when prosodic-word-initial. But this would require morphology to be able to "look ahead" and see the prosodic structure of the constituent that contains the numeral, violating the universal generalization that allomorphy's sensitivity to phonology is inward rather than outward (e.g. Carstairs-McCarthy 2017).

7. Conclusion

This paper has argued that not only does the numeral '2' in Mandarin have two forms, but the numeral '1' also does. One of '1''s forms can undergo tone sandhi, an analysis that is consistent with the tone sandhi process undergone by a class of lexical items in the language. The two numeral forms are allomorphs, and their alternation depends on the morphosyntactic context (i.e. the linear order of the numeral's pronounced sister) rather than the use of the numeral. Furthermore, the contextual form is a free-standing word, while the absolute form is a bound morpheme, and there is implicational requirement on the morphological size of multipliers.

Appendix. Challenges to the NP-conjunction-plus-ellipsis approach to complex cardinals

Section 4.1 has introduced two competing analyses of NPs that contain complex cardinals in the literature–He's (2015) *CardP-conjunction approach* and I&M's (2006, 2018) *NP-conjunction-plus-ellipsis approach*. I&M's proposal extended beyond complex cardinals to nested complex cardinals like *nine hundred thousand books* and modified cardinal constructions like *a beautiful two weeks*, and their analysis for these constructions is right-branching cascading: [nine [hundred [thousand books]]] and [a [beautiful [two weeks]]]. In addition to the evidence presented in section 4.1 and He (2015), this appendix provides two novel pieces of evidence suggesting that I&M's analysis does not work for Mandarin Chinese.

Appendix.1. Evidence 1 against NP-conjunction-plus-ellipsis: Impossibility of ClP-ellipsis in general

Recall that I&M's (2006, 2018) NP-conjunction-plus-ellipsis approach posits backward ellipsis of ClPs, and pronounces the multiplier and the base (I call the pronounced constituents that survive ellipsis *the stranded remnants*). But this sort of ClP-ellipsis is generally marginal. For example, it is not possible to elide the ClP and pronounce the simplex cardinal, whether in the contextual or the absolute form (66a-b); the Classifier^0 must also be pronounced (66c).

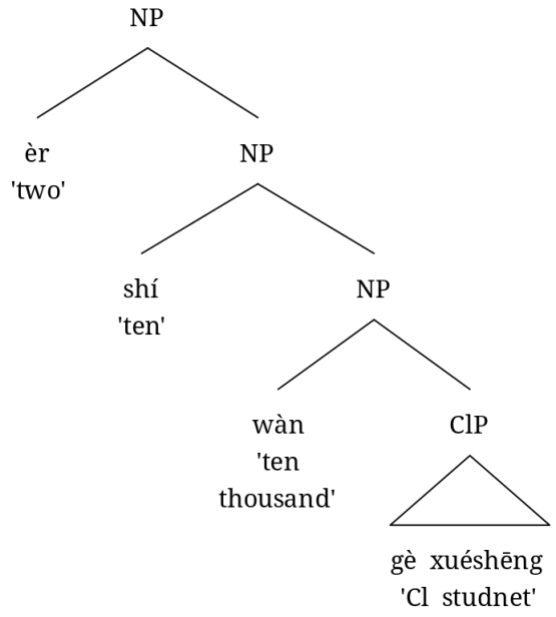
(66) Zhāngsān mǎi-le sān gè lí, ér Lǐsì mǎi-le …
Zhangsan buy-PRF three CL pear and Lisi buy-PRF

a. *liǎng [ClP ~~gè lí~~].
2.CONT CL pear
b. *èr [ClP ~~gè lí~~].
2.ABS CL pear
c. liǎng gè [NP~~lí~~].
'Zhangsan bought three pears, and Lisi bought two.'

Since ClP-ellipsis is generally not possible in Mandarin Chinese, it is implausible that it would derive complex cardinals as I&M claimed.

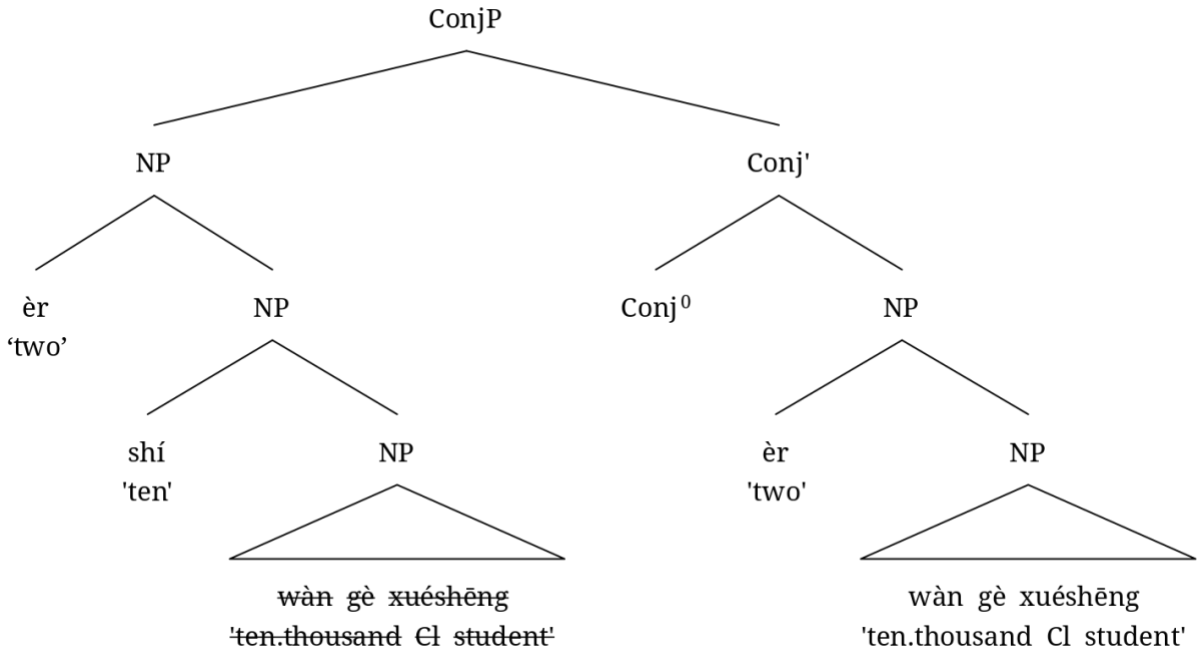
Furthermore, I&M, following Cheng & Sybesma's (1998) structure of Mandarin cardinal-classifiers, assigned a right-branching cascading structure to nested complex cardinals like '200,000 students' in Mandarin:

(67)



If the nested structure contains a complex cardinal like in '220,000 students', they would analyze it as backward ellipsis:

(68)



But the kind of ellipsis of the base plus the ClP (i.e. *wàn gè xuesheng* in (68)) required in I&M's analysis is generally not possible in Mandarin Chinese:

(69) Zhangsan bought 30,000 pears, and Lisi bought…
*liǎng [NP ~~wàn~~ [ClP ~~gè lí~~].
2.CONT ten.thousand CL pear

It is worth mentioning that it is better to pronounce the base *wàn* 'ten thousand' (70a) than not to (69), though (70a) is still not perfect. The best way is to include the Cl^0 in the remnant (70b).

(70) Zhangsan bought 30,000 pears, and Lisi bought…
a. ?liǎng [NP wàn [ClP ~~gè lí~~].
2.CONT ten.thousand CL pear
b. liǎng [NP wàn [ClP gè ~~lí~~].
'Zhangsan bought 30,000 pears, and Lisi bought 20,000.'

With ClP-ellipsis, a complex cardinal remnant is better than a simplex cardinal remnant, and the higher the base of the remnant, the better. (71a) pronounces a smaller number than (70a), and is worse.

(71) Zhangsan bought 15 pears, and Lisi bought…
a. ???sān shí èr [ClP ~~gè lí~~].
three ten 2.ABS CL pear
b. sān shí èr [ClP gè ~~lí~~].
'Zhangsan bought 15 pears, and Lisi bought 32.'

The contrast between (71a) and (70a) suggests that ClP-ellipsis is improved with a high cardinal remnant. We may wonder if this could save I&M's NP-conjunction-plus-ellipsis account, since it posits backward ClP-ellipses with quite large cardinal remnants (e.g. the remnants in (31) are 200 and 20), which might be possible according to (70a). But (70a) is not perfect, but it is perfectly fine for any cardinal number to be followed by a classifier and a noun as in (23b). I thus assume that (23b) cannot be derived by backward ClP-ellipsis due to the different acceptance levels of (23b) and general ClP-ellipsis.

Appendix.2. Evidence 2 against NP-conjunction-plus-ellipsis: Prosodic evidence from third tone sandhi

The second argument comes from a tone sandhi process in Mandarin. In two adjacent third-tone syllables, the first syllable turns into the second tone:

(72) σˇ → σ́ /__σˇ

One example is the compound *yǔ sǎn* 'umbrella', which surfaces as *yú sǎn*. The other example is the VP *mǎi jiǔ* 'buy wine', which surfaces as *mái jiǔ*.

In three adjacent third-tone syllables, the second syllable always undergoes tone sandhi. Whether or not the first syllable undergoes tone sandhi depends on the underlying syntactic structure (Shih 1986).

This is illustrated by the following examples. (73a) is a sentence where the subject is followed by a third-tone predicate, and thus has a left-branching structure. (73b) is a modified NP with a right-branching structure, where the third-tone modifier precedes the compound. In (73a), the first two syllables must both undergo tone sandhi (the syllables that undergo tone sandhi are marked in bold), while in (73b), the second syllable must have tone sandhi, but the first one optionally does.

(73) a. [[**yúsán**] xiǎo].
umbrella small
'The umbrella is small.'

b. [**xiáo** [**yú**sǎn]] or [xiǎo [**yú**sǎn]]
small umbrella
'A small umbrella'

Thus, we could diagnose the underlying syntactic structure of a string of three adjacent third-tone syllables based on whether the first syllable has to have tone sandhi. If it does, then the string has a left-branching structure; otherwise, it has a right-branching structure. I will use this test to diagnose the syntactic structure of cardinal-classifier phrases.

I&M posited a right-branching cascading structure for cardinal-classifier phrases, including what they called modified cardinal constructions like [a [beautiful [two weeks]]] and [a [long [ten miles]]] in English.

As we have seen in section 5, Mandarin has an indefinite numeral *jǐ* 'several', which is a place-holder for a simplex cardinal (i.e. between 1 and 9). *Jǐ* can be modified by *hǎo* 'so' and turned into *hǎo-jǐ* 'quite a few'. When followed by a third-tone classifier, we have a string of three third-tone syllables, as in (74A). Here the first syllable *hǎo* has to undergo sandhi, suggesting a left-branching structure [[háo-jí] wǎn], contrary to what I&M would assign to (74A).

(74) Q: Nǐ jīntiān hē-le jǐ wǎn shuǐ?
you today drink-PRF how.many CL water
'How many bowls of water did you drink today?'
A: **Háo-jí** wǎn. compare with *Hǎo-**jí** wǎn.
so-several CL
'Quite a few.'

Contrast (74A) with *liǎng wǎn shuǐ* 'two bowls of water', which has a right-branching structure according to Cheng & Sybesma (1998): [liǎng [wǎn shuǐ]]. This leads to two possible tone sandhi patterns (75a) or (75b). While I prefer the first syllable *liǎng* to have tone sandhi, it does not have to, and (75b) sounds better than *hǎo-jí wǎn* in (74A).

(75) a. Wo jīntiān hē-le **liáng** **wán** shuǐ. or b. … ?liǎng **wán** shuǐ.
I today drink-PRF 2.CONT CL water
'I drank two bowls of water today.'

To summarize, this appendix has provided two novel arguments based on ellipsis and tone sandhi that challenge I&M's NP-conjunction-plus-ellipsis approach to complex cardinals.

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