Suppletion 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

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(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. Unless otherwise specified, all the Mandarin data discussed in this paper are from standard Putonghua.[2] 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'

[2] A reviewer mentioned that Taiwan Mandarin allows *yī* '1' in all environments, which as we will see later behaves differently from standard Putonghua. I acknowledge there is dialectal variation in this, and leave this to future research.

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 (8): the contextual form appears when linearly followed by overt material at the point of vocabulary insertion of the numeral, otherwise the absolute form appears. Following Haspelmath's (2020) terminology, I call the contextual form and the absolute form *suppletive morphs*, distinct morphs that are nevertheless homosemous. In contrast, within the contextual form, *yì* and *yí*, which participate in the tone sandhi rule in (7), are what Haspelmath called *morph variants*–phonological variants of the same morph.

(8)*Suppletion rule*
a. numeral → contextual form / __ X, where X is pronounced
b. numeral → absolute form

This generalization, together with the key assumption that vocabulary insertion proceeds bottom-up, leads to a particular structure for enumerating numerals like *liǎng gè nǚhái* 'two girls', where the Cardinal head *liǎng* 'two' takes the Classifier Phrase *gè nǚhái* as its complement.

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 suppletive morphs. 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 addresses alternative analyses and their problems. Section 6 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 nǔhái.
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).

A reviewer asked why in (7), the tone changes from *yì* to *yí* rather than the other way around. This choice is based on simplicity: if phrased the other way around, this tone sandhi rule would be /yí/ → [yì] /__ {σ̄/σ́/σ̌} (i.e. yí changes to yì when followed by a non-fourth-tone syllable), which is more complex than the current rule.

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)]$_{word}$

There are two key differences between He's (2015) analysis and the current one. The rest of this section will focus on one of those differences and show that He's 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. Section 5.2 will discuss the second difference.

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 morphophonological 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:[3,4]

(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. ∅ **{*yì/yī/*liǎng/èr}** lóu

[3] I am grateful to Lu Jin for providing the judgments of Northeast Mandarin in this section.

[4] *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.

-th **1.CONT/1.ABS/2.CONT/2.ABS** floor
'the second floor

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

c. ∅ **{*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. ∅ **{qí/bá}** lù jūn
-th seven/eight route army
'The Seventh/Eighth Route Army'

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

Therefore, He's (2015) *yi*-sandhi analysis in (11a) 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 but the other lexical items in the *yi-bu-qi-ba* rule don't. Furthermore, He posited an additional sandhi process for *yi* (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 suppletive morphs

Having argued that Mandarin '1' and '2' each have the contextual form and the absolute form, this section argues that these two forms are suppletive morphs 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 suppletive morphs.

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).[5] 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

[5] 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 elide a classifier and an NP in Mandarin Chinese. This is argued for in the Appendix.

mass-classifier is one with long standing in the language (e.g. *jīn* as in (20c))[6]. 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'

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 allows 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*

[6] 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'.

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, a fact that this paper will not focus on.[7] 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'

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'

[7] Due to limited space, I do not discuss numerals as multipliers in great detail in this paper. In separate work, I focus on precisely that question, and observe that while the multipliers of the tens and ones bases have to be absolute, the multipliers of higher bases can be either contextual or absolute. My analysis of numerals as multipliers complements the analysis in this paper: I assume the same morphosyntactic structure for multiplier and base, whether the base is tens or higher (e.g. *èr shí* 'twenty' has the same structure as *liǎng bǎi* 'two hundred'). My solution to this puzzle relies on a conjecture based on languages like English and French that perhaps in all languages, multipliers of lower bases are less regular morphologically (e.g. suppletive, re-adjusted; English *twen+ty*) than those of higher bases (e.g. analytic; English *two#hundred*). If Mandarin follows this generalization, then perhaps the contextual form, which tends to occur as the multiplier of higher bases, is a free-standing word (parallel to English *two*), while the absolute form, which occurs as the multiplier of lower bases, is a bound morpheme (parallel to English *twen-*).

3.2. The two forms of ‘1’ and ‘2’ are suppletive morphs

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 suppletive morphs because when one form can’t surface for independent reasons, the other form surfaces, a behavior typical of suppletive morphs. If the forms of ‘2’ are suppletive morphs, and they occur in the same contexts as the forms of ‘1’, then the forms of ‘1’ must also be suppletive morphs.

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.[8] 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 suppletive morphs. Because the forms of ‘1’ occur in the same contexts as those of ‘2’,[9] I will infer that the two forms of ‘1’ are also suppletive morphs.

4. Suppletion rule for ‘1’ and ‘2’ based on morphosyntax

So far I have not contested 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 empirical generalization in (27).

(27) *Empirical generalization*
The contextual form occurs if the syntactic sister of the numeral is pronounced and linearly follows it; otherwise the absolute form occurs.

If this empirical generalization is correct, then the enumerating use and the abstract use may differ in their morphophonological contexts. Subsection 4.1 presents six pieces of evidence supporting (27). In subsection 4.1.1 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 subsections 4.1.2–4.1.5 discuss four types of derived use of numerals. It is hard to say if these

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

[9] 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.

derived numerals are enumerating or abstract, but they nevertheless still show the contextual-absolute alternation which depends on their morphophonological contexts. After that, subsection 4.1.6 shows 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 4.2 discusses abstract numerals briefly, which under the current view have a different morphosyntactic structure than enumerating numerals.

The generalization in (27) 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 suppletion of the numeral. We can thus put the generalization in (27) into the morphological rule in (8), repeated below, which essentially requires the contextual form to be followed by overt material at the point of its vocabulary insertion:

(8) *Suppletion rule*
a. numeral → contextual form / __ X, where X is pronounced
b. numeral → absolute form

Assuming vocabulary insertion proceeds bottom-up in the syntactic structure (e.g., Anderson 1982, 1992; Kiparsky 2000; Bobaljik 2000; Paster 2006; Embick 2010), this has consequences for the syntactic structure of numeral phrases because it 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 4.3 shows that this supports one particular structure for enumerating numerals.

As a reader goes through the evidence for (8) in this section, they may hold alternative generalizations in mind that are not based on the morphophonological context, but on the syntactic category of the numeral or the prosodic structure. Section 5 discusses those alternatives and their problems.

4.1. Evidence supporting the empirical generalization in (27)

4.1.1. 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*

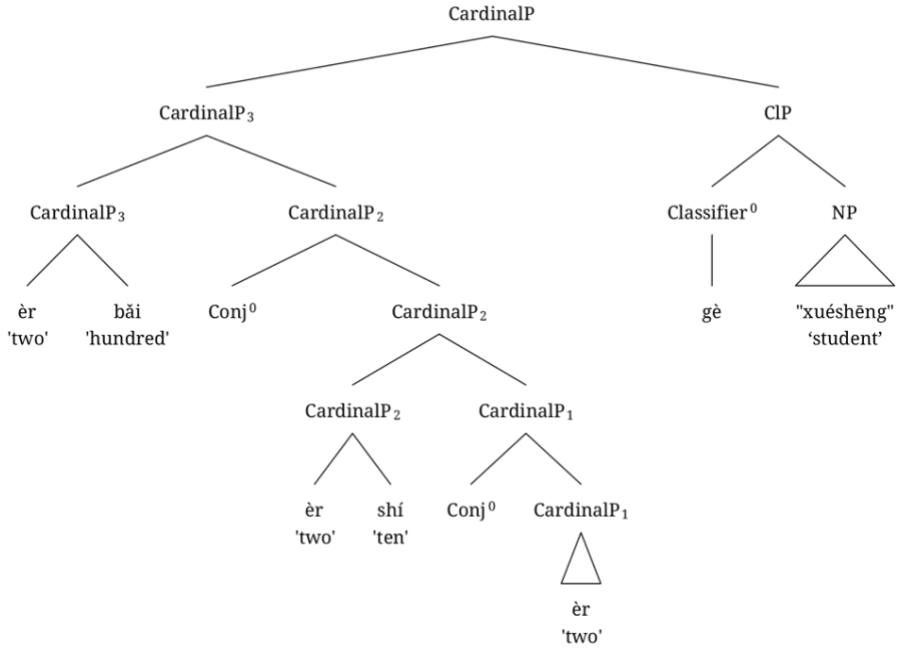
{yì/liǎng/yī/èr}	bǎi	{*yì/*liǎng/yī/èr}	shí	
1.CONT/2.CONT/1.ABS/2.ABS	hundred	1.CONT/2.CONT/1.ABS/2.ABS	ten	
{*yí/*liǎng/yī/èr}	gè	xuéshēng		
1.CONT/2.CONT/1.ABS/2.ABS	CL	student		

'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.

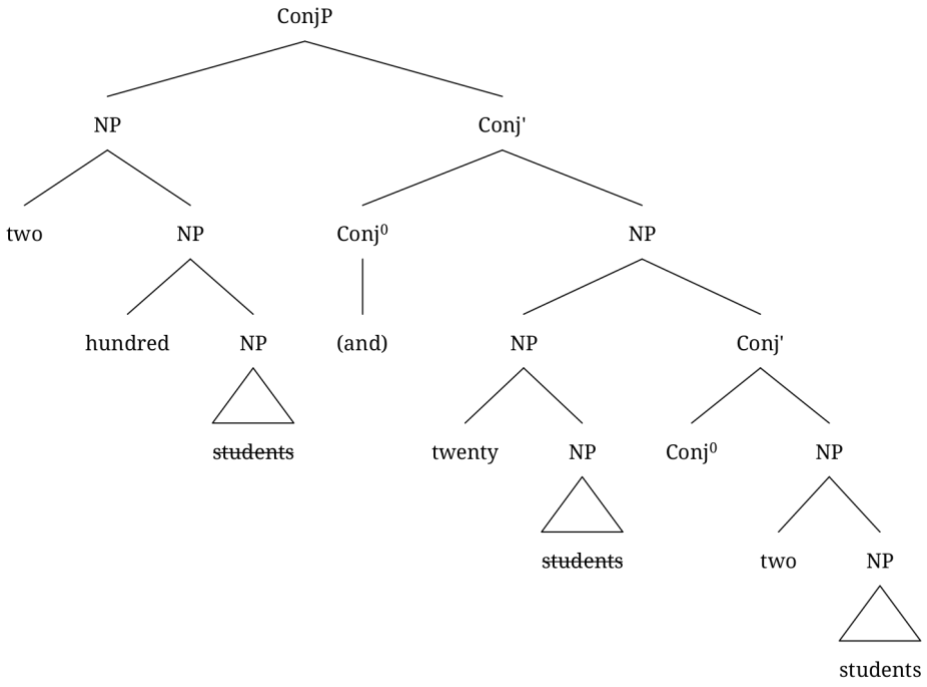
The tree below shows how He's CardP-conjunction approach would analyze (23b), but with some differences from He's original proposal. He focused on the structure internal to the CardP, and did not argue for exactly how the CardP merges with the Classifier and the NP, but just assumed that the CardP is 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 4.3 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.

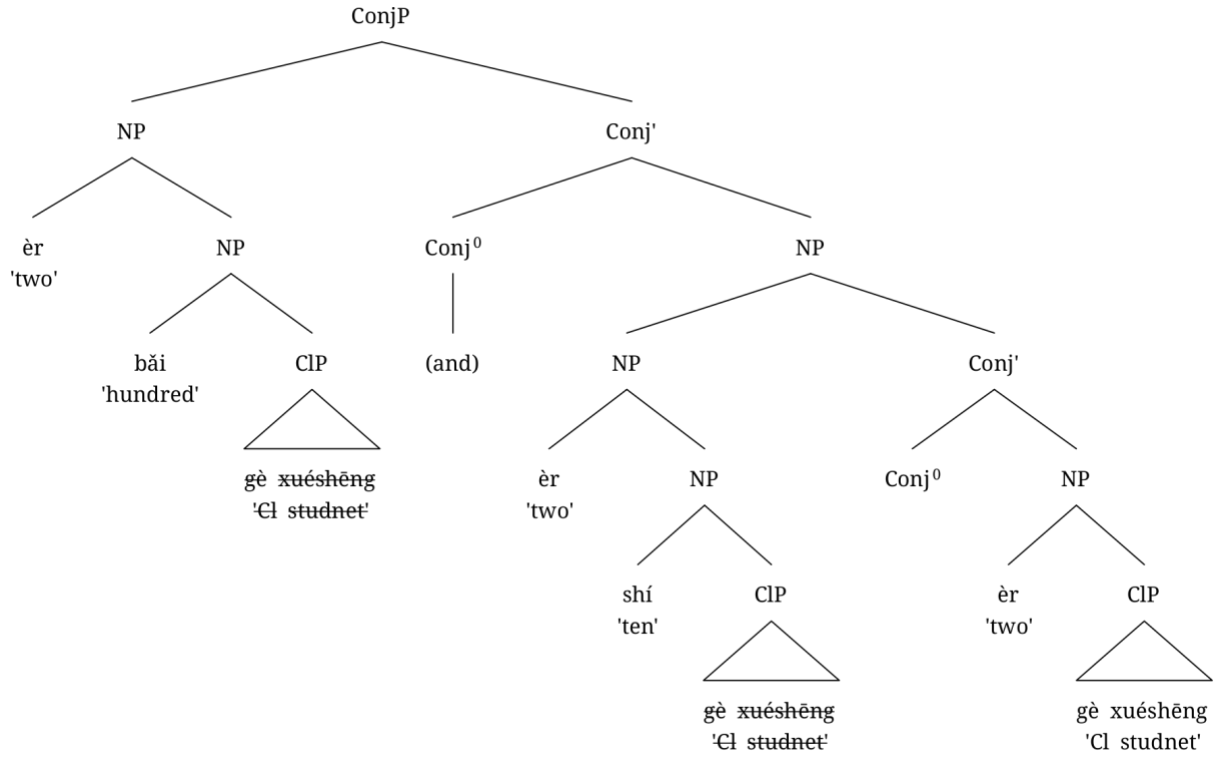
(30) *NP-conjunction-plus-ellipsis analysis of (23a)*



The key difference between these two approaches is whether the complex cardinals involve conjunction of CardPs or conjunction of NPs with hidden NP-structure. 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 last digit of the complex cardinal. Following would be I&M's NP-conjunction-plus ellipsis analysis of the enumerating complex cardinal (28):

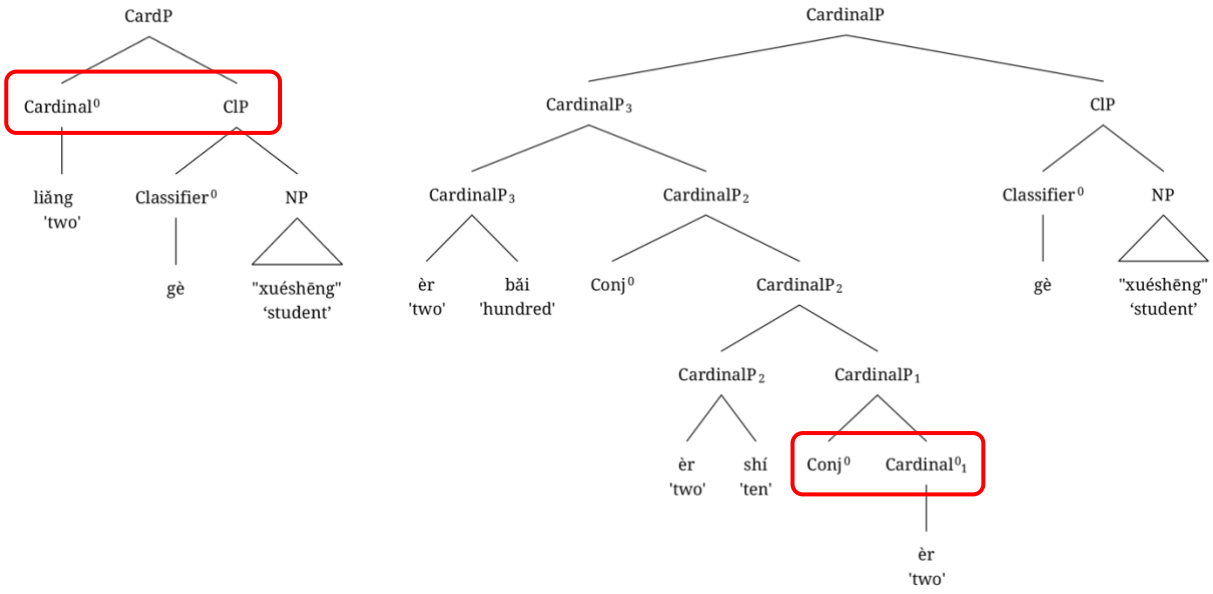
(31) *NP-conjunction-plus-ellipsis analysis of (28)*



If (28) does involve additive conjunction of '200 ~~students~~ + 20 ~~students~~ + 2 students' as I&M claimed, then we would expect the last digit '2' in (28) to appear in the same form as it does in '2 students' because '2' occurs in the same morphophonological context in both cases–its sister is the ClP *gè xuéshēng*. In '2 students', '2' appears in the contextual form *liǎng* (20a), but in (28) it appears in the absolute form *èr*, contrary to I&M's prediction.

He's CardP-conjunction approach together with the empirical generalization 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 ClP, which follows it and is pronounced. Thus, the numeral has the contextual form. In contrast, in (28) the numeral merges with the preceding null Conj^0. Because it is not followed by its sister, the numeral has the absolute form.

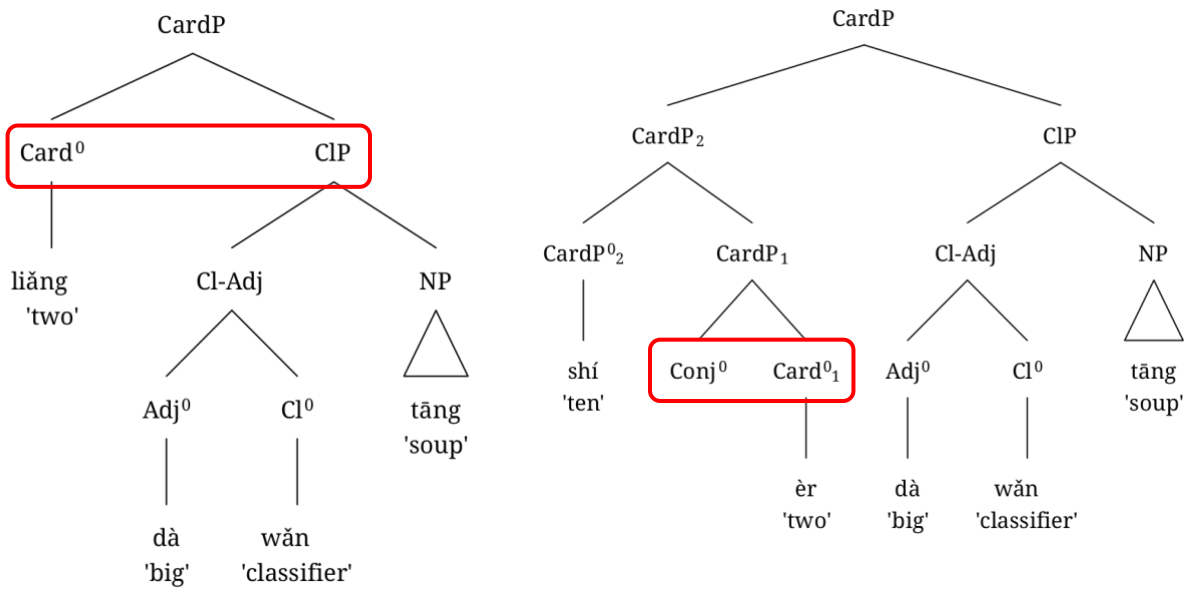
It is worth mentioning that while all the trees in this paper follow the conventions of the X-bar theory, the structures in (32a-b) may be an argument for adopting Bare Phrase Structure instead. If we follow the X-bar theory strictly, then the ClP is a complement to the simplex cardinal in (32a) but 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 will still follow the X-bar theory just for 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 key contrast between simplex cardinals and complex ones supports the generalization in (27), I will provide five more types of evidence supporting (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 in ways that support (27). The fifth piece of evidence suggests that the sister of the contextual form must be pronounced.

4.1.2. 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'

4.1.3. ‘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 [$_{\text{CondP}}$ yí [$_{\text{vP}}$ shuìxǐng]], jiù kāishǐ kàn shǒujī.
She once awake PRT start look phone
‘She started looking at her phone once she woke up.’

b. Tā [$_{\text{CondP}}$ yí [$_{\text{vP}}$ [$_{\text{PP}}$ 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 [$_{\text{CondP}}$ yì [$_{\text{vP}}$ 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.’

4.1.4. 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 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.

4.1.5. 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[10] 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.

(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]:

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

(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.[11]

4.1.6. 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'

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 has nothing to do with whether the numeral is enumerating or abstract, but 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.

4.2. 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

[11] 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.

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…'

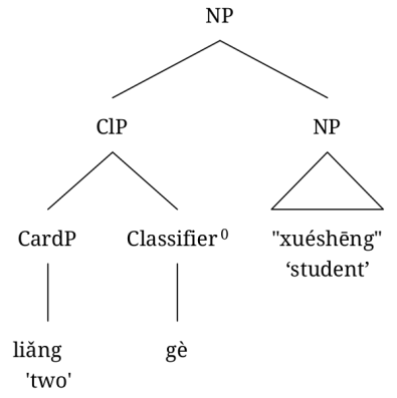
In interim summary, I have provided six pieces of evidence that lead to the empirical generalization in (27), where the numeral morphology depends on the linear order of the numeral's pronounced sister. This generalization can also account for the distinction between enumerating and abstract numbers.

4.3. Cardinal projects to the mother node

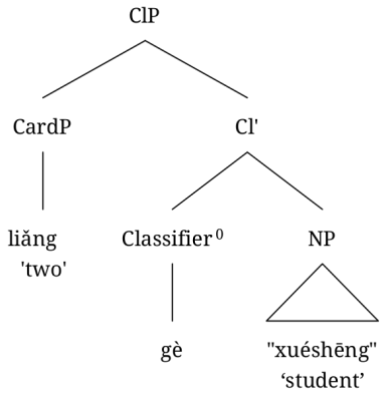
Having provided the evidence that supports the empirical generalization in (27), this subsection discusses the consequences this generalization has for the syntactic structure containing CardP. Subsection 4.1.1 focused on the internal structure of CardP, and so far I have not discussed how the CardP as a whole 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 structures that have been assumed for the CardP-ClP structure before, 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 different structures assumed for 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).

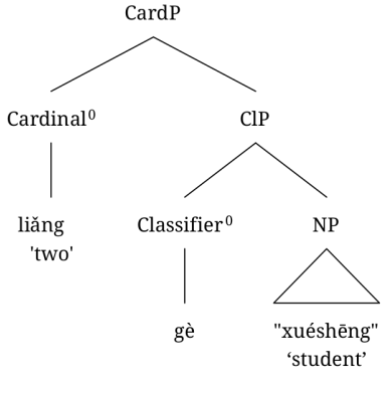
(45) a. *He (2015)*



b. *Cheng & Sybesma (1998)*



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

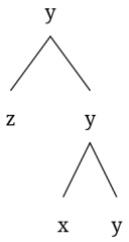


The empirical generalization in (27), together with key assumptions about bottom-up vocabulary insertion, supports analyses where the Cardinal projects ((45c), Tang 1990 and Cheng & Sybesma

1999). The generalization in (27) is an example of phonologically-conditioned suppletion 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 now return to the cases discussed in the previous subsections where the contextual form is selected 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. The cardinal is more embedded than Cl^0 in (45a&b) because the ClP contains the cardinal. Therefore, if we follow the generalization in (8) and assume bottom-up insertion, then they lead to a structure where the $Card^0$ takes the ClP as its complement and projects (45c).

To summarize, this section has argued that the numeral's morphology depends on whether it is followed by overt material at the point of vocabulary insertion. This together with the assumption of bottom-up vocabulary insertion suggests that the enumerating cardinal is a head that takes the ClP as its sister.

5. Alternative analyses and their problems

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

5.1. Alternative 1: 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:

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

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

b. *Zhuō shàng yǒu yì hóng běn shū.
   Desk on have 1.CONT red CL book

Second, the alternative proposals are challenged by two 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 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.

5.2. Alternative 2: *Yi* undergoes two-way tone sandhi depending on word-finality

Section 2 presented He's (2015) analysis of *yi*-sandhi as two-way tone sandhi (11), repeated below, and discussed some issues with that analysis. This subsection lays out more differences between He's analysis and the current one.

(11) *He's (2015) morphophonological rule of* yi-*sandhi*
   a. /yī/ → [yí] / __ σ]$_{word}$
   b. /yī/ → [yì] / __ σ (non-falling tone)]$_{word}$

There are two key differences between He's analysis and the current one. First, He took the three forms of *yi* to be phonological variants of the same morph (i.e. morph variants), while I posit two distinct suppletive morphs–the form that doesn't undergo sandhi *yī*, and the form that does *yì* and *yí*. Section 2 showed that the current analysis is more economical because there is no other sandhi process in Mandarin like He's proposed *yi*-sandhi, but the currently proposed *yi*-sandhi is part of a broader rule called the *yi-bu-qi-ba rule*.

The other difference between He and the current analysis is that He's rules refer to word boundaries, while my analyses in (7) and (8) do not rely on any notion of wordhood. He did not explain what is a word boundary and how it is derived. If it is a prosodic word boundary, what sorts of syntactic constituents are mapped to a prosodic word? For the purpose of the argument, let us follow the basic assumption in syntax-prosody mapping theories such as edge-based theories (e.g. Selkirk & Shen 1990; Selkirk 1995) and Match Theory (e.g. Selkirk 2009; Selkirk 2011; Elfner 2012; Ito & Mester 2013; Elfner 2015; Ito & Mester 2015) that an X^0 corresponds to a prosodic word. He's analysis plus this assumption cannot account for the data involving *yi* 'once' in (37) because *yi* 'once' is a Conditional head there, and should therefore correspond to a prosodic word. Since *yi* is its own prosodic word, and therefore final in this word, He predicts 'once' to surface as *yī*, contrary to fact.

5.3. 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 further specified that a prosodic word corresponds to a compound. She also 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. 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 suppletive morphs rather than morph variants 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 suppletion's sensitivity to phonology is inward rather than outward (e.g. Carstairs-McCarthy 2017).

6. 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 broader class of lexical items in the language. The two numeral forms are suppletive morphs, 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.

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

Section 4.1.1 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 4.1.1 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

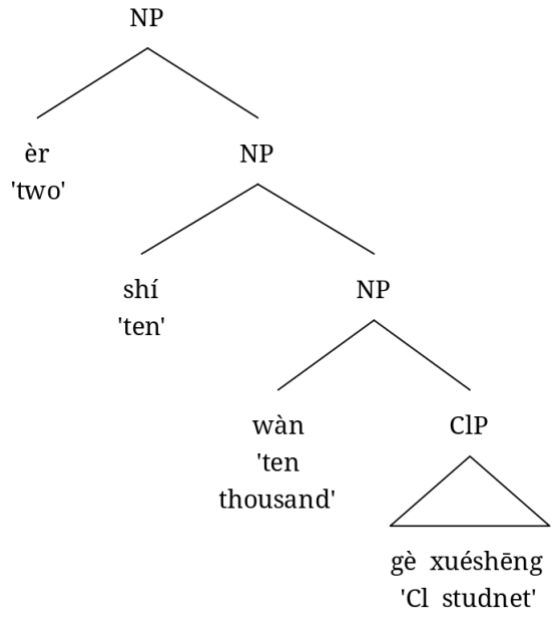
Recall that I&M's (2006, 2018) NP-conjunction-plus-ellipsis approach posits backward ellipsis of ClPs, and pronounces the final multiplier and base (I call the pronounced constituents that survive ellipsis *the stranded remnants*). But this sort of ClP-ellipsis is generally marginal. For example, it is not possible to elide the ClP and pronounce the simplex cardinal, whether in the contextual or the absolute form (48a-b); the Classifier^0 must also be pronounced (48c).

(48) 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.

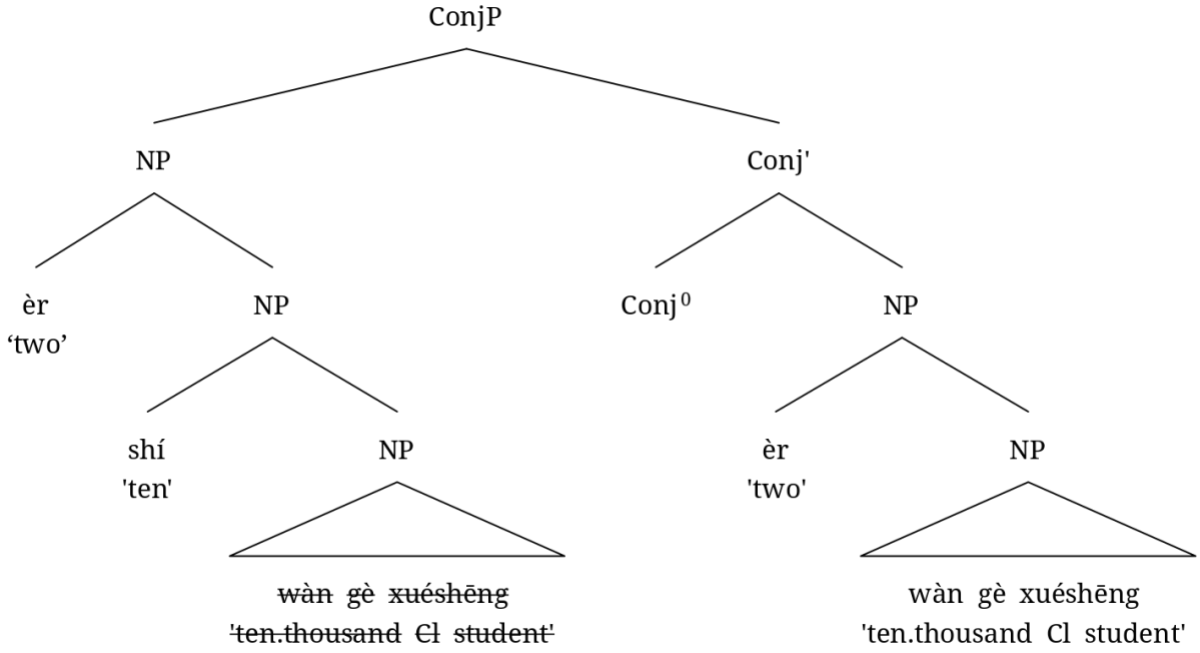
Furthermore, I&M, following Cheng & Sybesma's (1998) structure of Mandarin cardinal-classifiers, assigned a right-branching cascading structure to nested complex cardinals like '200,000 students' in Mandarin:

(49)



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

(50)



But the kind of ellipsis of the base plus the ClP (i.e. *wàn gè xuesheng* in (50)) required in I&M’s analysis is generally not possible in Mandarin Chinese:

(51) 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' (52a) than not to (51), though (52a) is still not perfect. The best way is to include the Cl^0 in the remnant (52b).

(52) 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. (53a) pronounces a smaller number than (52a), and is worse.

(53) 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 (53a) and (52a) 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 (52a). But (52a) 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:

(54) 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. (55a) is a sentence where the subject is followed by a third-tone predicate, and thus has a left-branching structure. (55b) is a modified NP with a right-branching structure, where the third-tone modifier precedes the compound. In (55a), the first

two syllables must both undergo tone sandhi (the syllables that undergo tone sandhi are marked in bold), while in (55b), the second syllable must have tone sandhi, but the first one optionally does.

(55) 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.

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 (56A). 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 (56A).

(56) 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 (56A) 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 (57a) or (57b). While I prefer the first syllable *liǎng* to have tone sandhi, it does not have to, and (57b) sounds better than *hǎo-jí wǎn* in (56A).

(57) a. Wǒ 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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References

Anderson, Stephen R. 1982. Where's morphology? *Linguistic Inquiry* 13. MIT Press: 571–612.

Anderson, Stephen R. 1992. *A-Morphous Morphology*. 1st ed. Cambridge University Press. https://doi.org/10.1017/CBO9780511586262.

Bobaljik, Jonathan David. 2000. The ins and outs of contextual allomorphy. In *University of Maryland Working Papers in Linguistics*, ed. Kleanthes K. Grohmann and Caro Struijke, 10:35–71.

Bultinck, Bert. 2005. Numerous Meanings: The Meaning of English Cardinals and the Legacy of Paul Grice. Current Research in the Semantics / Pragmatics Interface Volume 15. Antwerp: Universitaire Instelling Antwerpen.

Carstairs-McCarthy, Andrew. 2017. Phonological Constraints on Morphological Rules. In *The Handbook of Morphology*, ed. Andrew Spencer and Arnold M. Zwicky, 144–148. John Wiley & Sons, Ltd. https://doi.org/10.1002/9781405166348.ch7.

Chao, Yuen Ren. 1970. *A Grammar of Spoken Chinese*. Berkeley, CA: University of California Press.

Cheng, Lisa Lai-Shen, and Rint Sybesma. 1998. Yi-wan tang, yi-ge tang: Classifiers and massifiers. *Tsing Hua Journal of Chinese Studies* 28: 385–412.

Cheng, Lisa Lai-Shen, and Rint Sybesma. 1999. Bare and not-so-bare nouns and the structure of NP. *Linguistic Inquiry* 30. The MIT Press: 509–542.

Cheng, Lisa Lai-Shen, and Rint Sybesma. 2012. Classifiers and DP. *Linguistic Inquiry* 43. The MIT Press: 634–650.

Elfner, Emily. 2012. Syntax-Prosody Interactions in Irish. University of Massachusetts, Amherst.

Elfner, Emily. 2015. Recursion in prosodic phrasing: evidence from Connemara Irish. *Natural Language & Linguistic Theory* 33: 1169–1208. https://doi.org/10.1007/s11049-014-9281-5.

Embick, David. 2010. *Localism versus Globalism in Morphology and Phonology*. The MIT Press. https://doi.org/10.7551/mitpress/9780262014229.001.0001.

Greenberg, Joseph H. 1978. Generalizations about Numeral Systems. In *Universals of Human Language*, ed. Joseph H. Greenberg, Charles A. Ferguson, and Edith A. Moravcsik, 3:249–295. Stanford, CA: Stanford University Press.

Haspelmath, Martin. 2020. The morph as a minimal linguistic form. *Morphology* 30: 117–134. https://doi.org/10.1007/s11525-020-09355-5.

He, Chuansheng. 2015. Complex numerals in Mandarin Chinese are constituents. *Lingua* 164: 189–214. https://doi.org/10.1016/j.lingua.2015.06.014.

Hurford, James R. 1975. *The Linguistic Theory of Numerals*. Cambridge Studies in Linguistics 16. Cambridge: Cambridge University Press.

Ionin, Tania, and Ora Matushansky. 2006. The Composition of Complex Cardinals. *Journal of Semantics* 23: 315–360. https://doi.org/10.1093/jos/ffl006.

Ionin, Tania, and Ora Matushansky. 2018. *Cardinals: The Syntax and Semantics of Cardinal-Containing Expressions*. Linguistic Inquiry Monographs 79. Cambridge, MA: The MIT Press.

Ito, Junko, and Armin Mester. 2013. Prosodic subcategories in Japanese. *Lingua* 124: 20–40. https://doi.org/10.1016/j.lingua.2012.08.016.
Ito, Junko, and Armin Mester. 2015. The perfect prosodic word in Danish. *Nordic Journal of Linguistics* 38: 5–36. https://doi.org/10.1017/S0332586515000049.
Kiparsky, Paul. 2000. Opacity and cyclicity. *The Linguistic Review* 17. De Gruyter Mouton: 351–366. https://doi.org/10.1515/tlir.2000.17.2-4.351.
Myler, Neil. 2017. Exceptions to the Mirror Principle and morphophonological 'action at a distance.' In *The Structure of Words at the Interfaces*, ed. Heather Newell, Máire Noonan, Glyne Piggott, and Lisa deMena Travis. Vol. 1. Oxford University Press. https://doi.org/10.1093/oso/9780198778264.003.0005.
Paster, Mary. 2006. Phonological Conditions on Affixation. University of California, Berkeley.
Róna-Tas, András. 1999. Chuvash and historical morphology. *Acta Orientalia Academiae Scientiarum Hungaricae* 52. Akadémiai Kiadó: 1–15.
Rothstein, Susan. 2013. A Fregean semantics for number words. In *Proceedings of the 19th Amsterdam Colloquium*, ed. Maria Aloni, Michael Franke, and Floris Roelofsen, 179–186.
Rothstein, Susan. 2017. *Semantics for Counting and Measuring*. Key Topics in Semantics and Pragmatics. Cambridge: Cambridge University Press. https://doi.org/10.1017/9780511734830.
Selkirk, Elisabeth. 1995. Sentence prosody: Intonation, stress and phrasing. In *The Handbook of Phonological Theory*, ed. John A. Goldsmith, Jason Riggle, and Alan C. L. Yu, 550–569. Oxford: Blackwell.
Selkirk, Elisabeth. 2009. On clause and intonational phrase in Japanese: The syntactic grounding of prosodic constituent structure. *Gengo Kenkyuu*: 35–73.
Selkirk, Elisabeth. 2011. The Syntax-Phonology Interface. In *The Handbook of Phonological Theory*, ed. John Goldsmith, Jason Riggle, and Alan C. L. Yu, 1st ed., 435–484. Wiley. https://doi.org/10.1002/9781444343069.ch14.
Selkirk, Elisabeth, and Tong Shen. 1990. Prosodic domains in Shanghai Chinese. In *The Phonology-Syntax Connection*, ed. Sharon Inkelas and Draga Zec, 313–337. Chicago, IL: University of Chicago Press.
Shih, Chih-Lin. 1986. The Prosodic Domain of Tone Sandhi in Chinese. University of California, San Diego.
Tang, Chih-Chen J. 1990. Chinese Phrase Structure and the Extended X'-Theory. Cornell University.
Wągiel, Marcin, and Pavel Caha. 2021. Complex simplex numerals. *Acta Linguistica Academica* 68: 470–515. https://doi.org/10.1556/2062.2021.00460.
Wang, Chunmeng. 2014. The Prosody-Syntax Interaction in the "yi-bu-qi-ba" Rule: A Morphologically Conditioned Tone Change in Mandarin Chinese. University of North Carolina at Chapel Hill.
Wei, Minglong. 2020. The negation marker mei in Northeastern Mandarin. In *Chinese Lexical Semantics*, ed. Jia-Fei Hong, Yangsen Zhang, and Pengyuan Liu, 147–155. Lecture Notes in Computer Science. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-38189-9_15.
Zhang, Zheng-sheng. 1988. Tone and Tone Sandhi in Chinese. Ohio State University.