Num-Cl adjacency and the morphological movement of numerals in Mandarin

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In Chinese, numerals and classifiers are in principle adjacent to each other, forming a prosodic unit. Apparent violation of Num-Cl adjacency is observed when a zero-level adjective modifies the classifier. Such violation is not observed when the adjectives are phrasal. The current study provides a comprehensive description and analysis of different conditions of Num-Cl Adjacency constraints in Mandarin. Specifically, this paper proposes that the Num-Cl adjacency effect is reducible to the numeral lowering at PF, which is motivated by the morphological dependency of numerals rather than a requirement on the linear relation between numerals and classifiers. This analysis accounts for all observations regarding word order between the numeral, the classifier, and the different types of adjectives in a unified way. In addition, it is shown that the numeral-lowering analysis is also applicable to complex numerals and can solve the problem of some approximant numerals.

Keywords: numeral classifier, pre-numeral modifiers, morphological movement, complex numerals, Mandarin

1. Introduction

Num-Cl adjacency is a cross-linguistic generalization. Greenberg (1972: 28) generalizes that of the six theoretically possible word orders for numeral, classifier, and noun, only four of them are attested, namely, Num-Cl-N, N-Num-Cl, Cl-Num-N, N-Cl-Num. This postulates that numeral and classifier are always adjacent and will not be interrupted by a noun.[1]

1. According to Aikhenvald (2000) and Simpson (2005), the Cl-N-Num word order exists in Ejagham, Thai, and Nung. However, Her (2017) argues that the putative classifiers in Ejagham are actually nouns, and the numeral *one* appearing to the right of the noun is in fact an article.

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In Mandarin, the numeral noun phrase appears in one of four attested word orders, namely Num-Cl-NP, and the numeral and classifier form a prosodic unit, because there is a pause between Num-Cl and NP, while sometimes the particle *de*[2] can also be inserted between them (Y.-H. Audrey Li 2013), as shown in (1) and (2):

(1) |*yì tái*| *bīngxiāng*|
one CL fridge
'a fridge'

(2) *shí wàn tái de bīngxiāng*
ten ten-thousand CL PRT fridge
'100,000 fridges'

Even though the noun will not interrupt the Num-Cl adjacency in Chinese, some zero-level adjectives[3] modifying classifiers will do so, yielding the Num-A-Cl-N sequence, as shown in (3). However, the slot between numeral and classifier cannot accommodate phrasal adjectives, which is demonstrated by the non-licensing of the occurrence of the modification marker *de*, degree adverbs, or reduplication, shown in (4) below. In contrast, these phrasal adjectives can precede numerals, as shown in (5). I shall refer to them as PNACs (Pre-Numeral Adjectives for Classifiers) in the following.

(3) *yí dà píng shuǐ*
one big bottle water
'a big bottle of water'

(4) a. *yí dà (*de) píng shuǐ*
one big PRT bottle water
'a big bottle of water'
b. **yí hěn dà (de) píng shuǐ*
one very big PRT bottle water
Intended: 'a very big bottle of water'

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2. In quantity reading, *de* between Num-Cl and NP is phonologically inserted to reflect focus-encoding (Y.-H. Audrey Li 2013).

3. Chinese modified noun phrases can be divided into two types based on whether the modifier is followed by the modification marker *de* or not (Zhu 1982). Lu (1988), Tang (1990), and Lu (2017) argue that "A-N" is actually a compound or a lexical item, while "A *de* N" is a phrase. In other words, the adjectives in the former sequence are not phrases; only those in the latter form are. Following Tang (1990), we refer to adjectives without *de* as zero-level adjectives, and to adjectives followed by *de* as phrasal adjectives.

c. **yí dàda (de) píng shuǐ*
one big-big PRT bottle water
Intented: 'a very big bottle of water'

(5) *hěn dà de yì píng shuǐ*
very big PRT one bottle water
'a very big bottle of water'

In short, although both zero-level adjectives and phrasal adjectives can modify a classifier, they appear on different sides of the numeral. As a result, they seemingly impose different effects on Num-Cl adjacency.

A full description of Num-Cl adjacency in Chinese should include the three statements listed in item (6):

(6) Three facts about the Num-Cl adjacency in Chinese:
a. Numerals and classifiers are often adjacent and form a prosodic unit.
b. Zero-level adjectives for classifiers can be inserted between numerals and classifiers.
c. Phrasal adjectives for classifiers are located before numerals instead of between numerals and classifiers.

Num-Cl adjacency has been ascribed to certain syntactic rules which, however, lack detailed arguments. For instance, Cheng & Sybesma (1999: Footnote 16) assume that Mandarin classifiers obligatorily cliticize to numerals. Zhang (2013: 173) suggests that the surface adjacency may be the result of certain morphosyntactic operations, but no further explanation is given. Jin (2019) regards Num-Cl adjacency itself as a syntactic rule that no overt or covert constituents are allowed between them. The two remaining facts involving the modification of adjectives are studied independently. On the one hand, the aforementioned studies have not touched upon the effects of adjectives on Num-Cl adjacency. On the other hand, studies of pre-classifier adjectives and those of pre-numeral adjectives are always treated separately from one other. For instance, the pre-classifier adjectives are explained from the perspective of a syntactic property of these pre-classifier adjectives (Tang 1990; Zhang 2013; Luo et al. 2017, among others). The pre-numeral adjectives are taken to be base-generated adjectives above the whole "Num-Cl-NP" phrase (Hsieh 2008), and so have never entered into discussion of Num-Cl adjacency.

In this paper, I shall argue that the syntactic mechanism underpinning Num-Cl adjacency in Chinese is that numerals undergo lowering to Cl^0 and that this can capture all the facts concerning Num-Cl adjacency, including the prosodic phrasing of "Num-Cl", pre-classifier adjectives, and PNACs. Crucially, the motivation of numeral lowering is argued to be the morphological dependency of

numerals, which originally occurs because of prosodic factors. Furthermore, to generalize the morphological properties of all numerals in Mandarin, I shall also observe and analyze the distribution of complex numerals.

The remainder of this paper is structured as follows. In § 2, I shall argue that the Num-Cl adjacency is realized by the numerals' morphological movement, mainly by analyzing the derivation of PNACs. § 3 will argue that the numerals' morphological movement is motivated by their morphological dependency. Then in § 4, discussion turns to complex numerals, including their morphological properties and the behavior of simplex numerals inside them. § 5 concludes.

2. The syntactic mechanism under the Num-Cl adjacency in Mandarin

As discussed in § 1, both pre-classifier adjectives and pre-numeral adjectives for classifiers are related to the issue of Num-Cl adjacency. In brief, a zero-level adjective can be inserted in a Num-Cl, resulting in the a Num-Cl adjacency violation. Conversely, a phrasal adjective adhering to Num-Cl adjacency, yields the AP-Num-Cl-N order. Pre-classifier adjectives have been analyzed in different ways, but PNACs are less-studied and have not been included in the discussion of Num-Cl adjacency. In this section, I shall first briefly review the derivation of pre-classifier adjectives and proceed to the analysis of PNACs. I shall argue that PNACs are derived by the lowering of the numeral and that this derivation reveals the syntactic nature of Num-Cl adjacency.

2.1 The derivation of pre-classifier adjectives

Pre-classifier adjectives are limited to several zero-level adjectives, and they are usually monosyllabic, as can be seen in (7) and (8); sometimes two or three monosyllabic adjectives can stack (XuPing Li 2013; Zhang 2013), as in (9).

(7) *yí dà tiáo yú*
one big CL fish
'a fish, which is big.'

(8) *yí dà bēi jiǔ*
one big glass wine
'a big glass of wine' or 'a full glass of wine'

(9) *yì xiǎo báo piàn miànbāo*
one small thin piece bread
'a small, thin piece of bread'

The pre-classifier adjectives are analyzed as different syntactic items. Tang (1990), Cheng & Sybesma (1999) and Jin (2019) argue that the pre-classifier adjective and the classifier form a complex ClP head. According to the Lexical Integrity Hypothesis, the adjective inside a complex head is not allowed to extend to a phrase. Xuping Li (2013) proposes that the pre-classifier adjective is projected as the specifier of ClP, while Zhang (2013: 230) proposes that the pre-classifier adjective is an adjunct of UnitP, and the adjective undergoes morphological merger with the unit word in PF, so the adjective is limited to monosyllabic form without adverbial modification or reduplication, but the stacking of adjectives is allowed, as in (9). Luo et al. (2017) argue that the pre-classifier adjective functions as a degree morpheme that evaluates the degree on a dimension of the unit, and accordingly, as a head, it projects Deg(ree)P above ClP. This also excludes the possibility of other degree adverbs or reduplication of the adjectives.

I shall follow the complex head analysis since it can account for all the facts observed about pre-classifier adjectives. For one thing, it explains why pre-classifier adjectives must be zero-level (Tang 1990; Cheng & Sybesma 1999; Jin 2019); and for another, with the complex head analysis, the conventional distribution of "Adj-Cl" can be attributed to its compound property. The (un)grammaticality of complex Adj-Cl heads cannot be predicted by the semantics; for example, *gāo* 'high' can semantically modify *luò* 'stack' and form a pre-numeral modifier for *luò* 'stack', as shown in (10a), but *gāo* cannot directly modify *luò* 'stack', as shown in (10b). This means that the Adj-Cl pattern is conventional rather than showing constraint by semantics.

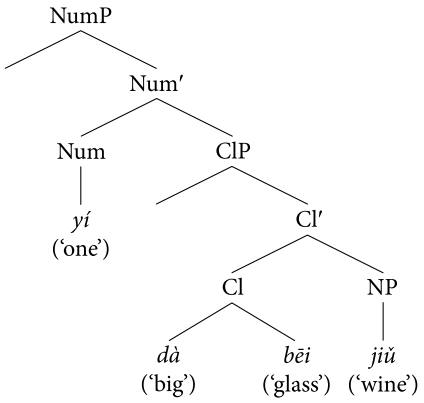
(10) a. *hěn gāo de yí luò shū*
very high PRT one stack book
'a very high stack of books'

b. **yí gāo luò shū*
one high stack book
Intented: 'a high stack of books'

In contrast, other analyses fail to account for any of these observations. To start with, whether it is a specifier or an adjunct, the pre-classifier adjective would be wrongly predicted to have phrasal status. Zhang (2013) does try to support this idea by assuming a monosyllabic constraint on adjectives, but this constraint is not consistent with stacked adjectives of size. Luo et al. (2017) propose that the pre-classifier adjective being a degree morpheme is also problematic, because the stacked adjectives of size usually indicate properties in different dimensions, which goes against their claim that the adjective serves to evaluate the degree in one certain dimension.

Following Tang (1990) and Cheng & Sybesma (1999), the syntactic structure of the Num-A-Cl-NP sequence should be as in (11).

(11)



The reason why pre-classifier adjectives cannot extend to phrases is that these adjectives are a part of a complex head, but this does not exclude the possibility of the base-generation of a phrasal modifier, neither does it explain why the slot between the numeral and the classifier cannot accommodate a phrasal adjective. So far, the syntactic mechanism of Num-Cl adjacency and what causes phrasal adjectives for classifiers to be pre-numeral has never been clarified. These issues will be demystified by analyzing the derivation of pre-numeral adjectives for classifiers in the next subsection.

2.2 The derivation of pre-numeral adjectives for classifiers

As mentioned in § 1, the relation between PNACs and pre-classifier adjectives, as well as the effects of PNACs on Num-Cl adjacency, have long been overlooked. PNACs are proposed to be base-generated above numerals; Hsieh's (2008) argument is that a pre-numeral adjective can semantically modify the classifier only when the numeral is *yī* 'one', so that a pre-numeral adjective actually modifies the Num-Cl-NP sequence. However, this argument is contrary to the fact, as shown in (12). Here the numeral is *jǐ* 'several', and the classifier *luò* 'stack' is semantically connected to the pre-numeral adjectives *gāogao de* 'very tall', which predicates the height of each stack of books rather than that of several stacks as a whole.

(12) *gāogao de jǐ luò shū*
high-high PRT several stack book
'several high stacks of books'

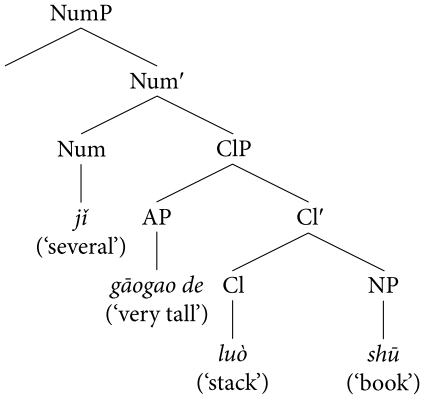
Considering that PNACs semantically scope over classifiers rather than numerals, I propose that they are base-generated as an adjunct in ClP and that the final word order AP-Num-Cl-NP is formed by the numeral's lowering to Cl^0 in PF.

I adopt the right-branching analysis of "Num-Cl-NP", in which the numeral and the classifier project two independent projections above NP, and NumP dominates ClP (Cheng & Sybesma 1999; Simpson 2005; Tang 2005; Li 2014, among others),[4] as shown in (13). So, the base-generated syntactic structure of noun phrases with PNACs should be as in (14) and (15).

(13) $[_{NumP}\ Num^0\ [_{ClP}\ Cl^0\ [_{NP}\ N^0]]]$

(14) $[_{NumP}\ Num^0\ [_{ClP}\ [AP]\ [_{Cl'}\ Cl^0\ [_{NP}\ N^0]]]]$

(15)



If this base-generated hierarchy structure were linearized directly, the final word order would be Num-AP-Cl-NP, which is ungrammatical. To form the expected AP-Num-Cl-N sequence, the relative order of the numeral and the adjective needs to be adjusted, and there are generally two ways to do this: either move AP up or move Num downwards or backwards. The current study prefers the second option.

The approach that moves AP upwards is widely used for Chinese adnominal modifiers but is problematic for PNACs. Adnominal modifiers optionally appear between the classifier and the noun or in pre-numeral position, as seen in (16).

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4. The syntactic structure of numeral noun phrases is a controversial topic. The proposals for it can be mainly divided into three approaches: a right-branching, left-branching, or split analysis. In the left-branching analysis, the classifier forms a constituent with the numeral first, and they are in a specifier position of a projection above NP. In the split analysis, the right-branching and left-branching structures co-exist in Chinese, depending on the subcategory or semantic function of a classifier. More details about analyses of Chinese numeral noun phrases can be found in Jin (2019: Chapter 3), Her & Tsai (2020).

(16) a. *yí ge hěn gāo de rén*
one CL very tall PRT person
'a very tall person'
b. *hěn gāo de yí ge rén*
very tall PRT one CL person
'a very tall person'

These pre-numeral modifiers may lead to a definite (Wu 1997; Hall 2015) or specific (Sio 2006; Zhang 2006, 2015; Jin 2020) reading, evidenced by the fact that they cannot be used in existential sentences. It is still controversial as to whether these pre numeral modifiers move up into FocusP inside DP (Zhang 2006, 2015; Yip 2018; Jin 2020) or into a referential projection, namely, DP or SpecificP (Sio 2006; Hall 2015).

However, neither of these landing sites can be carried over to PNACs. On the one hand, PNACs obligatorily precede numerals (see (17)), so they are not likely to be focused because [+focus] is an optional feature. On the other hand, PNACs do not necessarily yield a definite or specific interpretation. As shown in (18), the noun phrase with a PNAC can occur in existential sentences. So, the adjective does not necessarily move into either DP or SpecificP. I shall not exclude the possibility that PNACs further move into FocusP or projections related to referential property, but neither of these moves could be an obligatory operation for deriving PNACs. Besides FocusP or DP (or SpecificP), there is no other possible landing site available for moved pre-numeral modifiers, so the approach that APs move upwards is ruled out.

(17) a. **liǎng gāogao de luò shū*
two tall-tall PRT stack book
Intended: 'two tall stacks of books'
b. *gāogao de liǎng luò shū*
tall-tall PRT two stack book
'two tall stacks of books'

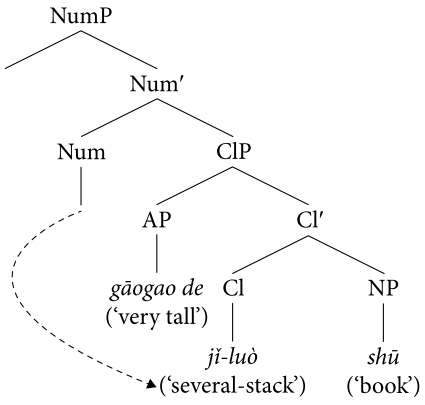
(18) *Zhuōzi shang yǒu gāogao de liǎng luò shū.*
desk on have tall-tall PRT two stack book
'There are two tall stacks of books on the desk.'

For the reasons above, the downward or backward movement of the numeral is the only possible way to derive the expected word order. Since both Num and Cl are functional heads, and the former c-commands the latter, the most attractive approach is to lower Num to Cl^0 in PF, left-adjoining it to Cl.[5] In this way, the

5. In addition to lowering, there are other two morphological operations that can alter linear word order: Local Dislocation and Prosodic Inversion (Embick & Noyer 2001; 2007). These

morphological merger will not be affected by the intervention of the adjuncts, and AP ends up in the pre-numeral position, as in (19).

(19)



2.3 Interim summary

The derivation of PNACs reveals the fact that numerals undergo morphological movement and are morphologically merged with classifiers. This mechanism can account for the three facts concerning Num-Cl adjacency in Chinese (see (6), repeated here as (20)).

(20) Three facts about the Num-Cl adjacency in Chinese: (=(6))
   a. Numerals and classifiers are often adjacent and form a prosodic unit.
   b. Zero-level adjectives for classifiers can be inserted between numerals and classifiers.
   c. Phrasal adjectives for classifiers are situated before numerals instead of between numerals and classifiers.

As for the first fact, the morphological merger of numerals and classifiers in PF can better explain why numerals and classifiers form a prosodic or morphological unit. Even though numeral and classifier project as two independent heads in the c-command relation, which do not form a syntactic constituent; they merge into a morphological unit through numerals' lowering in PF, so that in surface structures numerals and classifiers are often adjacent and pronounced as a phonological phrase with a prosodic boundary between Num-Cl and N.

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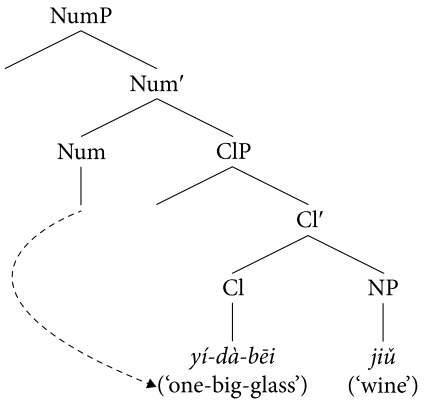
two operations are applied after Linearization and Vocabulary Inversion, and will cause the two adjacent elements involved to be morphologically merged or prosodically phrased, but PNAC and Num do not form a morphological or phonological unit. So, neither of them can be the way to derive the expected AP-Num-Cl-N sequence.

Pre-classifier adjectives can also be compatible with the morphological merger of numerals and classifiers. Since the pre-classifier adjective and the classifier have already been a complex head, the lowered numeral will be left-adjoined to the adjective rather than to the classifier, as shown in (21).

(21)



In sum, with the analysis of pre-classifier adjectives and PNACs, the mystery as to the Num-Cl adjacency has been solved, fully explaining all three facts concerning it. However, to make this proposal more convincing, two additional points need to be considered. First, the lowering of an element is often motivated by its cliticization, but Chinese numerals are never tagged as clitics, because they have lexical meanings and are not phonologically reduced (except for *yī* 'one' when it is used as an indefinite article). I shall argue in § 3 that the lowering of numerals is due to their morphological dependency, which is established under the influence of Chinese disyllabification. Second, what happens with complex numerals also needs to be observed, but when the classifier is modified by adjectives, the numeral tends to be small, usually from 1 to 10, so PNACs cannot provide much information about complex numerals, thus I shall present and explain the distribution of complex numerals through other types of phrases in § 4.

3. The morphological dependency of numerals

Section 2 argues that the nature of Num-Cl adjacency in Chinese is such that Num undergoes lowering to Cl^0, but it has remained unclear what the motivation is of the morphological movement of numerals, given that Chinese numerals are unlikely to be clitics.

Cheng & Sybesma (1999) propose that classifiers are clitics or suffixes to numerals. However, even if classifiers were clitics, they could not attract numerals

to lower at PF. Moreover, the assumption that classifiers are clitics or suffixes is intuitive but problematic. If the classifier were a clitic or a suffix, it would not be able to stand without a host. However, in Mandarin and many other Chinese varieties, classifiers can appear without numerals. For instance, "Cl-N" can be used as an object in Mandarin (e.g. (22)) and used freely in Cantonese (e.g. (23)). Another reason why Chinese classifiers are not clitics from a diachronic perspective will be discussed in § 3.2.

(22) *Zhāngsān mǎi le běn shū.* (Mandarin)
Zhangsan buy ASP CL book.
'Zhangsan bought a book.'

(23) *Go leotsi jiu hou lek sin dak.* (Cantonese)
CL lawyer need very smart only-okay.
'The lawyer had better be very smart.' (Cheng & Sybesma 1999: 524)

Instead, I propose that the lowering of the numeral is motivated by its morphological dependency. In this section, I shall argue for the morphological dependency of numerals based on the cyclic lowering of the numeral when the classifier is null and explain its historical cause.

3.1 A numeral's lowering to N^0

There are two logical possibilities for the motivation of numeral lowering: (1) to meet the requirement on Num-Cl linear adjacency (similar to Jin's (2019) proposal), and (2) to rescue the numeral's morphological dependency. Since the former is concerned with classifiers and the latter is not, what happens when no classifier is present will help us distinguish which candidate motivation is plausible. With the two candidate motivations, we can make two different predictions respectively:

Prediction 1: If the numeral's lowering serves to meet the requirement on Num-Cl linear adjacency, no such lowering will occur when no classifier is present.

Prediction 2: If the numeral's lowering serves to rescue its morphological dependency, such lowering will occur regardless of whether or not a classifier is present.

In this subsection, I shall confirm Predication 2 by analyzing the distribution of modifiers for non-classified nouns in Chinese.

Generally, in classifier languages, a classifier is required in a numeral noun phrase, but there are some exceptions in which nouns can combine with numerals

without classifiers, as in Vietnamese, Thai, Burmese (Simpson & Ngo 2018), and Shan (Little et al. 2020). Such nouns that directly combine with numerals without a classifier are usually referred to as non-classified nouns. Mandarin also contains such nouns, parts of which are kinship terms used to indicate a pair of families or relatives, such as the following:

(24) *liǎng (*ge) fūqī*
two CL husband-wife
'the couple (*lit.* the two people, who are husband and wife)'[6]

(25) *sān (*ge) yésūn*
three CL grandfather-grandchild
'the three people, who are grandfather and grandchildren'

An interesting and relevant phenomenon is that modifiers for these non-classified nouns obligatorily precede the numeral. Even though the modifiers bear semantic relation only with the noun, they cannot directly precede the noun, intervening between the numeral and the non-classified noun, as seen here:

(26) a. *shànliáng de liǎng fūqī*
kind-hearted PRT two husband-wife
'the kind-hearted couple'
b. **liǎng shànliáng de fūqī*
two kind-hearted PRT husband-wife
Intended: 'the kind-hearted couple'

(27) a. *wúzhù de sān yésūn*
helpless PRT three grandfather-grandchild
'the three helpless people, who are a grandfather and his grandchildren'
b. **sān wúzhù de yésūn*
three helpless PRT grandfather-grandchild
Intended: 'the three helpless people, who are a grandfather and his grandchildren'

These pre-numeral modifiers show properties similar to those of PNACs. First, they obligatorily precede any numeral; second, they do not contribute to the

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6. The numeral noun phrases formed by such kinship terms and numerals often refer to people previously mentioned, making them always definite, regardless of the presence of a demonstrative. Only *jiěmèi* 'sister' or *xiōngdì* 'brother' can be used in indefinite numeral nouns without classifiers, for example:

(i) *Tāmen jiā zhǐ yǒu sān jiěmèi/xiōngdì.*
they family only have three sister/brother
'There are only three sisters/brothers in their family.'

referentiality. So, they are also impossible to derive through AP raising. Hence, numeral lowering in PF is only possible to derive the M(odification)P-Num-N sequence. The difference from PNACs is that the numeral in this structure is left-adjoined to a noun instead of to a classifier, and this difference is related to whether there is an overt classifier.

Following Simpson & Ngo (2018), non-classified nouns are associated with a phonetically null classifier,[7] so the syntactic structure of "Num-N" will be as in (28). When the non-classified noun is modified, the base-generated syntactic structure will be as in (29). To obtain the final word order MP-Num-N, numerals need to further lower to N^0 and left-adjoin to nouns, as shown in (30).

(28) $[_{NumP}$ Num $[_{ClP}$ ø $[_{NP}$ N]]]

(29) $[_{NumP}$ Num $[_{ClP}$ ø $[_{NP}$ [MP] $[_{N'}$ [N]]]]

7. Simpson & Ngo (2018) further argue that the null classifier in Thai and Burmese is affix-like, triggering the noun's adjunction to the classifier, because the canonical order is N-Num-Cl in Thai and Burmese, and the non-classified nouns appear in the regular position of classifiers, as in:

(i) a. *soong pii*
two year
'two years'

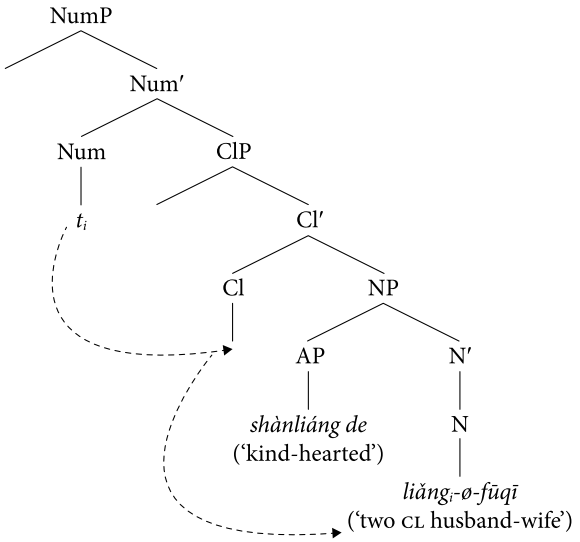
b. **pii soong*
year two
Intended: 'two years'

As for Mandarin non-classified nouns, considering the Num-Cl-N canonical order, there is no direct evidence that the noun moves into Cl^0, and if the non-classified noun in Mandarin moves to Cl^0, the adnominal modifiers will be left following the noun, as shown in (ii). To derive "MP-Num-N", the N-to-Cl movement has to be followed by movement of MP. Since the raising of MP into DP/FocusP is excluded, only the remnant movement of NP can derive the expected word order, as shown in (iii). However, the remnant movement of NP is ad hoc, and no motivation is provided. So, N-to-Cl movement will not be a plausible explanation for Mandarin non-classified nouns.

(ii) $[_{NumP}$ Num $[_{ClP}$ N_i+ø $[_{NP}$ [MP] $t_i]]]$

(iii) $[_{DP}$ $[_{NumP}$ $[_{NP}$ [MP] $t_i]_j$ Num $[_{ClP}$ N_i+ø $[t_j]]]]$

(30)



According to the derivation above, Prediction 1 will be excluded, while Prediction 2 will be confirmed. Specifically, when the classifier is not present (phonologically null), the lowering of the numeral takes place as well and it even lowers further to N^0. This means that the numeral lowers not to meet a requirement on the linear relation between numerals and classifiers, but to make the numeral adjacent to another overt syntactic head c-commanded by it. In the regular [Num [Cl [N]]] structure, the classifier is the first overt syntactic head c-commanded by the numeral, so the numeral just lowers to Cl^0. In [Num [ø [N]]], the classifier has no phonological form, here the numeral needs to cyclically lower to N^0. Thus, the motivation for a numeral lowering to Cl^0 or to N^0 can only be characterized as the numeral's morphological dependency.

3.2 The prosodic reason for a numeral's morphological dependency

This subsection will provide a further explanation to the morphological dependency of numerals from a diachronic perspective. Since numerals (except for *yī* 'one') consistently express lexical meaning, their morphological dependency cannot possibly be the result of a semantic grammaticalization. However, it could be that the development of disyllabification in Chinese and the influence upon the Num-Cl sequence is the cause of the morphological dependency of numerals. Specifically, during the process of disyllabification, in which Chinese developed from a primarily monosyllabic language into a primarily disyllabic language, monosyllabic simplex numerals presented prosodic deficiency; and since Num-

Cl is frequently used as a prosodic unit, the compounding of Num-Cl occurred, weakening the numeral's morphological independence.

The hypothesis of monosyllabic numerals' prosodic deficiency under disyllabification can be indirectly evidenced by the diachronic relation between classifiers and the tendency towards disyllabification.

According to Li & Zhang (2016), the development of disyllabification tendency in Chinese and that of Chinese classifiers was synchronic. In the Shang Dynasty (1300–1046 BC), disyllabic morphemes were in an early stage, while classifiers started to appear in "N-Num-Cl" as self-classifiers, such as "羌百羌 *qiāng bǎi qiāng* ('a hundred Qiang people')". During the Spring and Autumn Period, the Warring States Period (779–221 BC), and the Qin Dynasty (221–207 BC) the proportion of disyllabic words in literature increased, and the system of nominal classifiers was basically established, with an inventory of classifiers numbering over 200, and the Num-Cl-N sequence appeared, as in "一匹雛 *yì pǐ chú* ('a little duck')". Since the Weijin Period (220–420 AD), disyllabic words have dominated the Chinese lexicon, and the nominal classifier entered a mature stage in many respects, such as quantity, categories, and word orders. The synchronic development of disyllabification and Chinese classifiers is argued to be evidence that the prosodic deficiency of Chinese simplex numerals is an important motivation for the appearance and development of Chinese classifiers (Shi 2006: 196; Li & Zhang 2016).

The other aspect in which the disyllabification affects Chinese numerals is that disyllabification promotes the compounding of "Num-Cl", in which the numeral's dependency is established.

The disyllabification in Chinese has two prominent diachronic effects on elements that frequently form a disyllabic prosodic unit: one is to turn the less-substituted word into a functional element, usually into a clitic with grammaticalized function and reduced pronunciation, and the other is to turn two lexical words into a compound (Wu 2003). And due to the complicated properties and relation of numerals and classifiers, these two types of effects can be seen in the Num-Cl sequence.

On the one hand, classifiers were indeed grammaticalized from nouns (Li 2000; Wang 2004: 279), but they are unlikely to have completely turned into clitics, because: (a) many of them still keep some semantic meaning; for instance, *tiáo* is used as an individual classifier for something long and thin, because the original meaning of *tiáo* was long and thin branches; and (b) the classifier in Chinese is actually a half-open word class, since container nouns can usually be used as container classifiers, as in 一瓶水 *yì píng shuǐ* 'a bottle of water', and even verbs or adjectives are allowed to be used as temporal classifiers in specific situations, for example, 一彎彩虹 *yì wān cǎihóng* 'a rainbow (lit. one bend rainbow)'.

On the other hand, over the course of compounding triggered by disyllabification, the lexical boundary between numerals and classifiers gradually blurred. It is probably debatable why it was the numeral — rather than the classifier or both of them — that became morphologically dependent when their lexical boundary disappeared. I shall suggest that it was due to an imbalance in the number of numerals and classifiers. The number of frequently used classifiers far surpasses that of frequently used simplex numerals, i.e. the numbers 1–10. This means that within the prosodic frame of Num-Cl, the simplex numerals show a higher frequency than classifiers, and the simplex numerals' morphological independency is weakened more severely than that of the classifiers.

In short, under the strong tendency towards disyllabification, the prosodic deficiency of simplex numerals has turned into a morphological dependency, along with the establishment of a classifier system and the compounding of "Num-Cl".

4. Issues with complex numerals

As argued in §3.2, the morphological dependency of simplex/monosyllabic numerals is related to their prosodic deficiency, and the numerals used as examples in previous sections are all simplex. To prove a relationship between numerals and classifiers and numerals' morphological movement, complex numerals must be taken into consideration, which can be di- or even multi-syllabic. There are two important questions regarding complex numerals: What happens to the simplex numerals inside a complex numeral, and do complex numerals undergo morphological movement? In §4.1, I shall follow Ionin & Matushansky's (2006) proposal of an inner syntactic relation of complex numerals and argue that simplex numerals that form complex numerals also undergo lowering and that complex numerals as a whole undergo morphological movement as well. In §4.2, I shall diverge a bit to argue against the opinion that Ionin & Matushansky's (2006) proposal cannot be applied to Chinese complex numerals, by solving the problems proposed by He (2015) and Her & Tsai (2020).

4.1 The morphological movement of numerals inside complex numerals, and exceptions

The Chinese numeral system follows the pattern [(n × base) + m, where m < base] (Comrie 2013; Her & Tsai 2020), containing multiplication and addition. Generally, the bigger additive appears to the left of the smaller one, as in (31); the multi-

plier occurs right before the multiplicand, as in (32); and a complex numeral can contain both multiplication and addition, as in (33).

(31) *shí wǔ*
ten five
'fifteen' (10+5)

(32) *wǔ shí/ bǎi/ qiān/ wàn*
five ten hundred thousand ten thousand
'fifty/five hundred/five thousand/fifty thousand' (5×10/100/1,000/10,000)

(33) *wǔ bǎi sān shí*
five hundred three ten
'five hundred thirty' (5×100+3×10)

Since the morphological movement serves to rescue the simplex numeral's morphological dependency caused by prosodic deficiency, one may expect that complex numerals, which are di- or multi-syllabic, need not be adjoined to another overt syntactic head. The facts observed are contrary to this expectation. The morphological property of complex numerals can be observed through their relation with non-classified nouns.[8] Complex numerals show complicated distributions with non-classified nouns. I shall describe and analyze multiplicative complex numerals and additive ones respectively.

4.1.1 Multiplicative complex numerals

As for multiplicative complex numerals, the base numerals affect the relation between complex numerals and non-classified nouns. If the base numerals are *shí/bǎi/qiān* 'ten/hundred/thousand', the complex numeral cannot be separated

8. PNAC is not a good tool to observe complex numerals, because when the numeral is over 10, the classifier is not likely to be modified by either pre-classifier adjectives or PNACs for some pragmatic reason; for example:

(i) a. ?*shí-èr dà píng shuǐ*
twelve big bottle water
b. ?*hěn dà de shí-èr píng shuǐ*
very big PRT twelve bottle water
'twelve (very) big bottles of water'

from the non-classified noun by an adnominal modifier,[9] as shown in (34), similar to a simplex numeral shown in (35).

(34) a. *shīyè de wǔ shí/ bǎi/ qiān rén*
unemployed PRT five ten hundred thousand person
'50/500/5,000 unemployed people'
b. **wǔ shí/ bǎi/ qiān shīyè de rén*
five ten hundred thousand unemployed PRT people
Intended: '50/500/5,000 unemployed people'

(35) a. *shīyè de wǔ rén*
unemployed PRT five person
'5 unemployed people'
b. **wǔ shīyè de rén*
five unemployed PRT person
Intended: '5 unemployed people'

As argued in § 3, the obligatory adjacency of simplex numerals and non-classified nouns is due to the numeral lowering to N^0. Those complex numerals obligatorily adjacent to non-classified nouns must have undergone lowering to N^0 as well. However, the lowering is a head-to-head movement in nature, and it is unlikely that a complex numeral projects as a head. So, in order to explain the morphological movement of complex numerals in detail, we have first to discuss the syntax relation inside a complex numeral.

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9. If the base numerals are *wàn/yì* '10 thousand/100 billion' or bases denoting larger amounts, the complex numerals can be separated from the non-classified nouns with an adnominal modifier, as shown in (i).

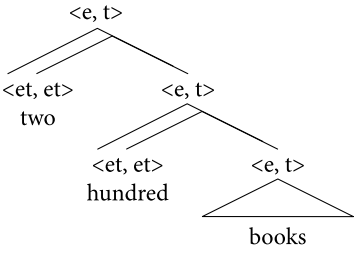
(i) a. *shīyè de wǔ wàn rén*
unemployed PRT five ten-thousand person
'50,000 unemployed people'
b. *wǔ wàn shīyè de rén*
five ten-thousand unemployed PRT person
'50,000 unemployed people'

This is because such big digit numbers as *yì/wàn* can also function as classifiers. *Yì/wàn* can be used directly before a classified noun without a classifier, while *shí/bǎi/qiān* cannot, as shown in (ii).

(ii) a. *sān shí/ bǎi/ qiān *(ge) értóng*
three ten hundred thousand CL child
'30/300/3,000 children'
b. *sān wàn/ yì (ge) értóng*
three ten-thousand hundred-million CL child
'30,000/300,000,000 children'

According to Ionin & Matushansky (2006), the multiplier and the multiplicand are in a head-complement structure, rather than forming a constituent, as shown in (36).

(36)



It has been widely observed that the multiplier-multiplicand relation in complex numerals and the Num-Cl relation are parallel. So the head-complement relation of multiplier-multiplicand proposed by Ionin & Matushansky (2006) happens to align with the syntactic relation of "Num-Cl" adopted in this paper, which can well capture the parallelism between multiplier-multiplicand and "Num-Cl", which has been observed by Au Yeung (2005; 2007), Her (2012), and Li (2014). Thus shall I apply Ionin & Matushansky's (2006) approach to Chinese complex numerals.[10]

Since the multiplier and the multiplicand are in a head-complement relation, this makes it possible for the simplex numeral to undergo morphological movement to be adjoined to the base numeral. The obligatory adjacency of a complex numeral and a non-classified noun demonstrates that not only the simplex numeral lowers to adjoin to the base numeral in a complex numeral, but the complex numeral they form will also lower to adjoin to the non-classified noun. As shown in (37), the multiplier *wǔ* 'five' lowers and is adjoined to the base numeral *bǎi* 'hundred'; then the complex numeral *wǔ-bǎi* 'five hundred' lowers further to Cl^0 and subsequently to N^0.[11] In this way, the adnominal modifier *shīyè*

10. He (2015) and Her & Tsai (2020) disagree with the application of Ionin & Matushansky's (2006) approach to Chinese complex numerals. I shall temporally put aside the problems proposed by them, and in §4.2 I shall return to these problems and solve them.

11. Another supporting evidence for complex numerals' lowering comes from PNACs. Compared to the pragmatic infelicity of PNACs before complex numerals, phrasal adjectives inserted between complex numerals and classifiers are much worse, namely, totally ungrammatical (see (i)).

de 'unemployed' does not move in the syntax, but appears in a pre-numeral position in the surface structure.

(37) *shīyè de wǔ bǎi rén*
unemployed PRT five hundred person
'500 unemployed people'
a. [$_{\text{NumP}}$ *wǔ* [$_{\text{numP}}$[12] *bǎi* [$_{\text{ClP}}$ ø [$_{\text{NP}}$ [$_{\text{MP}}$ *shīyè de*] [$_{\text{N}}$ *rén*]]]]]
b. [$_{\text{NumP}}$ [$_{\text{numP}}$ *wǔ-bǎi* [$_{\text{ClP}}$ ø [$_{\text{NP}}$ [$_{\text{MP}}$ *shīyè de*] [$_{\text{N}}$ *rén*]]]]]
c. [$_{\text{NumP}}$ [$_{\text{numP}}$ [$_{\text{ClP}}$ *wǔ-bǎi-ø* [$_{\text{NP}}$ [$_{\text{MP}}$ *shīyè de*] [$_{\text{N}}$ *rén*]]]]]
d. [$_{\text{NumP}}$ [$_{\text{numP}}$ [$_{\text{ClP}}$ [$_{\text{NP}}$ [$_{\text{MP}}$ *shīyè de*] [$_{\text{N}}$ *wǔ-bǎi-ø-rén*]]]]]

4.1.2 Additive complex numerals

Now I shall turn to additive complex numerals. If an additive complex numeral contains at least one conjunct indicating a number below 10,000, it has to be adjacent to the non-classified noun, as shown in (38).[13]

(38) a. *shīyè de shí wǔ rén*
unemployed PRT ten five person
'15 unemployed people'

(i) a. ? *hěn dà de èr-shí xiāng shū*
very big PRT two-ten box book
b. * *èr-shí hěn dà de xiāng shū*
two-ten very big PRT box book
Intended: 'twenty very big boxes of books'

Based on these empirical data showing the similarities between simplex numerals and complex numerals, I preliminarily assume that this is due to the overgeneration of numeral lowering from monosyllabic simplex numerals to di- or multi-syllabic complex numerals. However, further study of this question will have to be left to the future.

12. NumP is the highest projection in a complex numeral, while numP is an intermediate layer in a complex numeral.

13. If all conjuncts indicate numbers higher than 10,000, the complex numeral can be separated from the non-classified noun, as in (i). This is also because the base numeral can function as either a classifier or a numeral.

(i) a. *shīyè de wǔ yì líng wǔ bǎi wàn rén*
unemployed PRT five hundred-million zero five hundred ten-hundred person
'505,000,000 unemployed people'
b. *wǔ yì líng wǔ bǎi wàn shīyè de rén*
five hundred-million zero five hundred ten-hundred unemployed PRT person
'505,000,000 unemployed people'

b. **shí wǔ shīyè de rén*
ten five unemployed PRT person
Intended: '15 unemployed people'

Following Ionin & Matushansky (2006), the additive complex numerals are derived from conjuncts and PF deletion of NP in the first conjunct or right node-raising, as shown in (39) and (40). As for Chinese, since morphological merger takes place between numerals and classifiers, PF deletion, as in (41), is the preferred choice.

(39) [*two hundred* ~~*books*~~] (*and*) [*twenty books*]

(40) [*two hundred* ~~*books*~~] (*and*) [*twenty* ~~*books*~~] [books]

(41) [*èr-shí-*~~*ge*~~ ~~*rén*~~] (CONJ) [*wǔ-ge rén*]
two-ten-CL person five-CL person
'twenty-five people'

Generally, in each conjunct, the simplex numeral or multiplicative complex numeral will undergo lowering. When there is a pre-numeral modifier, the modifier needs to undergo left-node raising before PF deletion, as shown in (42).

(42) *shīyè de èr shí wǔ rén*
unemployed PRT two ten five person
'25 unemployed person'

a. [$_{\text{NumP}}$ *èr* [$_{\text{numP}}$ *shí* [$_{\text{ClP}}$ ø [$_{\text{NP}}$[$_{\text{MP}}$ *shīyè de*] [$_{\text{N}}$ *rén*]]]]] (CONJ) [$_{\text{NumP}}$ *wǔ* [$_{\text{ClP}}$ ø [$_{\text{NP}}$[$_{\text{MP}}$ *shīyè de*] [$_{\text{N}}$ *rén*]]]]

b. [$_{\text{NumP}}$ [$_{\text{numP}}$ [$_{\text{ClP}}$ [$_{\text{NP}}$[$_{\text{MP}}$ *shīyè de*] [$_{\text{N}}$ *èr-shí-ø-rén*]]]]] (CONJ) [$_{\text{NumP}}$ [$_{\text{ClP}}$ [$_{\text{NP}}$[$_{\text{MP}}$ *shīyè de*] [$_{\text{N}}$ *wǔ-ø-rén*]]]]

c. [*shīyè de*] [[$_{\text{NumP}}$ [$_{\text{numP}}$[$_{\text{ClP}}$[$_{\text{NP}}$[$_{\text{MP}}$ ~~*shīyè de*~~] [$_{\text{N}}$ *èr-shí-ø-rén*]]]]] (CONJ) [$_{\text{NumP}}$ [$_{\text{ClP}}$ [$_{\text{NP}}$[$_{\text{MP}}$ ~~*shīyè de*~~] [$_{\text{N}}$ *wǔ-ø-rén*]]]]]

d. [*shīyè de*] [[$_{\text{NumP}}$ [$_{\text{numP}}$ [$_{\text{ClP}}$ [$_{\text{NP}}$ [$_{\text{N}}$ *èr-shí-ø-*~~*rén*~~]]]]] (CONJ) [$_{\text{NumP}}$ [$_{\text{ClP}}$ [$_{\text{NP}}$ [$_{\text{N}}$ *wǔ-ø-rén*]]]]]

In sum, Chinese complex numerals also undergo morphological movement. In a multiplicative complex numeral, the multiplier and the multiplicand are in a head-complement syntactic relation, paralleling the Num-Cl relation. In a full noun phrase, the multiplier will pick up the multiplicand, and then they will adjoin to the classifier or the non-classified noun together. As for additive complex numerals, since they are derived from conjuncts and PF deletion, they are also adjoined to a classifier or a non-classified noun.

4.2 The applicability of Ionin & Matushansky's (2006) approach to Chinese

With Ionin & Matushansky's (2006) non-constituent analysis, the observed facts about the morphological movement of complex numerals are well explained. However, He (2015) brings up several pieces of evidence for the contention that Ionin & Matushansky's (2006) non-constituent analysis is not suitable for Chinese complex numerals, and Her & Tsai (2020) also argue for this contention by arguing that Li's (2014) explanation for "Num-Cl-*duō*-NP" with the non-constituent approach is problematic. Since the non-constituent analysis is the main tool for explaining the distribution of Chinese complex numerals and the "Num-Cl-*duō/bàn*-NP" sequence is also often used as evidence against the right-branching analysis of "Num-Cl-NP", which is the foundation of my proposal of numeral lowering. So, in this subsection I shall argue that "Num-Cl-*duō/bàn*-NP" can be properly explained based on right-branching analysis and Ionin & Matushansky's (2006) approach and that the evidence proposed by He (2015) is also invalid.

4.2.1 New analysis for *duō/bàn*

In Chinese, *duō* 'more' and *bàn* 'half' can be inserted between Cl and N, as shown in (43)–(44). In addition, *duō* can also follow the base of a multiplicative complex numeral, indicating an approximate number smaller than the base numeral preceding it, as in (45).

(43) *yì píng duō píjiǔ*
one bottle more beer
'more than one bottle of beer (fewer than two bottles of beer)'

(44) *yí ge bàn píngguǒ*
one CL half apple
'one and a half apples'

(45) *sān shí duō ge píngguǒ*
three ten more CL apple
'thirty-some apples'

As for the derivation of *duō/bàn*, Her (2012), Li (2014), and Her & Tsai (2020) propose that "Num-Cl-*duō/bàn*-NP" is derived by the conjunction and PF deletion or right-node raising, but they have a debate on the syntactic relation of the multiplier-multiplicand and "Num-Cl-NP". Li (2014) opts for the right-branching analysis of "Num-Cl-NP", so the conjuncts include NP, as in (46) and (47). In contrast, Her (2012), Her & Tsai (2020) argue for the left-branching analysis, so the conjuncts do not include NP, as in (48).

(46) [*shí mǐ* ~~*bù*~~] ~~(*yòu*)~~ [*bàn* ~~*mǐ*~~ *bù*]
ten meter cloth and half meter cloth
'a 10.5-meter cloth'

(47) [*shí mǐ* ~~*bù*~~] ~~(*yòu*)~~ [*duō* ~~(*yìdiǎr*)~~ *bù*]
ten meter cloth and more slightly cloth
'a cloth of more than 10 meters, but less than 11'

(48) [[*shí mǐ*] (CONJ) [*bàn/duō* ~~*mǐ*~~]] [*bù*]
ten meter half/more meter cloth
'a 10.5-meter cloth'/'a cloth of more than 10 meters, but less than 11'

However, both analyses have some problems. According to Her & Tsai (2020), the problem with Li's (2014) analysis is that assuming a covert element *yìdiǎr* 'slightly' following *duō* is unreasonable, because *yìdiǎr* is semantically substantive and its presence or absence will result in a semantic difference. In the analysis of Her (2012) and of Her & Tsai (2020), the problem is that the underlying conjunct in which *duō* preceding a classifier will result in the wrong interpretation. *Duō* preceding a classifier should be interpreted as 'several', as in (49); in contrast *duō* following a classifier or a measure word indicates a fraction below the value of 1, so the post-Cl *duō* will not be derived from a pre-Cl *duō*. As in (48), if the underlying conjuncts are *shí mǐ* and *duō mǐ*, the number value of this conjunction will be 10+Y (Y>1), which is not the correct interpretation.

(49) *duō* *ge* *yuè*
several CL month
'several months'

I agree with the idea that *duō/bàn* and the element preceding them form one of the conjuncts, but I propose a different way of deriving *duō/bàn* within the conjuncts. I propose that *-bàn* and *-duō* are also morphologically dependent when indicating 0.5 and a fraction Y (0<Y<1), and that they are base-generated in the same position as a usual simplex numeral, which is a head c-commanding the classifier or the base numeral; then *-duō/bàn* undergoes lowering in PF and becomes right-adjoined[14] to the classifier and the base numeral.

Semantically, in "X-Cl-*duō/bàn*-N", *-bàn* indicates the fraction 0.5; and *-duō* denotes a faction Y (0<Y<1), which is distinguished from *duō* preceding the classifier. The total quantity of "X-Cl-*duō/bàn*-N" is X+0.5 or X+Y (0<Y<1). As in (50), the total number is *sān* 'three' plus *-bàn* 'half', which results in 3+0.5 = 3.5. In (51), the total number is *liǎng* 'two' plus *-duō* 'more', which results in 2+Y (0<Y<1).

14. The difference that *-duō/bàn* is right-adjoined while simplex numerals are left-adjoined, is lexically determined.

Similarly, in a complex numeral "X-B(ase) N(umeral)-*duō*", *-duō* following a base numeral can also be interpreted as a fraction Y (0<Y<1), and the value of "X-BN-*duō*" is X×BN+Y×BN (where 0<Y<1), as in (52).

(50) *sān ge bàn yuè*
three CL half month
'three and a half months'

(51) *liǎng píng duō píjiǔ* (2×bottles + Y×bottles, where 0<Y<1)
two bottle more beer
'more than two bottles of beer but less than three'

(52) *sān qiān duō ge rén* (3×1,000 + Y×1,000, where 0<Y<1)
three thousand more CL person
'more than 3,000 people (but fewer than 4,000)'

Syntactically, "X-Cl-*duō/bàn*-N" or "X-BN-*duō*" contains at least two conjuncts, one of which is "X-Cl" or "X-BN", while the other is "Cl-*duō/bàn*" or "BN-*duō*". In the latter conjunct, *-duō/bàn* denoting a fraction is base-generated in Num^0, similarly to simplex numerals, and due to the morphological dependency, they undergo lowering as well and are right-adjoined to Cl or BN in PF. With the combination of two conjuncts, some elements in the first conjunct will be deleted in PF, just like a normal additive complex numeral. The derivation of "X-Cl-*duō/bàn*-N" or "X-BN-*duō*" will be as (53) and (54) respectively.

(53) *sān ge bàn/ duō yuè*
three CL half more month
'three and a half months'/'more than three months but less than four'
a. [$_{NumP}$ *sān* [$_{ClP}$ *ge* [$_{NP}$ *yuè*]]] (CONJ) [$_{NumP}$ *-bàn/duō* [$_{ClP}$ *ge* [$_{NP}$ *yuè*]]] (base-generation)
b. [$_{NumP}$ [$_{ClP}$ *sān-ge* [$_{NP}$ *yuè*]]] (CONJ) [$_{NumP}$ [$_{ClP}$ *ge-bàn/duō* [$_{NP}$ *yuè*]]] (numeral lowering)
c. [$_{NumP}$ [$_{ClP}$ *sān-~~ge~~* [$_{NP}$ *~~yuè~~*]]] (CONJ) [$_{NumP}$ [$_{ClP}$ *ge-bàn/duō* [$_{NP}$ *yuè*]]] (PF deletion)

(54) *sān qiān duō ge rén*
three thousand more CL person
'more than 3,000 people (fewer than 4,000 people)'
a. [$_{NumP}$ *sān* [$_{numP}$ *qiān* [$_{ClP}$ *ge* [$_{NP}$ *rén*]]]] (CONJ) [$_{NumP}$ *-duō* [$_{numP}$ *qiān* [$_{ClP}$ *ge* [$_{NP}$ *rén*]]]] (base-generation)
b. [$_{NumP}$ [$_{numP}$ *sān-qiān* [$_{ClP}$ *ge* [$_{NP}$ *rén*]]]] (CONJ) [$_{NumP}$ [$_{numP}$ *qiān-duō* [$_{ClP}$ *ge* [$_{NP}$ *rén*]]]] (numeral lowering)
c. [$_{NumP}$ [$_{numP}$ *sān-~~qiān~~* [$_{ClP}$ *~~ge~~* [$_{NP}$ *~~rén~~*]]]] (CONJ) [$_{NumP}$ [$_{numP}$ *qiān-duō* [$_{ClP}$ *ge* [$_{NP}$ *rén*]]]] (PF deletion)

In this analysis, I propose that *-duō/bàn* are morphologically dependent when denoting fractions, that they are base-generated in Num^0 or the position of a multiplier, and that they then undergo lowering and are morphologically merged with a classifier or a base numeral. This analysis can account for *-duō/bàn* in different positions, that is, post-BN or post-Cl, in a unified approach, and accurately predict their mathematical interpretation. In addition, this analysis of *-duō/bàn* demonstrates that Ionin & Matushansky's (2006) approach can be extended to Chinese and capture the alignment of Num-Cl and multiplier-multiplicand in combination with the right-branching analysis of "Num-Cl-NP".

4.2.2 Against He's (2015) several pieces of evidence

He (2015) brings up seven minor pieces of evidence in syntatic, semantic and morpho-phonological perspectives for the idea that Ionin & Matushansky's (2006) non constituent approach cannot be applied to Chinese complex numerals. I re-categorize these seven minor arguments into four major ones and I shall now argue against this evidence item by item.

He's first piece of evidence is that the non-constituent approach cannot correctly predict the interpretation of the Chinese approximant numeral *lái*, which denotes a small portion (generally within the range of ±10%) of the quantity denoted by the base numeral preceding it, exemplified in (55).

(55) *yì bǎi lái ge xuéshēng*
one hundred PRT CL student
'around100 students (i.e., 90–110)'

In fact, with the non-constituent approach, *lái* can be explained in a way similar to *-duō/bàn*. Specifically, *-lái* is also morphological dependent when denoting an approximant numeral ranging from −10% to +10%. So, the full derivation of a noun phrase containing *lái* should be as in (56).

(56) *yì bǎi lái ge xuéshēng*
one hundred PRT CL student
'around100 students (i.e., 90–110)'
a. [*yì bǎi ge xuéshēng*] (CONJ) [*-lái bǎi ge xuéshēng*] (base-generation)
b. [*yì-bǎi ge xuéshēng*] (CONJ) [*bǎi-lái ge xuéshēng*] (numeral lowering)
c. [*yì-bǎi-ge xuéshēng*] (CONJ) [*bǎi-lái-ge xuéshēng*] (numeral lowering)
d. [*yì-~~bǎi-ge xuéshēng~~*] (CONJ) [*bǎi-lái-ge xuéshēng*] (PF deletion)

He's (2015) second piece of evidence is that the non-constituent approach will over-generate some ungrammatical phrases, shown as (57)–(59), and also incorrectly predict that no numeral phrases can be used in arithmetic sentences, shown in (60).

(57) **yí wàn bǎi ge xuéshēng*
one ten-thousand hundred CL student
Intended: '1 million (10,000×100) students'

(58) **sān sì bǎi ge xuéshēng*
three four hundred CL student
Intended: '1,200 (3×4×100) students'

(59) **sān shí ge xuéshēng*
three ten CL student
Intended: '13 (3+10) students'

(60) *sān shì jīshù.*
three COP odd-number
'Three is an odd number.'

As for the over-generation problem, Ionin & Matushansky (2006) have suggested that it can be excluded by extra-linguistic conventions. Specifically, to avoid (57)–(59) in Mandarin, the conventions will be: (a) the multiplier of a base is smaller than the base; (b) the multipliers of the small base numerals, namely, *shí, bǎi, qiān*, will not be bigger than 10; and in a multiplicative numeral, there is at most one non-base numeral; (c) in an additive complex numeral, a conjunct is always bigger than the ones to its right.

As for the numerals in arithmetic sentences, they are actually different items from numerals denoting quantities. Bylinina & Nouwen (2020) argue that numerals denoting mathematical entities are of type *d*(egree), which is similar to type *e*, except that their domain is ordered; while numerals simply expressing quantities are of type <e, t>. So arithmetic numerals do not necessarily have the same syntactic and morphological properties as the ones used as quantifiers.

The third bit of evidence brought up by He is that the non-constituent analysis will encounter a semantic problem with a conjoined NP. As shown in (61) and its underlying structure in (62). He (2015) suggests that each conjunct minimally requires one man and one woman, so the well-formed reading of this conjunction would require two men and two women, which is contrary to the fact that the phrase only requires at least one man and one woman.

(61) *shí wǔ ge nánrén hé nǚrén*
ten five CL man and woman
'fifty men and women'

(62) [*shí ge nánrén hé nǚrén*] (CONJ) [*wǔ ge nánrén hé nǚrén*]

However, while it is true that each conjunct minimally requires one man and one woman, this requirement is essentially a presupposed proposal rather than a

numerical value. Logically, A ∩ A =A, so the intersection of the two same proposals will still be that there is at least one man and one woman. This semantic problem that He (2015) is concerned with is thus solved.

The fourth piece of evidence presented by He concerns some morpho-phonological phenomena of Mandarin numerals, such as the tone sandhi of the numeral *yī* 'one', *èr* 'two' and *liǎng* 'two' alternation, and *liǎ* 'two-CL' and *sā* 'three-CL' reduction.

Specifically, *yī* only stays in its citation tone T1 (*yī*) when it is the single digit number of an additive numeral or the multiplier of the base numeral *shí* 'ten', as shown in (63)–(64). In other cases, *yī* 'one' will undergo tone sandhi, with the tone changing to T2 (*yí*) or T4 (*yì*).

(63) *èr shí yī ge rén*
two ten one CL person
'21 people'

(64) *yī shí sān ge rén*
one ten three CL person
'13 people'

The problem proposed by He is that in the non-constituent analysis, when *yī* is the single digit number of an additive numeral, the use of *yī* in its citation tone, as in (65), will be problematic, because in the underlying structure, *yī* alone precedes a classifier, in which case the tone sandhi will take place, as in (66).

(65) *shí yī zhāng zhǐ*
ten one CL paper
'eleven papers'

(66) [*shí zhāng zhǐ*] (CONJ) [*yì zhāng zhǐ*]
ten CL paper one CL paper

According to Halle & Marantz (1993), Embick & Noyer (2001; 2007), the post-syntactic operations can be divided into at least two stages by Vocabulary Insertion and Linearization. Since PF deletion often takes place in conjunction structures, and PF deletion can rescue some island violations (Bošković 2011; 2020), this operation must have been in the earlier stage prior to Vocabulary Insertion and Linearization. However, the tone sandhi as a phonological process must take place at the last stage before a phonological form is output, which is after PF deletion. So, the proposed problem with the tone sandhi of the numeral *yī* 'one' is entirely non-existent.

Similarly, the problem of *liǎng* and *èr, liǎ* and *sā*, can be cancelled as well when the timing of operations are taken into consideration. *Èr* and *liǎng*, as allomorphs

meaning 'two', are competitors during Vocabulary Insertion. *Liǎ* and *sā* are the reduction of "*liǎng*-CL" and "*sān*-CL" respectively, which is an optional phonological operation after Vocabulary Insertion and Linearization. So, both of them take place after the PF deletion in complex numerals.

To sum up, the four problems that He (2015) proposes to be arguments against the applicability of Ionin & Matushansky's (2006) non-constituent approach to Chinese complex numerals can be solved or cancelled. Instead, Ionin & Matushansky's (2006) approach provides an explanation to many phenomena about Chinese complex numerals. Especially, the approximant numerals *-lái* can be unified with *-duō/bàn* in one approach, in which the semantic relation between them and the elements preceding them can be interpreted.

5. Conclusion

This paper argues that the syntactic mechanism underlying Num-Cl adjacency is: numerals undergo morphological movement to Cl^0 in PF. This morphological movement can provide a good answer as to why Num-Cl form a prosodic unit even though they do not form a syntactic constituent, and why the slot between numerals and classifiers can only accommodate zero-level adjectives but not phrasal adjectives. A simplex numeral's morphological movement is motivated by its morphological dependency, which is established under the profound influence of disyllabification in Chinese. Moreover, morphological movement also involves di- or multi-syllabic complex numerals. Following Ionin & Matushansky (2006), the multiplier and the multiplicand are in a head-complement relation, aligned with the Num-Cl relation. In this structure, not only the multiplier lowers to be adjoined to the multiplicand, but the multiplier-multiplicand sequence also lowers further to Cl^0 or N^0, whichever is occupied by the first overt element c-commanded by the numeral. Thus, both simplex numerals and complex numerals should be adjoined to an overt syntactic head.

The analysis for Num-Cl adjacency is mainly based on the right-branching analysis of Num-Cl-NP. Even though the right-branching analysis is not the main topic of this paper, the analysis of PNACs and the analysis of *-duō/bàn* could serve as supporting evidence for it. By combining the right-branching analysis and the proposal of numerals' morphological movement, several problems about numeral noun phrases can be solved.

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List of abbreviations

AP	Adjective Phrase
ASP	aspectual marker
BN	Base Numeral
CL	classifier
ClP	Classifier Phrase
CONJ	conjunction
COP	copula
DP	Determiner Phrase
FocusP	Focus Phrase
MP	Modification Phrase
N	Noun
NP	Noun Phrase
NUM	numeral
NumP	Numeral Phrase
PF	Phonetic Form
PNAC	Pre-Numeral Adjective for Classifiers
PRT	particle
SpecificP	Specificity Phrase
UnitP	Unit Phrase

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