Mandarin neutral tones as unstressed tones

Grammaticalization, stress, and tone sandhi

Abstract

The paper delves into the morpho-phonological operations of Mandarin Neutral Tones (NTs), investigating their status and correlations with grammaticalization, stress, and tone sandhi. I propose a unified account, considering the interfaces between phonetics, phonology, morphology, and syntax. Specifically, I challenge the traditional toneless view of Mandarin NTs and argue that NTs are not something special but can be analyzed as unstressed mono-moraic tones. Mandarin NTs are classified into three types, based on their morpho-syntactic distributions and tonal operations. Type 1 NTs are underlyingly Lr, L, including affixes and reduplication. Type 2 NTs are clitics as grammatical markers, with high-low tone distinction. Type 3 NTs are de-stressed with L-insertion and involve morphologically reduced words, most of which are function words and compounds. NTs are intimately associated with degrees of grammaticalization. Furthermore, I highlight the asymmetric nature of the phonological processes, with Type 3 processed later than Types 1 and 2. The analysis contributes to the potential existence of grammatical tones (GTs) and the unification of Mandarin T3 sandhi and NT-sandhi, where both are the low-tone sandhi triggered by the Obligatory Contour Principle (OCP). Overall, the paper offers a novel perspective on Mandarin NTs and addresses the puzzling status of NTs, along with their interaction with several phonological issues in Chinese languages.

Keywords

Neutral tone (NT), unstressed tone, grammatical tone (GT), grammaticalization, stress, tone sandhi

1. Introduction

In Chinese languages, neutral tone (NT) is commonly considered to be the byproduct of syllable weakness.[1] In Mandarin, NTs are usually mono-moraic and unstressed, with their tones perceptually light and short. Debates have long stood for their tonal status. Previous discussions argue that Mandarin NTs are toneless (e.g., Yip 1980; Duanmu 2000, 2007, 2014), highly depending on the preceding syllable (e.g., Chao 1948, 1968; Dong 1958; Lin 1962, 1985; Lee and Zee 2008), while growing pieces of phonetic evidence manifest the existence of tonal targets in NTs (e.g., Chen and Xu 2006; Li and Li 2022). In this study, I argue that NTs are unstressed mono-moraic tones (cf. Rolle 2018; Sande 2022), which are underlyingly toned or de-stressed with L-insertion for morpho-syntactic considerations.

Specially, three types of NTs are identified in the paper, based on the tonal operations and morpho-syntactic distributions. Type 1 NTs are underlyingly Lr, L, including affixes and reduplication. Type 2 NTs are clitics as grammatical markers, with high-low tone distinction within low tone register. Type 3 NTs are de-stressed with L-insertion and involve morphologically reduced words, most of which are function words and compounds. In addition, there is a high-low tone distinction working for semantic differences of sentence-final particles (SFPs), which can further be evidence of Mandarin NTs as grammatical tones (GTs). In general, I challenge the toneless view of Mandarin NTs and propose a unified account to capture the intricate patterns.

The paper is organized as follows: Section 2 sets the scene for the complicated interactions between stress, syllable weight, and tone, with foci on tonal structures and tone sandhi triggered by the Obligatory Contour Principle (OCP). Section 3 introduces the fundamental properties of NTs and reviews previous phonetic and phonological analyses of Mandarin NTs. Section 4 examines the distributions and tonal representations of NTs, with novel considerations from their morpho-syntactic properties. Three types of NTs are identified for the following morpho-phonological analysis. A unified proposal is given in section 5 to analyze the tonal operations of different types of NTs. Some significant notes are highlighted in section 6, with extensive discussions about the interaction between NTs, grammaticalization, tone sandhi, and cross-dialectal variations. Section 7 will give concluding remarks on the general pattern of Mandarin NTs.

2. Stress, Syllable Weight & Tone

Before reviewing previous analyses on Mandarin NTs and proposing a formal analysis, I spare

[1] I originally referred NT to be a consequence of syllable weakening, as previous studies mostly term it so; however, it should be clarified, especially under the present proposal, that some types of NTs are born to be weak; instead of being derived through syllable weakening. Therefore, "syllable weakness" would be a more neutral term to describe the status. I thank an anonymous reviewer who pointed this out.

this section to set up theoretical foundations for NTs. In the paper, I argue that NTs are unstressed tone. To set up the scene, several fundamental questions have to be answered. First of all, does Mandarin have stress, especially word stress? Second, if Mandarin has stress, how is it realized in a word? Third, what is the relation between stress and tone in Mandarin?

To shed light on these puzzles, I will discuss the complicated interactions between phonological weight, and stress. Then, I will discuss how stress is related to tonal association, tonal preservation, and tone sandhi, where a modified version of tonal representations will be proposed in section 2.3, by synthesizing pieces of literature. Lastly, I will go through four stressed tones in Mandarin, the operation of Mandarin T3 sandhi, and some phonological implications of investigating Mandarin NTs.

2.1. Stress in Mandarin

To argue that NTs are unstressed tones, it should be clarified whether Mandarin has stress, especially word stress. Unlike Indo-European languages such as English or Dutch, Chinese languages are not stress-prominent languages, where stress patterns are not as observable as in Indo-European languages. Chao (1968) points out the difficulty of identifying stress in Chinese languages by native speakers. Hyman (1977) even claims that Chinese languages are a group of languages without stress. However, untransparent stress prominence does not entail the absence of stress. Duanmu (1990, 1993, 1997, 1999, 2000, 2007, 2009, 2014) proposes a series of arguments to defend the existence of stress in Chinese. Hsieh (2021) also recognizes the existence of word stress in Chinese via cross-dialectal comparisons. The central debate between two divergent views is attributed to the indistinctiveness of stress in Chinese. Since Chinese languages have tones, the pitch of lexical tones is mixed with pitch prominence, particularly in a short realization, such as a syllable or word. Also, stress may be realized differently across languages (Beckman 1986; Hayes 1995). Stress appears not to show off in a typical manner in Chinese (Hsieh 2021), which is perceptually less distinguishable and makes it harder to identify the existence of stress. Again, this does not entail that there is no stress in Chinese languages.

The standard theory of stress— Metrical Theory (MT) (Liberman 1975; Liberman & Prince 1977; Prince 1980; Halle and Vergnaud 1987; Hayes 1995; Halle 1998) offers a good insight into this debate. Stress is not an absolute concept but a result of comparing weightedness. A well-known rule of stress assignment is the Weight-Stress Principle (WSP) (Prince 1990; Duanmu 2009), which outlines that stress assignments are constrained to heavy syllables.

(1) The Weight-Stress Principle (WSP)

A syllable is stressed iff it is heavy.

Nevertheless, heavy syllables are not stressed all the time (Prokosch 1939), where WSP can be violable (Hayes 1980). Heavy syllables may not be stressed, or not primarily stressed all the time; light syllables can still be stressed in some languages (Prince 1990; Danmu 1993,

1999, 2007, 2014). There does not seem to be a clear definition of stress patterns since stress across languages is assigned differently. WSP appears to be a tendency.

Each phonological unit (e.g., syllable, foot, prosodic word, etc.) will obtain different amounts of metrical force. Essentially, the stress of a syllable may be obtained not only through stress assignment but can be inherently given by its weightedness. Heavy syllables can have inherent stress (Hayes 1980, Halle and Vergnaud 1987, Prince 1990), while light syllables do not. Following this flow, Duanmu (1993) argues that since all the regular syllables in heavy are stressed, they bear inherent stress and are underlyingly toned.[2,3] However, syllables cannot be equally stressed or, in the framework of MT, cannot get the same amount of metrical force, where primary and secondary stress should be distinguished. Stress clash (i.e., two adjacent stresses) should be resolved by removing stress from one of the syllables (i.e., deaccenting). The contrast is not told by lexical items or morphemes themselves but is marked later at the post-lexical level. The difference between lexical and post-lexical stress is shown in (2). More precisely, such stress contrasts are given post-syntactically, since stress has some correspondence to syntactic structures (e.g., modifier-head relation; head-complement relation) (Kiparsky 1975, 1985; Selkirk 1984; van der Hulst 2012, 2014; among others).

(2) Lexical & post-lexical stress

Inherent stress	⇒	lexical level
Primary vs. secondary stress	⇒	post-lexical/post-syntactic

Let us turn back to see Mandarin stress patterns. See Table 1 for Mandarin disyllabic stresses. In Mandarin, disyllabic combinations can be heavy-heavy or heavy-light syllables (Daunmu 1999, 2007, 2014).[4] According to Duanmu (1993), Mandarin heavy syllables are inherently stressed at the lexical level. While both syllables cannot be stressed equivalently, it is necessary to identify which heavy syllable gets primary stress. The ultimate stress pattern may depend on syntactic dependency and information load (Duanmu 2007, 2014).[5] In Mandarin, the stress of heavy-heavy syllables is less distinguishable (Chao 1968; Shi 2004; Wang and Feng 2006; Duanmu 2007, 2014). It usually falls on the second syllable, i.e., 2-1 stress is the most common type (Xu 1982), while 1-2 stress is not something unseen in Mandarin (e.g., *gōng chéng* 'work project') (Duanmu 2007, 2014). In contrast to heavy-heavy syllables,

[2] As a typical Mandarin syllable complies with the CGVX sequence (C: onset consonant; G: prenuclear glide; V: nucleus vowel; X: coda glide or nasal), elements in the Rime are always sonorants; hence, a standard syllable is regarded as bi-moraic (Duanmu 1993, 1999, 2007, 2014).

[3] By contrast, in languages in which syllables just have simple rimes, like Shanghainese, syllables are born to be light and short; the stress contrast is not lexically given but is assigned later by rules at the post-lexical level.

[4] Light-heavy or light-light syllables are not attested in Mandarin.

[5] Duanmu (2007) has a lot of arguments about stress assignment in Mandarin. For example, he proposes that words with more information are spoken with more stress (the Information-Stress Principle). See also Duanmu (2014) and Hsieh (2021) for more discussions. I will leave the discussion of the primary-secondary stress assignment here since it is not the focus of the paper.

the stress contrast in heavy-light syllables is clear, whereas the light syllable is unstressed with NTs (Chao 1968; Wang and Feng 2006; Duanmu 2007, 2014).[6]

Table 1 Disyllabic stress in Mandarin

	Heavy-heavy	**Heavy-light**
Lexical	on heavy syllables	on the heavy syllable
Post-lexical	primary-secondary stress	—
Stress output	1-2 2-1	1-0

Note: 1=primary stress; 2=secondary stress; 0=no stress

Following Duanmu (1993) and considering stress at different levels, I assume that Mandarin heavy syllables are inherently stressed. Regarding heavy-heavy syllables, the distinction between primary and secondary stress is post-lexically/post-syntactically determined. As to heavy-light syllables, since heavy syllables are stressed, the output stress patterns will stick to the inherent stress arrangement at lexical levels, whereas light syllables are unstressed. Only when lexical stress arrangements cannot offer clear distinctions, post-lexical stress assignments will be involved in resolving the stress patterns.

To sum up, Mandarin should have stress (Duanmu 1990, 1993, 1997, 1999, 2000, 2007, 2014; Hsieh 2021), even though it is not as explicit as stress-prominent languages. From a broader perspective, stress is a universal phenomenon existing across languages, while the realization of stress may differ from one language to another (Beckman 1986; Hayes 1995), through divergent phonetic and phonological exponents (van der Hulst 2014).

2.2. Stress & Tone

One aspect of the consequences of stress arrangement is tonal patterns. In tone languages like Mandarin, the relation between stress and tone is crucial. A generalized tendency is that heavy syllables can either carry a tone or attract a tone from neighboring tones (Goldsmith 1984; Hyman 1987; Kenstowicz 1987; Sietsema 1989; Kisseberth and Cassimjee 1992; Duanmu 2007). In Mandarin, heavy syllables have underlying tones, while whether light syllables are toneless or carry a mono-moraic tone remains puzzling. The discussions will be developed in the following sections. This section focuses on the theoretical foundations of stress-tone relations.

Stress and tonal preservations have been discussed in the literature. Tone sandhi is widely found in tone languages. One of the crucial points is which tone to be changed and which one to be preserved. For heavy-light paired syllables, heavy (stressed) syllables tend to preserve

[6] Duanmu (2007, 2014) argues that light syllables do not carry tone (toneless), because NTs are the representation of tonelessness for him. I do not argue for a toneless nature in Mandarin light/unstressed syllables, while I agree that heavy syllables are underlying tones.

their underlying tones. As to heavy-heavy syllables, the preference of tone sandhi differs among languages. This can lead to a typological divergence, (i.e., left-dominance vs. right-dominance) (Yue-Hashimoto 1987; Chan and Ren 1988, Chan 1995; Chen 2000; Zhang 2007). Actually, the directionality of tonal dominance is a coincidence but is intimately related to stress or metrical force.[7] For languages where stress is dominant on the right side of disyllables (i.e., right-handed foot), they are usually right-dominant. Among Chinese languages, Mandarin, Min, and Southern Wu illustrate right-dominance, where the right syllable in disyllabic tone sandhi tends to preserve its underlying tone, while the right syllable undergoes tone sandhi mostly (see Zhang 2007 for more typological differences along with the directionality of dominance in Chinese languages).[8] In right-dominant Chinese languages, Mandarin is particularly well-known for Tone 3 (T3) sandhi. When two T3 syllables come together, the left T3 will undergo tone sandhi, which shows the right side is more dominant and not easy to change.

In short, stress is connected to the preference of tone sandhi and tonal preservation, which offers a good insight into Mandarin tonal patterns. Given the intimate relation between stress, weight, and tone discussed above, the representation of tone is supposed to correspondently reflect the pattern. For the foci of the paper, I will then introduce the basic tonal representations in section 2.3, showing the assumed tonal structures of stressed and unstressed tones as well as the interaction between stress and tone sandhi.

2.3. Tonal representation and association

By adopting Bao (1990, 1999) and Yip (1980, 1989), Chinese tones are comprised of register and contour. On the one hand, the specification of tone registers divides tones into two groups: high-registered (Hr) and low-registered (Lr).[9] On the other hand, tonal contours are realized by pitch points, either High (H) or Low (L), within a specified tone register. In the present paper, I adopt a modified version of the Chinese tonal structure, compared with Bao's system and Yip's system, as illustrated later in Table 2.

Bao's and Yip's systems assume the combination of register (Hr and Lr) and contour features (H and L) consists of a tone, which then is linked to a TBU. A TBU is thus linked with a syllable and it ends up carrying a contour tone or a level tone. Their systems, however, contradict recent literature on the status of TBU, where a TBU is essentially proven to be a mora, instead of a syllable (Woo 1969; Newman 1972; Hyman 1985; McCarthy and Prince 1986; Duanmu 1990; Odden 1995; Chen 2007; Liang and Wee 2022).[10] The idea is compatible

[7] In right-dominant languages, there can also be right-tone sandhi, and vice versa. Therefore, directionality is a tendency resulting from several factors.

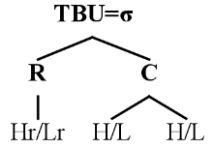
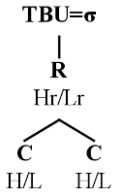
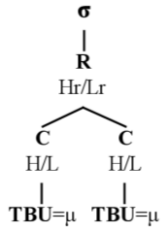
[8] It should be noted that even though left-side tone-sandhi is more dominant in right-dominant languages, it does not mean right-side tone sandhi is totally absent. For example,

[9] In Yip's (1980, 1989) sense, two registers are identified by [+/-upper], where [+upper] and [-upper] respectively correspond to Hr and Lr.

[10] An anonymous reviewer raised concerns about whether it is a universal fact that a mora is equal to a TBU. I also share reservations about the universalized version of mora as TBU across tone languages, while it appears to be clear that a mora-TBU correspondence can be maintained in contour tone languages. If one assumes a syllable,

with the view against Contour Tone Units (Duanmu 1994; see also Chen 2010).[11] In a language with contour tones, we need not assume a contour tone feature like [+/- raised] controlling the rising/falling contour (Yip 1980); instead, a contour tone can be realized by two TBUs with H/L tone features within a syllable, as shown in the modified version in Table 2. Adopting the idea, there should be two TBUs within a single syllable since a stressed syllable is consistently bi-moraic in Mandarin. The divergence between their systems and the increasing arguments infers that the tonal structure of Chinese should be revised.

Table 2 Chinese tonal representations

a. Bao (1990, 1999)	b. Yip (1980, 1989)	c. the modified version
		

Note: R= register; C=contour

I suggest a modified version to account for the tonal representations to resolve the mismatch. In the modified version, tonal contour features in each terminal node (i.e., H and L) are linked to TBUs (i.e., moras) for prosodic realization. This modification can better capture the prosodic-melodic mismatch (cf. Liang and Wee 2022). For example, more than one contour feature may be linked to a TBU, and vice versa. In addition, different from Bao's system, the modified version adopts Yip's proposal for the relation between tone registers and contour features. Bao assumes that the tone register and contour are two nodes dominated by the tone node, i.e., they are in the c-commanding relation; rather, in Yip's system, the register node dominates the contour nodes. Similar but divergent, both systems capture the fact that two contour features should belong to the same tone register, at least within a given syllable; this is to say, a syllable is marked with only one register. This generalization involves considerations of tonal harmony within a given domain and the economy of articulatory efforts. Within the consideration of Autosegmental Phonology (Goldsmith 1976), each tier is autonomous. Bao's system, where register and contour nodes are sisters, does not fit the multi-tier fashion. In his sense, tones would be synthesized by register and contour for a hybrid output, and register and contour nodes are not operating autonomously. On the contrary, Yip's proposal is relatively consistent with the spirit of Autosegmental Phonology, where tone register (Hr and Lr) and tone

rather than a mora, to be a TBU in Chinese, it would enforce an argument in favor of contour tone units, which contradicts Duanmu (1994) and Chen (2010).

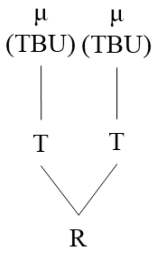
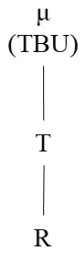
[11] I would like to thank an anonymous reviewer who drew my attention to Duanmu's (1994) proposal and reminded me that the modified version bears some resemblance to his proposal. Interested readers are suggested to refer to it. In this paper, the modified version aims to clarify and synthesize proposals on different tiers of the tonal structure scattered in the literature.

contour features (i.e., H and L) are in different tiers, where the former dominates the latter. Based on all the points suggested above, the modified version is conclusively given in Table 2.

2.3.1. Stressed & unstressed tones

Depending on whether the associated syllables are stressed, Mandarin tones can be divided into two groups. See Table 3. Stressed tones are conventionally considered to be lexical tones, which are bi-moraic and heavy; unstressed tones are then referred to as NTs, which are mono-moraic and light.

Table 3 Stressed vs. unstressed tones in Mandarin

	Stressed tone	**Unstressed tone**
Moraicity	Bi-moraic	Mono-moraic
TBU	2	1
Tonal representation		
Example	Lexical tones	Neutral tones

Note: R=register (Hr/Lr); T=tonal feature (H/L)

There is no doubt that stressed syllables are underlyingly toned, while the tonal patterns of unstressed syllables are differently argued. Recall that one of the views is that unstressed syllables are toneless (Yip 1980; Duanmu 2000, 2007, 2014). As shown in Table 3, there does not seem to be a good reason to claim the toneless nature of Mandarin NTs. Though unstressed syllables are short and light, they are still mono-moraic (i.e., with one TBU), which suggests they still have the capability to carry one tonal feature. Those who claim NTs are toneless may need to explain why unstressed syllables could not underlyingly carry tones, in preference to retaining at least one tonal feature. Therefore, I argue that we need not stick to the toneless view, where the possibility of being toned has been demonstrated by the tonal structure itself.

2.3.2. Mandarin stressed tones and tone sandhi

Before getting into more details of Mandarin unstressed tones, I would like to discuss some basic topologies of Mandarin, including stressed tones and operations of tone sandhi. Mandarin has four stressed tones, as illustrated in Table 4. T1 is a high-registered high-level tone (Hr, H), T2 is a high-registered rising tone (Hr, LH), T3 is a low-registered low-level tone (Lr, L), and T4 is a high-registered falling tone (H, HL) (cf. Daunmu 2007; Lin 2007; Hsiao 2015, 2024).

Table 4 Mandarin stressed tones (i.e., lexical tones)

Tone	Description	Register + contour	Tone value[12]	Example
T1	high-level	Hr, H	55	mā 'mom'
T2	high/mid-rising	Hr, LH	35	má 'paralyzed'
T3	low-falling	Lr, L	21	mǎ 'horse'
T4	high-falling	Hr, HL	53	mà 'scold'

When two T3-syllables are adjacent, the left T3 will be converted from Lr, L(L) to Lr, LH. Before discussing the tone sandhi pattern, the tonal representations of T3 should be clarified, which is represented differently from one analysis to another. In the paper, I assume that the underlying tone of Mandarin T3 is a single low tone (Lr, L) (cf. Duanmu 2000, 2007; Lin 2007; Hsiao 2015, 2024)[13], phonetically described as a low-falling tone (Xu 1997)[14], for two major reasons.

The first reason concerns the operation of Mandarin T3 sandhi. T3 sandhi takes place when two T3s meet, where the left T3 becomes a sandhi tone. The trigger of Mandarin T3 sandhi has been argued to be the realization of the obligatory contour principle (OCP) (cf. Leben 1973; Goldsmith 1976), for two low tones cannot be in the neighborhood (e.g., Shih 1986; Hsiao 1991, 2006). One may consider the fundamental restriction by the OCP and assume the OCP effect applies even in the input level, i.e., before tone sandhi. In this consideration, if one assumes T3 is underlying LL, instead of L, the OCP will be fundamentally violated in the input before tone sandhi, since the combination of LL is illegal in Mandarin.

The second reason involves the tonal representation of Mandarin T3 in daily use. Chao (1968) argues that T3 is always [214], namely Lr, LLH; Duanmu (2007), however, suggests [214] is rarely realized in daily conversations. The present analysis is aligned with Duanmu's viewpoint. In our observations, T3 is hardly realized as [214] *quán-shǎng* but usually represented as [21] *bàn-shǎng*. There is no convincing reason to assume the existence of a complex tone (Lr, LLH) for the underlying representation of Mandarin T3.

---

[12] This column summarizes Mandarin tone values in Chao's (1930) numeral system, which divides the pitch height of tones from 1 (low) to 5 (high).

[13] I would like to clarify the structural details of T3. To assume T3 to be an underlying single low tone (Lr, L) does not mean that there remains one mora or TBU. As demonstrated in Table 2 and 3, tonal features and TBUs are located in two different tiers. In typical cases, one expects one-on-one correspondence between tonal features and TBUs (e.g., Mandarin T2, and T4). When an underlying tonal representation only contains one tonal feature, the unlinked TBU can be satisfied by tone spreading, which is also a standard assumption of the Well-Formedness Condition (Goldsmith 1976). Therefore, I am not arguing that T3 is mono-moraic or unstressed. The idea of T3 as Lr, L is essentially following previous literature, such as Duanmu (2000, 2007), Lin (2007), and Hsiao (2015, 2024). I thank an anonymous reviewer who suggested it be better to make clarifications.

[14] An anonymous reviewer questioned why T3 is phonetically realized as a low-falling tone. For a phonologically low-level tone (e.g., Mandarin T3), it is hard for speakers to articulatorily reach the lowest F_0 point at the beginning of the tone; therefore, the phonetic description of T3 is low-falling (21), instead of low-level (11), to better fit the fact.

I thus conclude Mandarin T3 is better analyzed as a low-registered single low tone (Lr, L), of which viewpoint is consistent with Duanmu (2007), Lin (2007), Hsiao (2015, 2023), etc. In terms of the operation of T3 sandhi, an underlying single low tone will be spread to fulfill the second TBU in a syllable. Tone sandhi takes place later than tone spreading and makes the second low tone become a high tone within the low register (i.e., Lr, LL→Lr, LH). Note that the discussion of Mandarin T3 sandhi is of importance since this phenomenon can be a significant cue to identify the hidden low tone in Mandarin and other tonal operations, which will be developed in section 5.

3. Neutral Tones

Mandarin NTs are fundamentally unstressed, and phonologically reduced in many aspects. This section will identify the fundamental properties of Mandarin NTs, concerning phonetic and phonological characteristics in section 3.1. I review phonetic descriptions and experimental results from the literature in section 3.2 and previous phonological analyses in section 3.3. Lastly, I will give an interim summary and conclusion in section 3.4.

3.1. Properties

Many properties of NTs have been identified in the literature. Phonologically, NTs are considered toneless or atonic (Dow 1972; Yip 1980; Wang 2000; Li 2004), underspecified (Duanmu 2000), pitchless (Li and Thompson 1989), and completely neutralized (Huang 2020); this is to say, NTs do not have their underlying tones (see also Wan and Jager 1998 for similar descriptions). From a perspective of perception and production, NTs are regarded as short and light (Xu 1983) or short and lax (Cheng 1973). In terms of duration, NTs are usually as long as half of a standard syllable (Zadoenko 1958; Drecher and Lee 1966; Cheng 1973; Lin and Yan 1980; Cao 1986; Chen and Xu 2006; Lee and Zee 2008; among others). Interestingly, vowels in NT-syllables are usually found to be centralized, devoiced, or reduced (Zadoenko 1958; Chao 1968; Cheng 1973; Lin and Yan 1980; Cao 1986; Duanmu 2000, 2007; Wang 2004; Lee and Zee 2008). I conclude that the above-mentioned descriptive properties can be attributed to the unstressed/weak-stressed properties of NT (Xu 1983; Wan and Jadger 1998; Chen and Xu 2006; Huang 2020), whereby Mandarin NTs can be analyzed as unstressed tones. Contrary to a stressed syllable, an unstressed one is phonologically reduced, with respect to its duration, pitch range, and tenseness.[15] However, I argue that Mandarin NTs have their underlying tones, in contrast to the toneless point of view (e.g., Yip 1980; Duanmu 1999), which will be developed in section 3.2 and section 3.3.

[15] The use of "phonologically reduced" is the result of some structural mismatches. For example, a syllable can maximally be CGVX. While an NT syllable is mono-moraic, segment-carrying units (i.e., moras) are not enough for (G)VX in the rime. Some correspondent reductions will occur to adapt to the limited number of units.

3.2. Phonetic description

Documentations of Mandarin NTs emerge with respect to auditory/perceptual descriptions and acoustic realization, thus varying from one analysis to another. Acoustic evidence provides more concrete descriptions via the contour of F0, even though data may differ in various contexts (Wang 1997, 2000; Li 2003a, 2003b; Wang 2004; Sun 2006; Chen and Xu 2006; Li 2017; among others). A general tendency is that most of the tested Mandarin NTs are heading to a low tone/pitch, except for that preceding T3. For example, Lee and Zee (2008) conducted a production experiment to investigate the acoustic characteristics of Mandarin NTs in disyllabic and trisyllabic words.[16] Li (2017) also measures the F0 contours of NTs in comparison with four lexical tones in the same environment, as shown in Fig. 1.

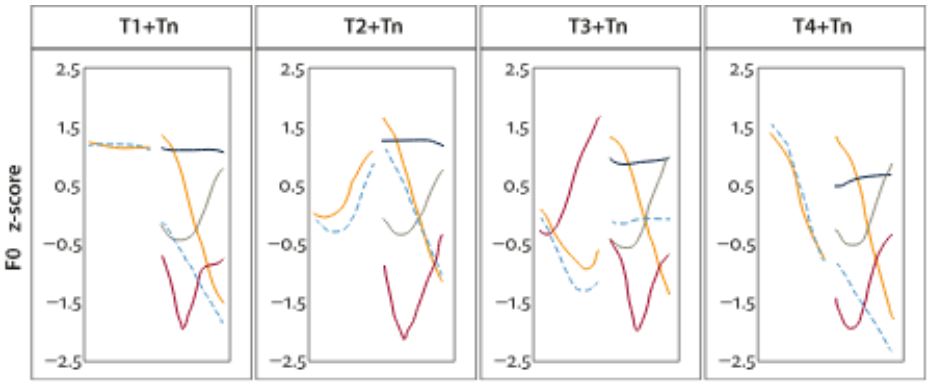


Fig. 1 z-scored normalized F0 contour of Mandarin NTs, with stressed tones (solid lines) and NTs (dotted lines) in the second syllables. (Li 2017)

By comparing the contour and the pitch height reported by previous studies, I conclude the F0 characteristics of Mandarin NTs as "mid-falling" after T1, "high-falling" after T2, "mid-level" after T3, and "low-level/falling" after T4. See Table 5 for the comparison of phonetic realization of Mandarin NTs in some previous studies.

Table 5 Phonetic realization of Mandarin NTs

	T1	T2	T3	T4
Dreher and Lee (1966)	41	31	23	21
Lin and Yan (1980)	41	51	33	21
Wang (1996)	41	52	33	21
Lee and Zee (2008)	31	41	33	21/11
Li (2017)	31	42	33	21

[16] See also Lee (2003) for an earlier version of Lee and Zee (2008). Note also that the Mandarin variant they visited was Beijing Mandarin, which is considered to be Standard Mandarin (Duanmu 2007). Different variants of Mandarin may have different behavior on the contour of NTs, which is compared and discussed in §3.4.

In general, Mandarin NTs show a pitch-falling inclination (see also Li 2017; Li and Li 2022).[17] Mandarin NTs seem to target at a low tone, thus presenting a falling F0 contour, except for that preceded by T3. A low tone is usually suggested to be aligned with the right edge of an NT-syllable. Li and Li (2022) explain the falling F0 contour can be regarded as the transitional realization from a full lexical tone to the target of an unstressed NT. Chen and Xu (2006) also confirm that the preceding tone gives rise to the tone variability of NTs. Even though the pitch contour can be greatly influenced by the ending pitch of the preceding tone, they all indicate this does not mean the absence of the tonal target of NTs.

Specifically, the preceding T3 gives some insight into the existence of a tonal target. Extensive studies have noticed its prominently higher ending pitch (e.g., Chao 1968; Cheng 1973; Lee and Wee 2008; Li 2017). Its tonal shape does not follow the other NTs following T1, T2, and T4, usually displaying a mid-level pitch, instead of a falling contour, where the targeted F0 for the offset is not as low as the others. It is thus suggested to carry an ending mid-tone or an ending high tone in low-register.

Aside from the F0 realization, many acoustic properties of Mandarin NTs have been widely studied as well (Lin and Yan 1980; Cao 1986; Wang 2004; Lu and Wang 2005; Lin 2012; Gao and Li 2018). One of the most notable features is the shorter duration. Tested in production experiments, an NT-syllable is half as long as a stressed syllable. A significantly shortened duration can be easily found in a contrasting pair like [stressed syllable + NT-syllable]. Its duration drop has also been revealed to serve as a crucial hint for adults and infants to identify the existence of NTs (Lin and Yan 1980; Lin 1985; Cao 1986; Li and Fan 2015; Fan et al. 2018).

The above-mentioned properties can all be ascribed to the unstressed properties of NTs. The ending low tones may show the resistance of stress, where a high pitch is not preferably realized in an unstressed syllable unless there are certain conditions in the phonetics or phonology of a given language.[18] This explains, from the perspective of phonetics, why the targeted pitch of Mandari NTs is low. Interestingly, NTs after T3 may not be realized low, but usually as like a Mid-tone. The higher pitch after T3 may be considered to be an articulatory reconciliation called post-low bouncing (Prom-on et al. 2012; see also Hyman 2007). When the pitches stay very low, an antagonistic force from the larynx emerges, in order to disturb the

[17] Readers are suggested to refer to Lee and Zee (2008), Li (2017), and Li and Li (2022) for detailed descriptions of the F0 realization. The present study only shows the summarized results for the purpose of formal phonological analysis in the following section.

[18] An anonymous reviewer wondered how to handle the unstress properties of NTs and NT-sandhi after T3 (LL+L→LL+M), where the pitch of NT is higher than the stressed T3 syllable. There are several alternative explanations and relevant possibilities: (1) In the constraint-based analyses, one may argue that OCP-L is a higher constraint than UNSTRESSED/H (an unstressed H tone), so a minor violation is acceptable. (2) Stress is realized differently across languages (Beckman 1986; Hayes 1995). We do not how stress is realized in Mandarin. If it is not realized by the height of pitch (maybe for tones that have occupied the role), it will not be a big deal for an unstressed H tone to show off in an unstressed condition. (3) Note that no matter L or H that NTs end up being, they are all realized in the low register. This can also be considered a behavior of resistance to stress, to some degree. The flexibility of pitch in the low register is relatively restricted than that in the high register. (4) Later in the paper, there will be a group of NTs (Type 2 NTs) that are represented as a fundamental Lr, H (M), which is not something bizarre in the realization of Mandarin NTs.

continuity of low pitches and naturally strike a new balance. Although the bouncing effect is proposed to model the pattern, it does not seem to be cross-linguistically applicable.[19] From a phonological perspective, the reason why a low target does not apply for NTs after T3 may be the avoidance of certain phonological principles (e.g., OCP, similar to Mandarin T3 sandhi). I will not emphasize too much here since it is not the purpose of this section. More discussion will be developed in section 3.3, about the potential trigger in phonological considerations.

On the other hand, another fact relevant to the unstressed properties is the shorter duration of NTs, compared with stressed syllables. As the durations of segments and syllables reflect the distribution of phonological weight as well as the allocation and the number of moras in a given syllable (Broselow, Chen, and Huffman 1997), this again shows that NT-syllables are light (mono-moraic) and unstressed. Interestingly, some phonological reductions are observed in NT-syllables. Vowels usually undergo shortening and weakening, as stress-driven reductions (e.g., Dauer 1980; Fowler 1981; Gordon 2011; de Lacy and Van der Hulst 2014). This effect is extensively documented in studies on Mandarin NT-syllables, where the peripheralization and reduction of the vowels emerge with the unstressed positioning (Zadoenko 1958; Chao 1968; Cheng 1973; Gao 1980; Lin and Yan 1980; Cao 1986; Duanmu 2000, 2007; Wang 2004; Lee and Zee 2008). In short, the unstressed properties and the corresponding reduced prominence cover the realization of Mandarin NTs.

3.3. Phonological analysis

Phonological analyses of Mandarin NTs center on the phonological representations of the tone values and the derivations of NTs, both synchronically and diachronically. Traditional analyses do not consider the possibility of a fixed tone value or tonal target (Chao 1968) and tonal underspecification (Duanmu 2007). Rather, the ending pitch height of Mandarin NTs suggests there is a low tone within a Mandarin NT-syllable (Yip 1980; Lin 1992, 2006; Wang 1997), while the assumed derivations differ in the previous accounts with explanations such as NTs as tone spreading (Yip 1980; Shen 1992) and hypothesized underlying low tones (Lin 1992, 2006). Another explanatory issue is the higher ending pitch of NTs after T3. Most of the analyses agree with the existence of a high tone (Yip 1980; Lin 1992, 2006; Shen 1992; Wang 1997; Duanmu 1999, 2000, 2007), but, again, their assumptions are explicitly divergent, with opinions on high-tone insertion (Yip 1980; Shen 1992; Wang 1997), *LL in a disyllabic foot as a polarity requirement (Duanmu 1999), floating high tone (Milliken 1989), low tone sandhi (Lin 1992, 2006), etc. A systematic review will be then given to scrutinize the advantages and the potential problems in previous analyses, with specific reference to Yip's (1980) tone-spreading analysis

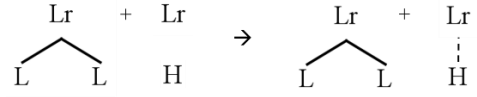
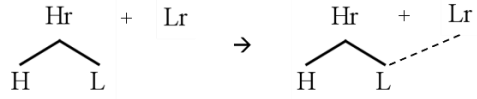
[19] Li and Li (2022) note that such an effect is possibly language-specific or dialect-specific. The phonetic motivation is appealing but may need some more examinations for confirmation. If the pitch raising of NTs after T3 is explained to be a phonetically driven result, one would expect it to appear more widely in different languages, while such post-low bouncing seems to be limited in certain languages. Here, I would just like to point out this analysis, while it is not in favor of the present analysis.

and Lin's (1992, 2006) underlying low-tone analysis.

3.3.1. Tone-spreading analysis

Tone-spreading analyses trace back to Yip (1980). Yip proposes the tone values of Mandarin NTs are inherited from the second tone (i.e., the nearest tone) in the preceding stressed syllable. By tone-spreading and association, the TBU in an NT-syllable can be satisfied. The tone register is specified as Lr. In Yip's analysis, NTs would be Lr, H after T1, T2, and T3, but Lr, L after T4. Note that NTs after T3 are not derived by tone-spreading but by independent high-tone insertion.

Table 6 Yip's (1980) tone-spreading analysis

a. T1 + NT	
b. T2 + NT	
c. T3 + NT	
d. T4 + NT	

Shen (1992) holds a similar proposal and further identifies three types of NTs with the distinction between underlying representations and surface representation: The first type is purely toneless with no full-tone counterpart, of which tone value is allocated by tone-spreading, as proposed by Yip (1980). The members of this type are often bound morphemes, which are greatly grammaticalized; the second one is de-stressed and de-tonic, i.e., underlyingly toned but phonologically reduced and thus toneless or tonally reduced on the surface representations, where the neutralized tone value on the surface contribute to the semantic differences from its counterpart in the full tone (e.g., *dà-yì* 'main point' vs. *dà-yi* 'careless')[20]; the third one is atonic, i.e., also underlying toned but toneless on the surface, while there is no meaning difference between the NT one and its full-tone counterpart. Shen already notes the divergent patterns of NTs, while it remains unclear how the distribution of different NTs is mapped onto their tonal

[20] This classification is apparently reasonable, but I argue that it is actually unnecessary, where Shen (1992) overgeneralizes such semantic differences. In the example given above, two words are identical in terms of segments, while this is just a coincidence since two words are semantically irrelevant. Neither of them is the reduced or grammaticalized form of the other. Many words in Mandarin are pronounced in the same or similar way, but semantically totally different. Shen's assumption is highly reliant on the orthographic equivalence.

representations and is also uncertain to which level the preceding syllable is related to the following NT-syllable. A fine-grained classification is necessary for the present analysis. One thing for sure is that the interaction between grammaticalization and stress plays a crucial role in tonal reduction and the emergence of NTs (see also Huang 2020 for a wide-ranging discussion about the interaction).

In general, there is no denying that the tone-spreading analysis offers insight into the intimate relationship between the preceding syllable and the NT-syllable in the pitch realization; this analysis, however, encounters empirical challenges. NTs are targeting a low tone, except for NTs after T3, while the analysis predicts a higher pitch of NTs after T1 and T3. The divergence between the tone-spreading analysis and acoustic measurements implies that purely tone-spreading does not work in explaining the tonal nature of Mandarin NTs.

3.3.2. Underlying low tone

Aside from assuming the underlyingly toneless nature of Mandarin NTs, one may alternatively consider hypothesizing an underlying tone. To the best of my knowledge, Lin (1992, 2006) was the first one to make this attempt and propose that Mandarin NTs have their underlying tones, on the side of the formal phonological analysis. See Table 7. It is argued that Mandarin NTs are underlyingly low tones. To explain the ending raising pitch after T3, the NT-sandhi rule is adopted. A sequence of three low tones is sensitive to the OCP, thus triggering a tone sandhi of the right-most L from L to H (L→H/L __). Last, similar to Yip (1980), tone-spreading applies to elaborate on the tonal assimilation and tonal co-articulation with the preceding syllable.

Table 7 Lin's (1992, 2006) analysis

	T1 + NT	**T2 + NT**	**T3 + NT**	**T4 + NT**
a. underlying representations	H + L	MH + L	LL + L	HM + L
b. NT-sandhi	H + L	MH + L	LL + H	HM + L
c. tone spreading	H + HL	MH + HL	LL + LH	HM + ML

It is reasonable to assume an underlying L for Mandarin NTs. Many phonetic analyses have observed the tonal target of NT towards a low or mid-low pitch (e.g., Xu and Wang 2001; Chen and Xu 2006; Li 2017; Li and Li 2022). Lin's analysis gives a novel vision into the underlying nature of Mandarin NTs, while there are two major problems unsolved. One concerns the NT-Sandhi Rule. Lin attributes the ending raising pitch of Mandarin NTs to the sandhi high tone and compares such tone sandhi with Mandarin T3 sandhi. A paralleled nature of these two sandhi rules is considered to seek an economic pattern of Mandarin tone sandhi, while it is unclear why the low tone that undergoes tone sandhi is the second tone from the first syllable in T3+T3 (L**L**+LL→L**H**+LL) but is the tone from the NT-syllable (i.e., the third tone

in a low) in T3+T0 (LL+**L**→LL+**H**).[21] Also, T3 is represented as LL in Lin's system but is recognized as a single L in many other systems (e.g., Duanmu 1999, 2000, 2007; Lin 2007; Hsiao 2015, 2024), where Lin assumes T3 is underlyingly LL, while the latter view considers LL to be the result of tone-spreading. The potential consequence of the LL assumption for T3 is the violated input of T3 in its underlying representation, since taking LL as the input of T3 has already violated the OCP and would turn LL into LH no matter which tone follows it (see section 2.2 for some discussion on the underlying representation of T3); otherwise, the sandhi rule needs to be conditioned by the avoidance of three sequential low tones instead of just two. This, however, makes the sandhi pattern more bizarre and makes it even more questionable which low tone to undergo tone sandhi.

The other problem involves the applicability of tone-spreading. Phonetic evidence has shown that NTs are easily influenced by the neighbor syllables (Chen and Xu 2006; Sun and Shih 2021; Li and Li 2022), while there is no convincing evidence to support the extension of such an effect to the phonological level. Tonal co-articulation is phonetic, while tone-spreading is phonological. The former contributes to articulatory and acoustic meddling (e.g., the floating F0 in the tonal onset), while the latter can further cause some phonological consequences (e.g., the applicability of tone sandhi). In Lin's (1992, 2006) system, the final output of T3+T0 (LL+LH) creates the applicable environment for the OCP. The tone-spreading analysis is thus problematic. Moreover, Mandarin NT-syllables are unstressed and mono-moraic. There is only one mora, namely one TBU, to carry a tone in an NT-syllable. Two tones will create the need for two TBUs. Thereby, the tone-spreading analysis again comes with a challenge for those who consider the effect to be not only phonetic but also phonological.

3.4. Summary of reviews

Previous investigations on Mandarin NTs have been trying to solve three major questions. Attempts for the first question involve the debate between the toneless point of view (Yip 1980; Shen 1992) and the underlyingly toned view (Lin 1992, 2006). The second question previous studies have made great efforts to is the raising pitch of NT after T3, with considerations such as high-tone insertion (Yip 1980; Shen 1992; Wang 1997), *LL in a disyllabic foot as a polarity requirement (Duanmu 1999), floating high tone (Milliken 1989), NT sandhi as the OCP (Lin 1992, 2006), etc. The third issue concerns the influence of the neighbor tones on NTs as well as the level of intimacy between the NT-syllable and the preceding syllable, phonetically as tonal co-articulation or phonologically as tone-spreading.

I conclude previous attempts with two highlights. First, with phonetic evidence support, it is reasonable to assume the existence of an underlying low tone in a Mandarin NT-syllable, as proposed by Lin (1992; 2006). Second, the attempt to unify the NT-sandhi and T3 sandhi with

[21] I simply point out this analytical problem for the literature review. An alternative analysis and the possible solution will be given in my proposal.

the OCP is worth considering, while some details need to be tailored. Last, regarding the pitch influence from the preceding syllable, tonal co-articulation seems to make more sense than tone-spreading to evaluate the variable tonal onset of Mandarin NTs. With thoughtful discussions and examinations above, a systematic proposal will be given in section 5, by adopting some of the previous considerations.

4. Distribution

In this section, I will overview the distribution and the tonal representations of Mandarin NTs, before the formal analysis given in section 5. Specifically, I examine the data documented in the literature with some novel documentation. The distribution of Mandarin NTs is miscellaneous, and various in contexts. Previous literature tends to consider the pattern of Mandarin NTs to be in common, while some studies raise doubts and notice that they are not the same (e.g., Shen 1992; Huang 2020; Zhang 2022). The tonal representations of some NTs are to a certain degree different from each other. Intricate as they are, I will first pigeonhole them into different groups, including bound morphemes, reduplication, and morphologically reduced words, based on their morpho-syntactic properties. With consideration of their phonological representations, three types of NTs are identified.

4.1. Morpho-syntactic considerations

The collective interpretations of Mandarin NTs lie in their unstressed properties. Cross-linguistically, the allocation of stress is intimately related to the morpho-syntactic structures. Stress reflects the morpho-syntactic roles of a word or morpheme. Escaping from the regular stress pattern in a given language, certain morphologically reduced words or bound morphemes are not prosodically valued, thus being removed from stress assignments. Such a process represents prosodic reflections upon grammaticalization.

The distribution of Mandarin NTs conforms with the general inclination in stress assignment (e.g., Chao 1965; Cheng 1973; Shen 1992; Lin 2001; more recently, see Huang 2020; Zhang 2022). Huang (2020), for instance, conducts a cross-dialectal survey on the interaction between grammaticalization and stress loss or reduction, also pointing out that the prosodic invisibility of NTs is highly relevant to the grammaticalization and functionality of morphemes or words. Zhang (2022) also makes an interesting diachronic overview of the grammaticalization of many NT-carrying words. As semantically bleached items are usually associated with NTs, it is then essential what kind of words and morphemes are neutralized and unstressed as NTs in Mandarin and if there is any correspondence between types of unstressed components and types of tonal representations.

4.2. Morpho-syntactic distribution

Based on the data and documented examples in the literature, I will develop a systematic

classification for the morpheme/words in Mandarin that are unstressed and involve tonal neutralization. Specifically, I divide them into three morphological types, including (1) bound morphemes (i.e., affix and clitic), (2) reduplication, and (3) morphologically reduced words (e.g., function words and compounds).

4.2.1. Bound morphemes

At the morphemic level, bound morphemes are often NT-carried. Bound morphemes are morphologically restricted and cannot stand alone as words, such as affixes and clitics. They are attached to another morpheme or have to find a host. Grammaticalization involves the reduction of morphosyntactic functions and phonological representations. Diachronically, there have been words that were originally meaningful but then their meanings were reduced and became meaningless via semantic bleaching. Along with meaning reduction, their forms themselves could also be reduced, with phonological reductions such as segment omission/deletion, duration shortening, pitch reduction, etc. There are two common types of products from grammaticalization: clitics and affixes. Clitics function like words with syntactic functions but cannot stand alone, which needs a host to attach with; affixes are reduced in phonological forms and cannot bear independent meanings, which need bases, usually words or morphemes, to attach with. Many cases of NTs can be found in these two types of bound morphemes.

Exhaustive grammaticalization leads to complete semantic erosion and such grammaticalized items usually become *affixes*, which are phonologically weakened and morphologically bound. For example, some nouns have been grammaticalized as nominal suffixes (e.g., *-zi*, *-tou*), notably with selection restriction with only nouns. Also, there are some conventionally fixed pairings between nouns and the grammaticalized noun suffixes (e.g., *zhuō-zi* ‘table’ but **zhuō-tou*). Adverb suffixes and aspect suffixes are also frequently used.

Table 8 Affixes with NTs

Type of affix	**Example**	
a. nominal suffix	*-zi, -tou*	*zhuō-zi* ‘table’
b. adverb suffix	*-de/-di*	*qīng-qīng-de* ‘slightly’
c. aspect suffix	*-le, -zhe, -guo*	chī-zhe fàn ‘eating rice’

Ongoing or partial grammaticalization, on the other hand, would not bleach morphemes to a great extent but could morphologically restrict their positioning and phonologically erode them, which have been regarded as *clitics*. Clitics are morphologically bound but still hold their own syntactic functions. Clitics can be usually found in grammatical markers, such as genitive markers, adverbial markers, and sentence-final particles (SFPs), as in Table 9. They are mostly syntactically located in functional projections. Interestingly, the generation of these clitics are

often words or morphemes diachronically grammaticalized from the lexical domain to the functional domain. For example, -le was generated from a verb meaning "to finish, to end," which is now still relevant to the meanings it has, serving as an SFP meaning "change of state" (e.g., Li and Thompson 1981; Pan 2021, 2022) or marking finiteness (Zhang 2019). The diachronic evolution of NT-clitics again manifests a close interaction between unstress and grammaticalization (cf. Huang 2020).

Table 9 Clitics with NTs

Type of marker	**Example**	
a. Genitive makers	*-de*	*tā-de* 'his,' *wǒ-de* 'my'
b. Adverbial marker	*-de*	*pǎo-dé kuài* 'run fast'
c. Sentence-final particle	*-de, -le, -a, -ma, -ba, -la,*	*zǒu ba* 'go (weak imperative)'

4.2.2. Reduplication

In the process of word formation, reduplication is also one of the common ways in Mandarin. Reduplication usually contributes to diminutive meaning, widely observed in expressions of kinship, naming, and child-directed speech (e.g., Chao 1968; Melloni and Basciano 2018; Sui 2018). Reduplications in Mandarin also express higher degrees of intensity of the base form (Chao, 1968, Li and Thompson, 1981, Tang, 1988; Lee-Kim 2016) or denote delimitative or tentative aspects (Li and Thompson 1981; Tsao 2001; Xiao and McEnery 2004).

Table 10 Reduplications with NTs

Type of reduplication	**Example**
a. diminutive	*bà-ba* 'father,' *jiě-jie* 'older sister,' *xīng-xing* 'star,' *shěn shen* 'wife of uncle'
b. child-directed speech	*shùi jiào-jiao* 'to sleep,' *chuān xiě-xie* 'to put on shoes,' *gǒu gou* 'dog'
c. intensifying	*chén diān-diān* 'very heavy,' *lěng bīng-bīng* 'very cold'
d. delimitative aspect[22]	*cháng-chang* 'to have a taste,' *kàn-kan* 'to have a look,' *zǒu.zou* 'to have a walk,' *xiáng-xiang* 'to consider for a while'

The phonological nature of reduplications is often compared with affixes since both are

[22] I would like to thank an anonymous reviewer who drew my attention to the different tonal behavior between types of reduplications. NTs after T3 can be realized as LL+M (e.g., *shěn shen* 'wife of uncle' in diminutive reduplication, *gǒu gou* 'dog' in child-directed reduplication) or LM+L (e.g., *zǒu.zou* 'to have a walk,' *xiáng-xiang* 'to consider for a while' in delimitative aspect). In the former realization, NTs have higher tonal targets (i.e., M-tone), while in the latter group, NTs remain low in pitch but the preceding T3s undergo tone sandhi, becoming LM. Later in Section 4.3., I will show diminutive reduplication and child-directed reduplication belong to a type of NT (Type 1), while delimitative reduplications for aspect are of another type (T3). What's more, delimitative reduplications are verbal reduplications, different from nominal reduplications. Delimitative reduplications can be the results of syntax, rather than word formation at the lexical level (Wang & Wu 2019; Chen 2023). In another words, reduplications are coincidences and can be separable, where, for example, aspectual particles can be inserted in between (e.g., *cháng-**le**-chang* 'have had a taste'), while the other types do not share the patterns and reduplicated components are not separable.

NT-carried (cf. Chao 1968; Zhu 1982). Reduplications, to some degree, can even be regarded as affixation (Sui 2018). This explains why they are classified in the same NT-type (later in section 4.3).

4.2.3. Morphologically-reduced words

At the word level, some words may involve stress removal and become unstressed with NTs, which are called *morphologically reduced words* (cf. Liang and Wee 2022). These words are mostly function words or compounds. Function words are words in functional projections, such as auxiliaries, prepositions or postpositions, complementizers, etc. Even though words that are NTs are often function words, function words do not always undergo de-stress. The distribution of NTs is restricted and constrained by certain conditions.

A Mandarin prosodic word is maximally trisyllabic, and only the domain-final function word may undergo de-stress.[23] See Table 11. In the disyllabic F+F or C+F sequence, only the second function word can be unstressed with NTs, including F+F examples such as *yīng-gāi* 'should,' and *xū-yào* 'need,' as well as C+F examples such as *wū-lǐ* 'inside the house,' and *chū-qù* 'go out.' In the trisyllabic C+F+F or C+C+F order, only the third function word would be unstressed and with NTs, including C+F+F examples such as *shù shàng-miàn* 'above the tree,' and *pǎo xià-qù* 'run and go down,' as well as C+C+F examples such as *xué-xiào lǐ* 'in the school.'

Table 11 Function words with domain-final NTs

Type of reduplication	Example
a. F+F	*yīng-gāi* 'should,' *xū-yào* 'need,' *xiǎng yào* 'want'
b. C+F	*wū-lǐ* 'inside the house,' *chū-qù* 'go out,' *huí-lái* 'come back,'
c. C+F+F	*shù shàng-miàn* 'above the tree,' *pǎo xià-qù* 'run and go down'
d. C+C+F	*shū-zhuō shàng* 'on the desk,' *xué-xiào lǐ* 'in the school

Remarkably, these function words are usually localizers (e.g., *shang* 'above,' *li* 'inside'), to combine with location and construct complete location words (e.g., *wū li* 'inside the house,' *shū shang* 'on the book') or are sometimes direction predicate (e.g., *qu* 'leave or go,' *lai* 'come') can incorporate with semantically compatible verbs to form new verbs or verb phrases (e.g., *chū qu* 'go out,' *huí lai* 'come back'). They, for syntactic and morphological reasons, usually

[23] In Table 11, only the last syllable can be unstressed with NTs. It is interesting to note that *wū-zi lǐ* 'inside the house' can have two NTs respectively on *zi* and *lǐ*. This example demonstrates a good implication of the different nature of Mandarin NTs. *Zi* is a bound morpheme, while *lǐ* is a function word, which is not morphologically bound as *zi*. In section 6, I will then discuss that bound morphemes are underlying unstressed with NTs, while function words are post-lexically de-stressed as NTs by the conditioned application. De-stress only allows the domain-final syllable to be de-stressed; this is, only one NT is allowed within a prosodic word. As for *wū-zi lǐ* 'inside the house,' the word-medial unstressed syllable is underlyingly decided, so it can escape from the position restriction of the de-stress rule. This again shows the asymmetric processing of Mandarin NTs.

appear in domain-finals, where the domain is referred to as a prosodic word.

Interestingly, there is a small group of NT-realization at the word level. They are not function words, but usually content words. They are also considered underlyingly toned but morphologically de-stressed in their surfaces. This operation is considered morphologically motivated (Shen 1992; Liang and Wee 2022), but it is not specified enough in the literature. Something worth remarking on is that they are often compound words. It has been noted in some languages that compounding is relevant to stress removal or stress reduction (Spanish in Bustos de Gisbert 1986, Hualde 2007, 2009; Rao 2015; English in Chomsky and Halle 1968; Halle and Keyser 1971, Ladd 1984; Russian in Gouskova and Roon 2013). The word-final component in a compound, such as *jiū* in *yán-jiū* 'research' and *xìng* in *gāo-xìng* 'happy,' is phonologically de-stressed with an NT; in contrast, the first word in a compound never undergoes de-stress (see also Yip 1980, Wright 1983, and Duanmu 1995 for a similar point made for word-initial stress-must). It is reasonable to hold the previous views, such as Shen (1992) and Liang and Wee (2022), that this group of words is de-stressed with certain morphological considerations in some given contexts since it is optional.

4.3. Morpho-phonological representations

Morpho-syntactic examinations lead the whole picture to a clearer pattern of what kind of morphemes or words are represented as NTs However, even though the above-mentioned examples can be unstressed with NTs, their tonal representations do not pattern together. Considering their morpho-syntactic distributions and morpho-phonological patterns (i.e., tonal representations), I will classify them into three major types.[24]

First of all, Type 1 NTs include affixes and reduplication. They are targeting L, except for those after T3; Type 1 NT after T3 is represented as M, i.e., Lr, H.[25]

Table 12 Type 1 NT[26]

a. nominal suffix	T1 + NT → HH + L	*zhuō-**zi*** 'table'
	T2 + NT → MH + L	*shí-**tou*** 'stone'
	T3 + NT → LL + M	*yǐ-**zi*** 'chair'
	T4 + NT → HM + L	*dù-**zi*** 'belly'
b. adverb suffix: *-de*	T1 + NT → HH + L	*qīng-**qīng** de* 'slightly'
	T2 + NT → MH + L	*kuài-**huo** de* 'merrily'
	T3 + NT → LL + M	*měi-**měi** de* 'beautifully'
	T4 + NT → HM + L	*kuài-**lè** de* 'happily'

[24] Tonal patterns and data were solicited from literature among multiple sources and provided by native speakers, which have been further confirmed by several native speakers of Standard Mandarin.

[25] For explanatory purposes, I tentatively don't specify the register and thus mark the perceptually mid-tone as M, instead of Lr, H.

[26] In Table 12, 13 and 14, I adopt LL to represent T3 (Lr, L), since it is clear to show the difference between mono-moraic and bi-moraic syllables, where LL is T3 and L is an NT. LL is the result of tone-spreading from Lr, L.

c. aspect suffix: *-le/ -zhe/ -guo*	T1 + NT → HH + L	*tīng-**le** gē* 'listened to music'
	T2 + NT → MH + L	*dú-**le** shū* 'read the book'
	T3 + NT → LL + M	*xiǎng-**zhe** shéi* 'whom to miss'
	T4 + NT → HM + L	*kàn-**guo** tā* 'saw him (before)'
d. reduplication	T1 + NT → HH + L	*mā-**ma*** 'mom'
(excluding delimitative)	T2 + NT → MH + L	*shú-**shu*** 'uncle'
	T3 + NT → LL + M	*sǎo-**sao*** 'aunt'
	T4 + NT → HM + L	*dì-**di*** 'young brother'

Second, Type 2 NT includes clitics as grammatical markers. These clitics have tones different from Type 1. As in Table 13, the pitch of Type 2 is higher than that of Type 1, but not as high as a high tone. As the tonal representation is in the middle of the pitch scale, it is better marked as M, to show its relatively higher tone and to differentiate it from L (Type 1) and real H. No matter which tone they follow, they behave like M. They do not have the representation of L on the surface, which is considered underlyingly toned as M.

Table 13 Type 2 NT

a. genitive marker: *-de*	T1 + NT → HH + M	*tā-**de** shū* 'his book'
	T2 + NT → MH + M	*shéi-**de** qián* 'whose money'
	T3 + NT → LL + M	*wǒ-**de** shū* 'my book'
	T4 + NT → HL + M	*shù-**de** pí* 'bark (the exterior of a tree)'
b. adverbial marker:	T1 + NT → HH + M	*fēi-**de** gāo* 'fly high'
verb + *de* + adverbial	T2 + NT → MH + M	*xíng-**de** zhèng* 'walk straight'
	T3 + NT → LL + M	*pǎo-**de** kuài* 'run fast'
	T4 + NT → HM + M	*tiào-**de** gāo* 'jump high'
c. SFP as finite marker:	T1 + NT → HH + L	*Tā shi bù xǐ huān kàn shū **de**.* 'He doesn't like to read'
-le/ -de	T2 + NT → MH + L	*Tā shi hěn xǐ huān zhè shū fáng **de**.* 'She loves the study room'
	T3 + NT → LL + L	*Nǐ zhī dào jiù hǎo **le**.* 'It would be good if only you know the news.'
	T4 + NT → HM + L	*Tā hěn cháng qù mǎi cài **de**.* 'She usually goes to the market.'
d. SFP as mood particle	T1 + NT → HH + M	*Nǐ ràng tā qù **a*** 'Let him go. (persuasive)'
	T1 + NT → HH + L	*Hǎo fán **a*** 'It's so annoying! (exclamative) '
	T2 + NT → MH + M	*Yī qǐ qù **ba*** 'Let's go together (weak imperative)'
	T2 + NT → MH + L	*Tā dù zǐ è **ba*** 'He is probably hunger (presumptive)'
	T3 + NT → LL + M	*Zǒu **ma*** 'Let's go? (interrogative)'
	T3 + NT → LL + L	*Yī qǐ zǒu **ma*** 'Let's go together! (polite request)'
	T4 + NT → HM + M	*Ràng tā qù **la*** 'We already let him go. (softening tones)'
	T4 + NT → HM + L	*Ràng tā qù **la*** 'Let him go! (polite request)'

Remarkably, it has been found in some examples (particularly in SFPs), that these clitics do have a L representation and that there is a tonal distinction that plays a role in marking meaning differences.[27] For example, ba^{L} serves as a weak imperative marker, while ba^{M} expresses speakers' attitude and guessing as the presumptive marker, where two components are located at different syntactic projections (see Simpson 2014; Pan 2021 for a comprehensive review of Mandarin SFPs). I thus suggest that they are underlyingly toned differently, as M or L, with high-low tone distinction for meaningful contrasts (Chao 1968; Matthews and Yip 1994; Sybesma and Li 2007; Simpson 2014). Overall, Type 2 NTs are underlyingly toned and automatous with tonal height. Different from Type 1, Type 2 NTs could have a higher pitch and high-low tone distinction for semantic dissimilarities.

Last, Type 3 NTs involve morphologically reduced words. Previous studies usually group Type 3 with other NTs together, considering only their surface patterns in common. Among all the NTs, Type 3 is the least discussed in the literature, not only because of the complicated patterns but also due to the lack of observations (cf. Liang and Wee 2022). Their tonal representations mostly can be patterned with Type 1, i.e., a single L, as shown in Table 14, where the tonal patterns are made when NTs are applicable.[28]

Table 14 Type 3 NT

a. function word 1:	T1 + T3 → HH + L	*wū-**li*** 'inside the house'
location word	T1 + T4 → HH + L	*shū-**shang*** 'on the book'
	T2 + T4 → MH + L	*qiáng-**shang*** 'on the wall'
	T3 + T3 → LH + L	*wǎn-**li*** 'inside the bowl'
	T4 + T1 → HM + L	*yòu-**bian*** 'on the right'
	T4 + T4 → HM + L	*lǐ-**mian*** 'of the interior'
b. function word 2:	T1 + T4 → HH + L	*chū-**qu*** 'go out'
direction word	T2 + T2 → MH + L	*huí-**lai*** 'come back'
	T3 + T4 → LL + L	*suǒ-**shang*** 'lock up'
	T4 + T4 → HM + L	*fàng-**xia*** 'put down'
c. compounds & other	T1 + T4 → HH + L	*gāo-**xing*** 'happy'
morphological reduced words	T2 + T2 → MH +L	*má **fán*** 'troublesome'
	T3 + T3 → LM + L	*dǎ-**shou*** 'bouncer'

[27] An anonymous reviewer wondered if there is any principle that determines the high-low tone distinction among Type 2 NTs. This is an intriguing question. From what we can observe so far, there seem to be no distinct reasons for such contrast. Diachronically, there might be some factors to lead to such contrasts, which can be less distinctive currently. I leave the discussion for future studies.

[28] Type 3 NTs may not always be applicable and the patterns seem to be complicated. Crucially, an anonymous reviewer indicates if the syllable carries a contrastive focus, NTs are not applicable and it will carry a full lexical tone, which seems to be irrelevant to word stress but focus prominence. Metrical theory may help to elaborate on this fact. Metrical force is cumulative and comparative. Word stress is the lowest in the prosodic hierarchy, while additional metrical force may be added to some upper layers, thus rescuing the syllable from de-stressing. Focus prominence is a good example of the cumulative nature of metrical force (cf. Haye 1980, 1995).

	T4 + T4 → HM + L	*zhào-**gu*** 'take care of'
	T4 + T4 → HM + L	*rèn-**shi*** 'recognize'
d. monomorphemic words[29]	T1 + T2 → HH + L	*bō **li*** 'glass'
	T2 + T2 → LM + L	*liú **lian*** 'durian'
	T3 + T3 → LM + L	*mǎ **nao*** 'agate'
	T3 + T4 → LL + L	*hǔ **po*** 'amber'

Something interesting is that in T3+T3→T3+NT cases, T3 undergoes the tone sandhi rather than NT, as in *wǎn-li* 'inside the bowl' and *dǎ-shou* 'bouncer,' which is different from the pattern of Type 1 NTs. The divergence will be explained in section 5.2 and section 5.3, with the proposed analysis. Given the variable tonal representation and its special morpho-syntactic category, Type 3 is suggested to be another independent type.

4.4. Interim summary

The distribution of Mandarin NTs is highly connected with the morpho-syntactic properties. Bound morphemes and reduplicated components are the majority, but it is not something unseen that morphologically reduced words also involve NTs, most of which are function words and compounds. The distribution generally complies with crosslinguistic conditions for unstress or de-stress, where less emphasized or less grammaticalized items can easily turn out to be unstressed, thus with NTs (cf. Huang 2020; Zhang 2022). Even though they are all in the domain of NTs, their tonal representations are not the same, with three types of NTs identified. Type 1 involves completely grammaticalized items (i.e., affix) and reduplicated elements. Type 2 includes clitics as grammatical markers. Partial grammaticalization does not erase the function of tonal marking but maintains meaningful contrasts with high-low tone distinction in the use of NTs. Type 3 involves morphologically reduced words (cf. Liang and Wee 2022), many of which are function words or compounds. Their tonal behavior differs both from types of NTs and with a word.

5. Tonal Operation

Based on the data and classified NTs, this section gives a unified phonological account for Mandarin NTs. First, the foundation of the phonological template will be discussed and established in section 5.1. Then, section 5.2 will examine how NTs are represented and phonologically vary from one type to another. Last, a unified schema will be summarized and proposed in section 5.3, to elaborate on the entire process of de-stress, inherited unstress, and tonal operation.

[29] I would like to thank an anonymous reviewer, who reminded me that there are a great number of monomorphemic words can represented as NTs as well. Basically, they pattern with Type 3 NTs, where when two T3 syllables come together, the left T3 will become LM for T3 sandhi, while the right T3 becomes an NT.

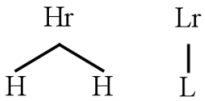
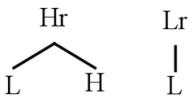
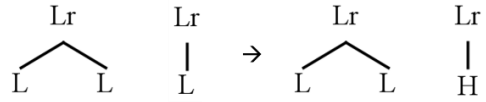
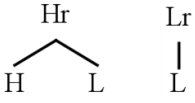
5.1. Phonological structure of NTs

NTs are characteristic of many unstressed properties, such as being short, light, and phonologically reduced. First, the phonological structure of an NT-syllable is supposedly different from a standard one. Unstressed syllables should be phonologically light, in contrast to stressed syllables. A stressed syllable is bi-moraic in general, while an unstressed one is mono-moraic. The number of moras within a given syllable should then show such a contrast. Second, the tone register of a given syllable should be independent. In other words, the preceding syllable will not assimilate the NT-syllable in terms of tone register. To say further, the tone register should have its own tier (Yip 1980). Last, the number of TBUs is tied to the weight of a syllable. In Yip's system, TBUs are located in a dimension independent of phonological weight, while recent literature has proven the uniformity between a TBU and a mora (e.g., Hyman 1985; McCarthy and Prince 1986; Duanmu 1990, 1994; Chen 2007; Liang and Wee 2022).[30] The template adopted in the present study has been illustrated in Table 2. The register tier dominates the TBU-tier, which is also the moraic tier due to the equivalence between a mora and a TBU. Tone is marked as H or L within a given tone register, either Hr or Lr.

5.2. Tonal operations

Type 1 NTs are targeting L, except for NTs after T3, which is M (i.e., Lr, H). Type 1 NTs are supposedly underlying L, as in Table 15. I argue that the divergence between NTs after T3 and NTs after T1, T2 and T4 can be attributed to tone sandhi (cf. Lin 1992, 2006; Duanmu 1999). The combination of T3+NT creates the environment of the OCP, where a LL sequence should be prohibited; therefore, the original L (Lr, L) undergoes tone sandhi and becomes M (Lr, H).

Table 15 Tonal operation of Type 1 NT

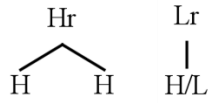
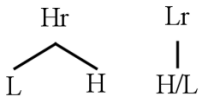
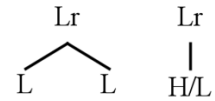
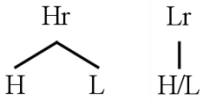
T1 + NT	**T2 + NT**
	
T3 + NT	**T4 + NT**
	

Type 2 NTs are different from Type 1 in terms of the morphosyntactic distribution and the

[30] I make reservations about whether the uniformity of TBU and mora is cross-linguistically valid. However, it is clear that TBUs and moras are shared in Mandarin (Daunmu 1990, 1994; Chen 2007; Liang and Wee 2022).

tonal representation. They are not always heading to L. The ending pitch of many of them is relatively higher than Type 1, which is better marked as H.[31] A clear high-low tone distinction in meaning contrasts can even be found in SFPs. This type involves many grammatical markers.

Table 16 Tonal operation of Type 2 NT

T1 + NT	**T2 + NT**
	
T3 + NT	**T4 + NT**
	

Interestingly, Type 2 NTs after T3 (i.e., T3+L) do not undergo tone sandhi but escape from the OCP. For example, *hǎo le* (T3+L) in *Nǐ zhī dào jiù hǎo le* 'It would be good if only you know the news' is an underlying low tone sequence, while neither of the low tones undergoes tone sandhi. I argue that this intriguing phenomenon is not exceptional but well-conditioned. Mandarin tone sandhi is domain-specific and cyclically applies in the phonological hierarchies from low to high, within each of the applicable prosodic constituents (Shih 1986; Chen 2000; Chen Y.J. 2015). The applicable domains include Phonological word (ω), Clitic group (C), Phonological phrase (Φ), and Intonational phrase (ι). It is convinced that Utterance (U), as the highest prosodic domain, does not involve the cyclic tone sandhi. SFPs are syntactically located at the complementizer phrase (CP). In Selkirk's (2011) Match Theory, which maintains the syntax–prosody isomorphism and constrains the alignment between syntax and prosody, a CP is typically matched with an Intonational phrase (ι). An SFP is at the higher CP-level and thus is not aligned with ι.[32] Instead, it is within a higher prosodic domain, namely U. For the unstressed properties, SFPs are utterance-final and U is not the operational domain of tone sandhi; therefore, when a low-tone SFP is put in a low-tone sequence, it may not trigger tone sandhi.

Last, the tonal operation of Type 3 NTs is intricate. Their tonal representations of Type 3 NTs mostly pattern with Type 1 NTs, while there remain some divergent representations. First, the adaptation of Type 3 NTs is optional, where there exist at least two surface representations: one is the same as the underlying tones, while the other is adjusted as an unstressed variant.

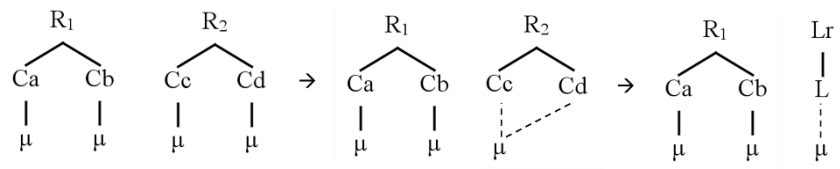
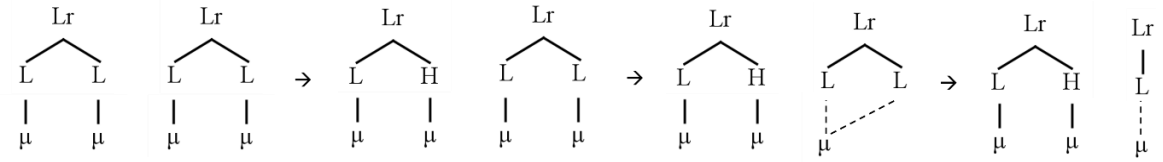
[31] In some variants and individual uses, they blur the boundary between Type 1 and Type 2 and make them all behave like L, while it is still undeniable for some people, especially those in older generations, they prefer to have a pitch contrast and pronounce it as M.

[32] Mandarin has components in the left peripheries, including Topic, Focus, Modal, and SFPs. At the higher projections among many split CPs, SFPs can be regarded as phonologically utterance-final particles, prosodically higher than the intonational phrase, which is aligned with a lower CP layer.

When Type 3 NTs apply, de-stress leads to the lessening of phonological weight and the moraic reduction, from a bi-moraic syllable to a mono-moraic syllable, where the original tone is replaced with L. Second, in the T3+NT sequence, Type 1 NT undergoes NT-sandhi and becomes M, while Type 3 NT does not. Instead, the preceding syllable (the stressed one) undergoes tone sandhi and becomes a sandhi tone LM, whereas the NT-syllable (i.e., the unstressed one) does not but remains L. This manifests the different nature of Type 3 NTs. If de-stress takes place before tone sandhi, the NT will become M, rather than L. Therefore, I argue that the OCP effect and the low tone sandhi happen before the operation of de-stress onto Type 3, while they occur after the stress assignment/reduction of Type 1. This explains the asymmetric nature of NTs in terms of Type 1 and Type 3, also highlighting the necessity of NTs in Type 1 and the optionality of NTs in Type 3 (Shen 1992; Zhang 2022).[33]

The proposed tonal operation of Type 3 is given in Table 17. A stressed component in the domain-final position (i.e., the final of a prosodic word) may become unstressed, with moraic reduction from two to one. L replaces the original tones, as grammatically conditioned.

Table 17 Tonal operation of Type 3 NT

Type 3 NTs without tone sandhi (T+T→T+NT)

Type 3 NTs with tone sandhi (=T3+T3→T3+NT)[34]


On the whole, de-stress is the crucial motivation of Type 3 NTs. Here, I would like to generalize the use of de-stress for reasoning the de-stress nature of Type 3 NT3. Earlier in section 4.2.3., I have mentioned the de-stress rule of compounds, which are widely observed across languages (e.g., Chomsky and Halle 1968; Halle and Keyser 1971; Ladd 1984; Bustos de Gisbert 1986; Hualde 2007, 2009; Gouskova and Roon 2013; Rao 2015), while the reason for other groups in Type 3 remains unsolved. Taking insights from the compound de-stress rule, let us first think about why compounds would be de-stressed. Under Metrical theory, metrical

[33] Zhang (2022) classifies NTs into two types: Intrinsic and Derived NTs. They respectively correspond to Type 1 and Type 3 in the present classification. Intrinsic NTs (i.e., Type 1) are obligatory, while Derived NTs are optional, where both the stressed or unstressed versions are available. See Zhang (2022) for more details on the type differences.

[34] For T3 (Lr, L), Table 17 simply represents its tonal representations after tone-spreading (L→LL), for the present focus is on the sensitivity of the following low-tone sandhi.

force is cumulative, being assigned to different prosodic levels. The formation of compounds suggests the loss of prosodic level and accordingly the amount of metrical force. For example, *white* and *house* are two individual words, where one is an adjective and the other is a noun. They consist of metrical force on several levels, including syllables, feet, prosodic words, etc. When forming a compound *white-house* 'the office of the US president,' the speaker would assign stress based on a word, instead of a phrase. Therefore, the loss of metrical force may shift the stress and lead to a different pattern based on word-level stress.

Despite the clear distinction in English, Mandarin is less likely to follow the same pattern, since fundamentally the definition of "word" is ambivalent and ambiguous. A morphological word can be mono-syllabic, while a phonological/prosodic word should be minimally di-syllabic (Duanmu 1999). Something interesting is that de-stress in Mandarin Type 3 NTs seems to apply when a prosodic disyllabic word shows a tendency of mono-morphemicity; this is to say, if a di-syllabic word is not as informative as a bi-morphemic word, then it may undergo de-stress. Mono-morphemic words are not as informative as bi-morphemic words, for the diachronic fusion of two morphemes. Morphologically reduced words and function words are also not as informative as two content words (morphemes). Following this assumption, one may predict loanwords also share the pattern as well, and they actually do (e.g., T1+T1→HH+**L** *kā* ***fei*** 'coffee,' T3+T1+T1 → LL+H+**L** *mǎ lā* ***song*** 'marathon').[35] To sum up, the loss of informativeness within a word and the increasing inclination toward mono-morphemicity explain why those words also undergo de-stress, becoming Type 3 NTs.

5.3. A unified procedure of NT operations

In the paper, three types of NTs are identified. Their tonal operations are obviously different, where an explicit contrast has been pointed out between Type 1 and Type 3. The former is obligatorily NT-carried, while the latter is optionally represented as NT. A thought-provoking comparison is found between Type 1 and Type 3 after T3, where the latter may trigger the preceding stressed T3 to undergo the low-tone sandhi. If the operation of de-stress and NT is taken before tone sandhi, one would expect NTs to undergo tone sandhi instead of the preceding T3. This implies the late processing of de-stress in Type 3. Considering all the factors and operations discussed above, I propose a unified schema to showcase the process of de-stress and tonal operation for types of Mandarin NTs in Fig. 2.

[35] There are many examples of Type 3 NTs that are also applicable. The paper does not aim to sort out all the possibilities but offers a principled classification and systematic explanations of why de-stress occurs and what is implied behind de-stress. More cases are left for future studies.

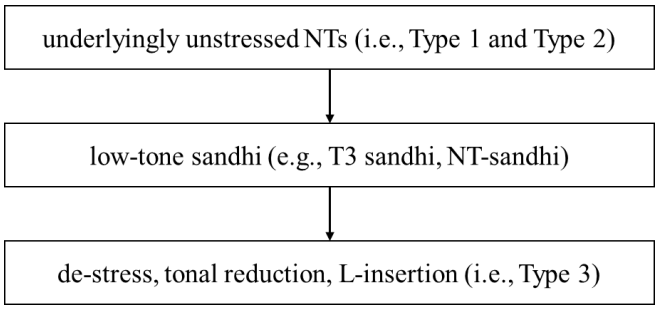


Fig. 2 Tonal process of Mandarin low-tone sandhi and NTs

Type 1 and Type 2 are underlyingly unstressed.[36] Type 1 NTs carries low-tones and undergo NT-sandhi. Type 2 NTs are underlying toned with M or L. By contrast, Type 3 NTs are underlying toned with full lexical tones, then de-stressed to be NTs. It is worth noting that both Type 2 and Type 3 NTs do not undergo NT-sandhi, but the reasons are different. For Type 2, even though T3 + NT sequences do not trigger NT-sandhi from L to M, it does not say its tone assignment takes place after tone sandhi. The reason why Type 2 NTs escape from tone sandhi is the unapplicable sandhi domain, where the prosodic domain of Type 2 NT is above an intonational phrase, so neither T3 nor NT undergoes tone sandhi.[37] Type 3 NTs, by contrast, are not born to be low-tone NTs. Only the original T3+T3 sequences involve tone sandhi, so the tones involving the low-tone sandhi are not the NT but the preceding T3. Overall, the properties of different NTs are concluded in Table 18.

Table 18 Summarized properties of Mandarin NTs

	Type 1	**Type 2**	**Type 3**
Underlying tone	L	M or L	underlyingly toned with lexical tone
Surface tone	L after T1, T2, T4 M after T3	M or L	L
NT-sandhi	O	X	X
T3-sandhi	X	X	O
Unstress status	before tone sandhi		after tone sandhi
Example	affixes, reduplication	clitics	morphologically reduced words (e.g., compounds and function words)

6. Discussions

6.1. Grammaticalization and NTs

The presented correspondence between morpho-syntactic categories and tonal operation

[36] Following Duanmu (1993), I assume NTs are light and do not have inherent stress. Therefore, they are considered to be underlyingly stressed. See section 2 for more clarification.
[37] Domain-sensitive tone sandhi and prosodic considerations have been discussed in section 5.2.

reflects an intimate interaction between grammaticalization and underlying representations. The optional de-stress for Type 3 NTs manifests a low degree of grammaticalization, but a developing inclination towards higher grammaticalization, de-stress is optional but still possible. Their underlying lexical tones may or may not be preserved. Type 2 NTs are partially grammaticalized. They are phonologically reduced and unstressed, but remain syntactically independent, hosting certain projections. They are morpho-phonologically restricted. Type 1 NTs are completely grammaticalized and morphologically bound. Elements in Type 1 are morphologically bound and phonologically reduced to a great extent.

Fig. 3 Degree of grammaticalization and type of NTs

Overall, the degree of grammaticalization in NTs follows the cline of crosslinguistic grammaticalization (cf. Hopper and Traugott 2003). Content words become function words and are reduced as clitics or even affixes. A clear pattern is established in Fig. 3, illuminating the strong correlation between grammaticalization and morpho-phonological operations (see also Huang 2020; Zhang 2022 for similar conclusions).

6.2. NTs as Grammatical tones (GTs)

In the long tradition, Chinese languages, especially Mandarin, are described as a language only with lexical tones; GTs are, by contrast, mostly active in African languages (Hyman 2016). The present study has seen the potential for the existence of GTs in Mandarin. Broadly speaking, tone languages in Africa and Asia are not entirely different but share many similarities. Though GTs may not be as obvious as in African languages, one should not easily refute the possibility, especially as tone languages may originally come from the same source in the beginning.

To the best of my knowledge, there has been no satisfying definition of what counts as a GT, where GTs are apparently but not precisely defined.[38] Hyman (2016) points out that GTs

[38] I would like to thank three anonymous reviewers, who all pointed out that the claim that NTs are GTs may be confusing and needs more clarification. Traditionally, the concept of GT has long relied on our understanding of African languages. GTs are relatively functional in languages where lexical tones are less prominent. This, however, caused the bias of defining GTs via African languages. GTs can be universal. In Asian languages, each syllable consists of a tone, while a tone in African languages is often shared by more than one syllable and is less functional.

and lexical tones have some overlapping functions, which makes it hard to distinguish one from the other sometimes. Lionnet, McPherson, and Rollle (2022) give a general definition that GTs are topological patterns restricted to specific (groups of) morphemes and not attributable to typical phonological grammars of a given language. Following this conception, Mandarin NTs can be considered as examples of GTs. I will elaborate more on the reasons as follows:

First of all, three types are tied to different classes of morphological units. Type 1 NTs are affixes or reduplication, Type 2 NTs are clitics, and Type 3 NTs are words that are morphologically reduced, such as compounds, function words, and mono-morphemic words. Unlike African languages, NTs appear not to have more detailed functions (e.g., tense, aspect, verb-type marking), while this does not mean NTs are not GTs. There is a possibility that GTs in Asian languages may be degenerated since lexical tones are relatively rich and more functional. For languages where lexical tones play crucial roles in signaling meanings, GTs can be less functional and thus degenerated, and the other way around. This has been shown to be a typological inclination among tone languages (Ratliff 1992; Hyman 2016).

Second, the use of NT reflects some, despite not all, grammatical relations. For Type 2 NTs, different tonal heights clearly indicate different grammatical functions. The tonal height of Type 2 can be a hint to identify SFPs that are the same in the segmental part; this is to say, even though SFPs are segmentally identical, high-low tone contrasts denote different semantics and grammatical functions. On the other hand, with no significant contrasts in high-low tone distinctions, Type 1 NTs also highlight the nature of GTs in Mandarin, and even Chinese languages. An underlying L can be regarded as a GT, when the component is extremely functional or morpho-phonologically bound, such as affixes and reduplicated components. Interestingly, Type 3 NTs apply for morphological considerations, of which operation is made after tone sandhi. It may appear to be special, while this is not something rare across languages. Tonal adjustments after syntax may be applicable on the way to Spell-out to better reflect the morpho-syntactic status. Overall, NTs can be taken as the signals of grammatical tones emerging in Mandarin, which may be found in other Chinese variants.

Third, to further defend the existence of GTs in Mandarin, some diagnostics can help identify which type of process they belong to. GT has been defined as a grammatically restricted operation of tones (Rolle 2018; Sande 2022; Lionnet, McPherson, and Rollle 2022). Tones of specific morphemes, constructions, or groups of morphemes are processed under grammatically-conditioned contexts, via operations such as toneme insertion, removal, replacement, shifting, assimilation, dissimilation, etc. Mandarin NTs comply with the definition, where only specific groups of morphemes or components come with NTs.

Under such contrasts, it is reasonable to assume GTs also exist in Asian tone languages, where GTs may just degenerate rather than completely disappear. Actually, Sande (2022) also indicates an example of Mandarin GT—*bu* 'not' tone sandhi, which is morpheme-specific but is well encoded in the language. In this section, I hope to draw readers' attention to the possibility of NTs in Mandarin, and more generally, across Asian tone languages.

Table 19 Diagnostics for different types of GTs (cf. Sande 2022)

	consistent realization	phonologically derivable	general phonology
item-based	✓	✓	✓
suppletive	—	—	—
process-based	—	✓	—

GTs can mainly be classified into three types, item-based, suppletive, and process-based (Rolle 2018; Sande 2022)[39]. Some diagnostic cues are illustrated in Table 19. Mandarin NTs display a diverse nature of NTs corresponding to item-based and process-based GTs. Both can be phonologically derivable. Divergent patterns are observed in the consistency of realization and the compliance of general phonology. Item-based GTs are even morpheme-specific or item-specific with consistent realization and can be derived from the phonological pattern of a given language, with high phonological legitimacy; process-based GTs are construction-triggered phonological operations, which may not apply everywhere but magnificently for some high-frequency items. Explicitly, a typological match can be found between Type 1/2 NTs and item-based GTs as well as between Type 3 NTs and process-based GTs. Type 1 and Type 2 NTs are obligatorily unstressed in NTs, with a consistent pattern of underlying tones, while Type 3 NTs are optionally processed with the de-stress rule. In general, types of GTs match types of Mandarin NTs. It can be concluded that Mandarin NTs are the representations of GTs.

6.3. Unification of Mandarin tone sandhi

In the complicated nature of Mandarin tonology, one of the most significant tonal processes is tone sandhi. Different types of NTs reflect the different priorities of tone sandhi. Triggered by the OCP, both T3 sandhi and NT-sandhi can be unified as the low-tone sandhi in Mandarin, where two underlying low tones are prohibited in the neighborhood, as illustrated in Table 20.

Table 20 Mandarin low-tone sandhi

X + Y	**underlying** →	**tone-spreading** →	**low-tone sandhi** →	**de-stress**
T3 sandhi	L + L	LL + LL	**LH + LL**	—
NT-sandhi	L + L	LL + L	**LL + M**	—
T3 sandhi in Type 3	L + L	LL + LL	LH + LL	**LH + L**

Assume there is an X+Y sequence, X and Y are two independent syllables. In the typical T3 tone sandhi, X and Y are both Lr, L, where X and Y are stressed. With a LL sequence across syllables, X will then be converted from Lr, LL (after tone spreading) to Lr. LH. This

[39] Rolle (2018) identifies item-based and process-based GTs. Sande (2022) further points out the possibility of suppletive GTs. Suppletive GTs are not found in Chinese and thus not in the current discussion, so I simply mention the first two kinds of grammatical tones.

demonstrates the right-dominant property in Mandarin tone sandhi (Shih 1986; Yue-Hashimoto 1987; Duanmu 1999; Zhang 2007). In the NT-sandhi (for Type 1 NTs), X is underlyingly Lr, L (before tone-spreading) and stressed; Y is also Lr, L but unstressed. As Y is an unstressed syllable, the tone of Y undergoes tone sandhi from Lr, L to Lr, H. Interestingly, the tone sandhi with Type 3 NTs is different from that with Type 1 but similar to T3 sandhi. In the underlying representations of Type 3 NTs, where X and Y are underlyingly stressed and toned with Lr, L, a T3 tone sandhi normally applies before the process-based GT application, where the de-stress rule optionally applies to Y. Clearly, the environments of Mandarin tone sandhi are all set to be the avoidance of a LL sequence, where two low tones are situated alongside the boundary of an applicable prosodic domain. A unification can thus be made to unify T3 sandhi and NT-sandhi as the low-tone sandhi. However, even though the environments to condition three kinds of tone sandhi are the same, a rising issue for the unification is which tone undergoes tone sandhi and why. In the observed pattern, X (left-syllable) undergoes tone sandhi when X and Y are stressed, but Y undergoes tone sandhi if Y is underlyingly unstressed.

The tone sandhi preference is stress-driven. Unstressed tones are more likely to undergo tone sandhi than stressed tones, since stressed syllables, on the contrary, tend to retain their underlying tones (Duanmu 1993). When two competing tones are both stressed, right-dominance is then decisive in determining which to be preserved, while this does not guarantee the second stressed syllable is more prominent or phonologically heavier than the first one, because the primary stress is not always going to the second syllable but the tone sandhi regularly applied to the left syllable.[40] In the unification of Mandarin tone sandhi, the autonomous role of stress and tone sandhi directionality in phonological operations is of great importance.

6.4. Cross-dialectal variations

One remaining challenge comes from the diverse variations of Mandarin NTs. NTs may be differently represented by speakers from different Mandarin variants. Mandarin has been widely spoken in regions such as China, Malaysia, Taiwan, Singapore, and many other south-eastern countries. Diverse variants are thus derived and adopted as influenced by local dialects. In investigating Mandarin NTs, studies usually consider Beijing Mandarin (BM) as the standard Mandarin variant for analyses (e.g., Duanmu 2007). The present analysis also centers on BM speakers' patterns for convenience of the current discussion, while it is acknowledged that NTs in different Mandarin variants are not the same as the pattern discussed above.

Taiwan Mandarin, for example, shows a different pattern of NTs. Taiwan Mandarin is found to be more syllable-timed. Stress contrasts (stressed vs. unstressed) are thus not as obvious as BM. Huang (2012) conducts a comprehensive acoustic study of NTs in Taiwan

[40] The primary stress may preferably go to the first syllable in nouns but the second syllable in verbs. Despite the difference in stress assignment, the left syllable regularly undergoes tone sandhi in Mandarin (cf. Duanmu 1993).

Mandarin. Tonal reduction, de-stress, and mono-moraic (light) syllables do not frequently appear. NTs in Taiwan Mandarin are represented in a stressed environment instead, except when the nucleus vowel is a mid-vowel (i.e., [ə] or [ɨ]). NTs are realized in a stressed full tone most of the time and have a mid-low target, which is however not always as low as a low tone. NTs in Taiwan Mandarin are possibly a bi-moraic ML.[41] Considering the intimate interaction between Taiwan Mandarin and Taiwanese, the stressed environment for NTs as well as the emergence of ML as the tonal representation may be the result of language contact between Mandarin and Taiwanese. Taiwanese is more rhythmic and syllable-timed than Mandarin. Taiwan Mandarin, as a mixture of Mandarin and Taiwanese, is also more syllable-timed than Mandarin (Huang 2012), which weakens stress-timing and the distinguishing role of stress. The originally unstressed NTs are realized as stressed, where a mono-moraic syllable is turned into a bi-moraic syllable. This creates the need for satisfying a new TBU (i.e., mora). To fulfill the bi-moraic need, an ML is realized for NTs in Taiwan Mandarin and consistently adopted for NTs after all the lexical tones. The choice of ML can be attributed to the phonetic imitation of Mandarin NTs. Mandarin NTs are mainly targeting L, while the onset F_0 is usually higher than the offset, presenting a falling contour, which is similar to the contour of ML. In stressed conditions, a falling contour is lengthened with less time pressure, thus fossilized with a perceptually-alike stressed tone, namely ML. ML does not exist in BM but in Taiwanese (cf. Cheng 1968; Chen 1987, 2000; Lin 1989; Chen 2018). Reasonably, the emergence of ML is easily incorporated into the phonological grammar of Taiwan Mandarin. NTs in Taiwan Mandarin exhibit a valuable instance concerning the influence of language contact on NTs.

Tianjin Mandarin has also been widely discussed in the literature (Wang and Jiang 1997; Wang 2002; Lu and Wang 2012; Li and Chen 2019). Comparable with BM, NTs in Tianjin Mandarin show a mid-low targeting inclination. The onset of NTs is influenced by the preceding lexical tone, where that of NTs after T2 (H) or T3 (LM) is notably higher than NTs after T1 (L) or T4 (HM) (Wang 2002; Li and Chen 2016, 2019). This may suggest progressive tonal co-articulation between the preceding lexical tone and NTs. The higher offset of the preceding tones penetrates the phonetic realization of the followed NT via interpolation (Shih 1997; van Santen & et.al. 1998; Li 2003b), which is similar to the contour of the onset F_0 in Mandarin NTs (Chen and Xu 2006). On the other hand, the offset of NTs seems to undergo tone sandhi or anticipatory tonal co-articulation, where the ending pitch is remarkably higher when the following tone is T1 (LL). This phenomenon is parallelled with Mandarin low-tone sandhi and complies with the universal OCP effect, where two low tones should be prohibited from being located in the applicable prosodic boundary; otherwise, one of the low tones will get raised and become Lr. H. As the NT is unstressed, it undergoes tone sandhi in preference to the stressed

[41] As NTs in TM are stably realized as lexical tones do, Huang (2012) also suggests TM may have the fifth tone but does not specify the tone values. On the other hand, following the definition of GT discussed above (Rolle 2018; Sande 2022), NT, even in TM, should not be considered as a lexical tone, for it is grammatically conditioned for certain words or morphemes only.

tones, echoing the pattern of NTs in BM. In short, Tianjin Mandarin demonstrates another interesting pattern, which is similar but by some means different from Mandarin NTs, suggesting future works pay more attention to.

Cross-dialectal variations of NTs manifest tonal adaptation in different dialects. Some similarities and divergences between BM and a given Mandarin variant have been discussed above. More and less, they follow the tonal pattern of BM by intimation and certain adjustments meant for the dialectal grammar. A broad investigation of NTs, though focusing on BM, is valuable to shed light on the pattern of NTs in different Mandarin variants.

7. Conclusion

The paper discusses the morpho-phonological operations of Mandarin NTs. I thoroughly examine the morpho-phonological status of NTs as well as the intimate interactions between grammaticalization, stress, and tone sandhi. A unified account is proposed, with cross-disciplinary considerations about the interfaces between phonetics, phonology, morphology, and syntax. NTs are grammatically conditioned and sensitive to certain morpho-syntactic and phonological environments. Defending against the peculiar status of NTs that previous literature assumes, I propose that NTs are not something special but can be analyzed simply as unstressed tones.

Based on the morpho-syntactic distributions and the morpho-phonological representations, Mandarin NTs can be classified into three types: Type 1 includes affixes and reduplications, where an underlying L is posited; Type 2 contains many clitics as grammatical markers, where the underlying tone can be M or L, with even clear high-low tone distinctions found in the cases of SFPs; Type 3 involves morphologically reduced words, many of them are compounds or function words. Type 1 and Type 2 are underlying unstressed and are obligatory NTs, while Type 3 is optionally realized. This highlights the asymmetric nature of phonological processes, where Type 3 is processed later than Type 1 and Type 2, and even later than the OCP-based low-tone sandhi. Different types of NTs also reveal the degree of grammaticalization in the synchronic and diachronic views.

Aside from the status of NTs, the present study has some implications. First, NTs are intimately correlated with grammaticalization. Second, NTs can be considered GTs, where NTs seem to be restricted to a certain group of morphemes and comply with the diagnostics of GTs (cf. Rolle 2018; Sande 2022). Third, I give some modifications to the tonal representation system by considering TBU to be a mora, further unifying Mandarin T3 sandhi and NT-sandhi as the OCP-based low-tone sandhi, where two low tones are prohibited in the applicable prosodic boundary. Fourth, a cross-dialectal comparison is made to universalize the pattern of NTs across the diverse Mandarin variants. Overall, the paper offers a novel insight into Mandarin NTs from the perspective of GTs and attempts to make progress on the unsolved status of NTs as well as the interaction with some other phonological issues.

References

Bao, Z. 1990. On the nature of tone. PhD dissertation, MIT.

Bao, Z. 1999. The structure of tone. Oxford University Press.

Beckman, M. 1986. Intonational structure in Japanese and English. Phonology Yearbook, 3.

Broselow, E., Chen, S. I., & Huffman, M. 1997. Syllable weight: convergence of phonology and phonetics. Phonology, 141, 47-82.

Cao, J. 1992. On neutral-tone syllables in Mandarin Chinese. Canadian Acoustics, 203., 49-50.

Cassimjee, F., & Kisseberth, C. W. 1992. The tonology of depressor consonants: Evidence from Mijikenda and Nguni. In Annual Meeting of the Berkeley Linguistics Society, pp. 26-40.

Chan, M. K. 1995. An autosegmental analysis of Danyang tone sandhi: Some historical and theoretical issues. Wuyu yanjiu [Studies of the Wu dialects], 145-184.

Chan, M. K., & Ren, H. 1988. Wuxi tone sandhi from last to first syllable dominance. Acta Linguistica Hafniensia, 212, 35-64.

Chao, Y.-R. 1930. A system of tone letters. Le Maître Phonétique 8 30.: 24–27.

Chao, Y. R. 1948. Mandarin primer: An intensive course in spoken Chinese. Harvard University Press.

Chao, Y.-R. 1968. A grammar of spoken Chinese. Berkeley: University of California Press.

Chen, C. 2023. Mandarin verbal reduplication and the one-delimitation principle. Proceedings of the Linguistic Society of America, 81, 5521-5521.

Chen, M. H. 2018. Tone sandhi phenomena in Taiwan Southern Min. University of Pennsylvania.

Chen, M. Y. 1987. The syntax of Xiamen tone sandhi. Phonology, 4, 109-149.

Chen, M. Y. 2000. Tone sandhi: Patterns across Chinese dialects Vol. 92. Cambridge University Press.

Chen, T. Y. 2007. The mora as tone-bearing unit. MA thesis, National Chung Cheng University.

Chen, T. Y. 2010. Some remarks on contour tone units. Journal of East Asian Linguistics, 192, 103-135.

Chen, Y., & Xu, Y. 2006. Production of weak elements in speech–evidence from f_0 patterns of neutral tone in Standard Chinese. Phonetica, 631., 47-75.

Chen, Y.J. 2015. Taiwan Mandarin tone sandhi and the intonational phrase. MA thesis, National Chengchi University.

Cheng, C. 1973. A Synchronic Phonology of Mandarin Chinese. Berlin, New York: De Gruyter Mouton. https://doi.org/10.1515/9783110866407

Cheng, R. L. 1968. Tone sandhi in Taiwanese. Linguistics, vol. 6, no. 41, 1968, pp. 19-42.

Chomsky, N & Halle, M. 1968. The sound pattern of English. New York: Harper and Row.

Dauer, R. M. 1980. The reduction of unstressed high vowels in Modern Greek. Journal of the International Phonetic Association, 101-2., 17-27.

de Lacy, P., & Van der Hulst, H. 2014. Evaluating evidence for stress systems. Word stress: Theoretical and typological issues, 149-193.

Dong, S. 1958 Yuyin changshi [Common sense in phonetics]. Beijing: Culture and Education Press.

Dow, F. D. 1972. A discussion on tone sandhi problems in Chinese. Journal of the International Phonetic Association, 21., 13-19.

Dreher, J., & Pao-ch'en, L. 1966. Instrumental investigation of single and paired Mandarin

tonemes. Douglas Advanced Research Laboratory. "

Duanmu, S. 1990. A formal study of syllable, tone, stress and domain in Chinese languages. PhD dissertation, MIT.

Duanmu, S. 1993. Rime length, stress, and association domains. Journal of East Asian Linguistics, 2, 1-44.

Duanmu, S. 1994. Against contour tone units. Linguistic inquiry, 254, 555-608.

Duanmu, S. 1995. Metrical and tonal phonology of compounds in two Chinese dialects. Language, 225-259.

Duanmu, S. 1997. Wordhood in chinese. Trends in Linguistics Studies and Monographs, 105, 135-196.

Duanmu, S. 1999. Metrical structure and tone: evidence from Mandarin and Shanghai. Journal of East Asian Linguistics, 81., 1-38.

Duanmu, S. 2000. Stress in Chinese. In Chinese phonology in generative grammar pp. 117-138. Brill.

Duanmu, S. 2007. The phonology of standard Chinese. OUP Oxford.

Duanmu, S. 2009. Syllable structure: The limits of variation. Oxford University Press.

Duanmu, S. 2014. Syllable structure and stress. The handbook of Chinese linguistics, 422-442.

Fan, S., Li, A., & Chen, A. 2018. Perception of lexical neutral tone among adults and infants. Frontiers in Psychology, 9, 306491.

Fowler, C. A. 1981. Production and perception of coarticulation among stressed and unstressed vowels. Journal of Speech, Language, and Hearing Research, 241., 127-139.

Gao, J., & Li, A. 2018. Production of neutral tone on disyllabic words by two-year-old Mandarin-speaking children. In Studies on Speech Production: 11th International Seminar, ISSP 2017, Tianjin, China, October 16-19, 2017, Revised Selected Papers 11 pp. 89-98. Springer International Publishing.

Gisbert, E. B. 1986. La composición nominal en español Vol. 14. Universidad de Salamanca.

Goldsmith, J. 1984. Tone and accent in Tonga. Autosegmental studies in Bantu tone, 19, 52.

Goldsmith, J. O. H. N. 1976. Autosegmental phonology Doctoral dissertation, Doctoral dissertation/Garland Press.

Gordon, M. 2011. Stress: Phonotactic and phonetic evidence. The Blackwell companion to phonology, 2, 924-948.

Gouskova, M., & Roon, K. 2013. Gradient clash, faithfulness, and sonority sequencing effects in Russian compound stress. Laboratory phonology, 42., 383-434.

Halle, M. 1998. The stress of English words 1968–1998. Linguistic Inquiry, 294, 539-568.

Halle, M., & Keyser, S. J. 1971. English stress p. 164. New York: Harper and Row.

Halle, M., & Vergnaud, J. R. 1987. Stress and the cycle. Linguistic inquiry, 181, 45-84.

Hayes, B. 1980. A metrical theory of stress rules Doctoral dissertation, Massachusetts Institute of Technology.

Hayes, B. 1995. Metrical stress theory: Principles and case studies. U of Chicago P.

Hopper, P. J., & Traugott, E. C. 2003. Grammaticalization. Cambridge University Press.

Hsiao, Y. E. 1991. Syntax, rhythm and tone: a triangular relationship. University of California, San Diego.

Hsiao, Y. E. 2008. Yinping tone sandhi in two Hakka dialects. Interfaces in Chinese Phonology: Festschrift in Honor of Matthew Y. Chen on his 70th Birthday, ed. by Yuchau E. Hsiao, Huichuan Hsu, Lian-Hee Wee & Dah-an Ho, 79–97. Taipei: Institute of Linguistics, Academia Sinica.

Hsiao, Y. E. 2015. Rethinking OCP effects on tone sandhi. Language and Linguistics, 166., 927-945.

Hsiao, Y. E. 2024. Chinese phonology. Routledge Research Encyclopedia of Chinese Studies. Taylor & Francis/ Routledge.

Hsieh, F.-F. 2021. Lun hanyu you cizhongyin [On the existence of word stress in Mandarin Chinese]. Studies in

Prosodic Grammar 71, 27-58.

Hualde, J. I. 2007. Stress removal and stress addition in Spanish. Journal of Portuguese Linguistics, 61.

Hualde, J. I. 2009. Unstressed words in Spanish. Language Sciences, 312-3., 199-212.

Huang, K. 2012. A study of neutral-tone syllables in Taiwan Mandarin. Phd dissertation, University of Hawaii at Manoa.

Huang, T. C. 2020. Grammaticalized function words in Chinese dialects: neutral tone and prosodic invisibility. PhD dissertation, National Chengchi University.

Hyman, L. 1977. On the nature of linguistic stress. Studies in stress and accent, 4, 37-82.

Hyman, L. 1985. A theory of phonological weight Vol. 19. Walter de Gruyter GmbH & Co KG.

Hyman, L. M. 1987. Prosodic domains in Kukuya. Natural Language & Linguistic Theory, 311-333.

Hyman, L. M. 2007. Universals of tone rules: 30 years later. Tones and tunes: Studies in word and sentence prosody, 1, 1-34.

Hyman, L. M. 2016. Lexical vs. grammatical tone: sorting out the differences. Tonal Aspects Lang, 2016, 6-11.

Kenstowicz, M. 1987. Tone and accent in Kizigua-a Bantu language. In Cortona Workshop in Phonology.

Kiparsky, P. 1975. Stress, syntax, and meter. Language, 576-616.

Kiparsky, P. 1985. Some consequences of lexical phonology. Phonology, 2, 85-138.

Ladd, D. R. 1984. English compound stress. Intonation, accent and rhythm, 253266.

Lee, W. S. 2003. A phonetic study of the neutral tone in Beijing Mandarin. In Proceedings of the 15th International Congress of Phonetic Sciences ICPHS 2003. Barcelona.

Lee, W. S., & Zee, E. 2008. Prosodic characteristics of the neutral tone in Beijing Mandarin. Journal of Chinese Linguistics, 361., 1-29.

Lee-Kim, S. I. 2016. Syntax-based phonological asymmetries: The case of adjective reduplication in Mandarin Chinese. Lingua, 179, 1-23.

Li, A., & Fan, S. 2015. Correlates of Chinese neutral tone perception in different contexts. In In The Scottish Consortium for ICPhS 2015 ed., Proceedings of the 18th International Congress of Phonetic Sciences.

Li, A., & Li, Z. 2022. Prosodic realization of tonal target and F0 peak alignment in Mandarin neutral tone. Language and Linguistics, 231., 47-81.

Li, C. N., & Thompson, S. A. 1989. Mandarin Chinese: A functional reference grammar. Univ of California Press.

Li, M. 2004. Neutral tones in disyllabic sequences across Chinese dialects: An OT account. MA thesis, Tianjin Normal University.

Li, Q., & Chen, Y. 2016. An Acoustic Study of Contextual Tonal Variation in Tianjin Mandarin. Journal of Phonetics 54: 123–150.

Li, Q., & Chen, Y. 2019 "Prosodically conditioned neutral-tone realization in Tianjin Mandarin." Journal of East Asian Linguistics 28: 211-242.

Li, Z. 2003a A perceptual account of asymmetries in tonal alignment. InKadowaki, Makoto & Kawahara Shigeto eds., Proceedings of the North East Linguistic Society 33: Massachusetts Institute of Technology, 147–166. Amherst: GLSA, University of Massachusetts Amherst.

Li, Z. 2003b. The Phonetics and Phonology of Tone Mapping in A Constraint-Based Approach. PhD dissertation, MIT.

Li. A. 2017. Putonghua butong xinxijiegou zhong qingsheng de yuyin texing [Phonetic correlates of neutral tone in different information structures]. Dangdai Yuyanxue [Contemporary Linguistics] 193. 348–378.

Liang, Y., & Wee, L. H. 2022. Melodic-prosodic duality of the syllable: An application to Chinese. Language and Linguistics, 231., 82-115.

Liberman, M. Y. 1975. The intonational system of English Doctoral dissertation, Massachusetts Institute of Technology.

Liberman, M., & Prince, A. 1977. On stress and linguistic rhythm. Linguistic inquiry, 82, 249-336.

Lin, H. 1992. On the nature of Mandarin tone and tone sandhi. Phd dissertation, University of Victoria.

Lin, H. 2006. Mandarin neutral tone as a phonologically low tone. Journal of Chinese Language and Computing, 162., 121-134.

Lin, M. 2012. Hanyu yudiao shiyan yanjiu [The experimental study of intonation in Mandarin Chinese]. Beijing: China Social Sciences Press.

Lin, M., & Yan, J. 1980. Beijinghua qingsheng de shengxue xingzhi [Acoustic characteristics of neutral tone in Beijing Mandarin]. Fangyan [Dialect] 19803. 166–178.

Lin, T. 1962. Xiandai haiyu qingyin he jufa jiegou de guanxi [The relation between neutral tone and syntactic structure in Modern Chinese]. Zhongguo Yuwen [Studies of the Chinese Language] 7. 301–334.

Lin, T. 1985. Tantao Beijinghua qingyin xingzhi de chubu shiyan [Preliminary experiments in the exploration of the nature of Mandarin neutral tone]. InLin, Tao & Wang, Lijia eds., Beijing yuyin shiyanlu [Working papers in experimental phonetics], 1–26. Beijing: Peking University Press.

Lin, Y. H. 1989. Autosegmental treatment of segmental processes in Chinese phonology. The University of Texas at Austin.

Lin, Y.-H. 2007. The Sounds of Chinese. Cambridge University Press.

Lionnet, F., McPherson, L., & Rolle, N. 2022. Theoretical approaches to grammatical tone. Phonology, 393., 385-398.

Lu, J., & Wang, J. 2005. Guanyu qingsheng de jieding [On defining “qingsheng”]. Dangdai Yuyanxue [Contemporary Linguistics] 20052. 107–112.

Lu, J., & Wang, J. 2012. Hanyu Qingsheng de Youxuanlun Fenxi [An Optimality Analysis of Neutral Tone in Chinese]. Tianjin: Tianjin University Press.

Matthews, S., & Yip, V. 1994. Cantonese: A comprehensive grammar. Routledge.

McCarthy, J. J., & Prince, A. S. 1986. Prosodic morphology. The handbook of morphology, 281-305.

Melloni, C., & Basciano, B. 2018. Reduplication across boundaries: The case of Mandarin. In The lexeme in descriptive and theoretical morphology pp. 339-380. Language Science Press.

Milliken, S. 1989. Why there is no third tone sandhi rule in Standard Mandarin. Paper presented at the Tianjin International Conference on Phonetics and Phonology, Tianjin, 7–10 June 1989.

Newman, P. 1972. Syllable Weight as a Phonological Variable: The Nature and Function of the Contrast Between “Heavy” and “Light” Syllables. Studies in African Linguistics 33.: 301–323.

Odden, D. 1995. Tone: African languages. J. Goldsmith Ed., The Handbook of Phonological Theory, Blackwell, Oxford 1995., pp. 441-475

Pan, V. J. 2021. Sentence-final particles in Chinese. In Oxford Research Encyclopedia of Linguistics.

Pan, V. J. 2022. Deriving head-final order in the peripheral domain of Chinese. Linguistic Inquiry, 531., 121-154.

Prince, A. 1980. A metrical theory for Estonian quantity. Linguistic inquiry, 511-562.

Prince, A. 1990. Quantitative consequences of rhythmic organization. Cls, 262, 355-398.

Prokosch, E. 1939. A Comparative Germanic Grammar. Linguistic Society of America.

Prom-on, S., Liu, F., & Xu, Y. 2012. Post-low bouncing in Mandarin Chinese: Acoustic analysis and computational modeling. The Journal of the Acoustical Society of America, 1321., 421-432.

Rao, R. 2015. On the phonological status of Spanish compound words. Word Structure, 81., 84-118.

Ratliff, M. 1992. Tone language type change in Africa and Asia:! Xũ, Gokana, and Mpi. Diachronica, 92, 239-257.

Rolle, N. R. 2018. Grammatical tone: Typology and theory. University of California, Berkeley.

Sande, H. 2022. Is grammatical tone item-based or process-based?. Phonology, 393., 399-442.

Selkirk, E. 1984. On the major class features and syllable theory. Language Sound Structure: Studies in Phonology/MIT Press, 107136.

Selkirk, E. 2011. The syntax-phonology interface. The handbook of phonological theory, 435-484.

Shen, X. S. 1992. Mandarin neutral tone revisited. Acta linguistica hafniensia, 241., 131-152.

Shi, B. 2004. Hanyu Putonghua ci zhongyin de yinxixue yanjiu [Phonological analysis of word stress in Putonghua]. Doctoral Dissertation. Beijing Language and Culture University.

Shih, C. 1986. The prosodic domain of tone sandhi in Chinese: phrasal phonology, tonal typology, mandarin, syntax-phonology interface. University Of California, San Diego.

Shih, C. 1997. Mandarin Third Tone Sandhi and Prosodic Structure. In Studies in Chinese Phonology, ed. Jialing Wang and Noval Smith, 81–123. Berlin: Mouton de Gruyter.

Sietsema, B. M. 1989. Metrical dependencies in tone assignmen.Doctoral dissertation, Massachusetts Institute of Technology.

Simpson, A. 2014. Sentence-final particles. The handbook of Chinese linguistics, 156-179.

Sui, Y. 2018. Affixation or compounding? reduplication in Standard Chinese. Exact Repetition in Grammar and Discourse, 127-157.

Sun, C. 2006. Chinese: A linguistic introduction. Cambridge University Press.

Sun, Y., & Shih, C. 2021. Boundary-conditioned anticipatory tonal coarticulation in Standard Mandarin. Journal of Phonetics, 84, 101018.

Sybesma, R., & Li, B. 2007. The dissection and structural mapping of Cantonese sentence final particles. Lingua, 11710., 1739-1783.

Tang, T. C. 1988. Guoyu xingrongci de chongdie guilü [Reduplication rules for adjectives in Mandarin Chinese]. Hanyu cifa jufa lunji [Studies on Chinese morphology and syntax], 29-57.

Tsao, F. F. 2001. Semantics and syntax of verbal and adjectival reduplication in Mandarin and Taiwanese Southern Min. Sinitic grammar: Synchronic and diachronic perspectives, 285-308.

Van Der Hulst, H. 2012. Deconstructing stress. Lingua, 12213, 1494-1521.

Van der Hulst, H. 2014. Word stress: Theoretical and typological issues. Cambridge University Press.

van Santen, J., Shih, C., and Mo¨bius, B. 1998. Intonation. In Multilingual Text-to-Speech Synthesis: The Bell Labs Approach, ed. Richard Sproat, 141–190. Dordrecht: Kluwer Academic Publishers.

Wan, I. P., & Jaeger, J. 1998. Speech errors and the representation of tone in Mandarin Chinese. Phonology, 153.,

417-461.

Wang, C. A. A., & Wu, H. H. I. 2020. Light verbs in verbal reduplication. Studia Linguistica, 742, 337-359.

Wang, J. 1997. The representation of the neutral tone in Chinese Putonghua. InWang, Jialing & Smith, Norval eds., Studies in Chinese phonology, 157–183. Berlin: Mouton de Gruyter. 10.1515/9783110822014

Wang, J. 2000. Shiyan yuyinxue shengcheng yinxixue yu hanyu qingsheng yingao de yanjiu [Experimental phonetics, generative phonology and the study of the pitch of neutral tone in Chinese]. Dangdai Yuyanxue [Contemporary Linguistics] 20004. 227–230.

Wang, J. 2002. Youxuanlun he Tianjinhua de Liandu Biandiao ji Qingsheng [Optimality Theory and Tone Sandhi and Neutral Tone in Tianjin Mandarin]. Zhongguo Yuwen 4: 363–372.

Wang, J. 2004. The neutral tone in trisyllabic sequences in Chinese dialects. In International Symposium on Tonal Aspects of Languages: With Emphasis on Tone Languages.

Wang, Z., & Feng, S. 2006. Tonal contrast and disyllabic stress patterns in Beijing Mandarin. Yuyan Kexue [Linguistic Science], 51, 3-22.

Woo, N. H. 1969. Prosody and Phonology. PhD dissertation, MIT.

Wright, M. S. 1983. A metrical approach to tone sandhi in Chinese dialects. University of Massachusetts Amherst.

Xiao, Z., & McEnery, A. 2004. A corpus-based two-level model of situation aspect. Journal of linguistics, 402., 325-363.

Xu, S. 1982. Shuangyinjie ci de yinliang fenxi [A quantitative analysis of disyllabic words]. Yuyan jiaoxue yu yanjiu, 2, 4-19.

Xu, Y. 1993. Contextual tonal variation in Mandarin Chinese. PhD dissertation, University of Connecticut.

Xu, Y., & Wang, Q. E. 2001. Pitch targets and their realization: Evidence from Mandarin Chinese. Speech communication, 334., 319-337.

Yip, M. 1980. The tonal phonology of Chinese PhD dissertation, MIT.

Yip, M. 1989. Contour tones. Phonology, 61., 149-174.

Yue-Hashimoto, A. O. 1987. Tone sandhi across Chinese dialects. Wang Li memorial volumes, English volume, 445-474.

Zadoenko, T. P. 1958. Hanyu ruodu yinjie he qingsheng de shiyan yanjiu,[An experiment on the weak-stressed syllables and the neutral tone in Chinese]. Zhongguo Yuwen, 78, 581-587.

Zhang, J. 2007. A directional asymmetry in Chinese tone sandhi systems. Journal of East Asian Linguistics, 16, 259-302.

Zhang, N. N. 2019. Sentence-final aspect particles as finite markers in Mandarin Chinese. Linguistics, 575., 967-1023.

Zhang, Y. 2022. Neutral tone in Mandarin: representation and interaction with utterance-level prosody. PhD dissertation, Cambridge University.

Zhu, D. 1982. Chaoyanghua he Beijinghua Chongdieshi Xiangshengci de Gouzao [Structures of Reduplicative Onomatopoeia in Chaoyang and Beijing], Fangyan 2, 174–180.Bao, Z. 1990. On the nature of tone. PhD dissertation, MIT.