The distribution of tone affects prosodic parsing in Beijing Mandarin: Evidence from retroflex lenition

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1 Background

1.1 *Retroflex lenition*   Lenition is a process causing consonants to have more open articulations and thus be more sonorous (Kingston 2008). Groups of sounds with different sonority can be illustrated on a scale. A partial list of the sonority scale relevant to the topic of this paper is listed in (1).

(1)   Obstruents < Approximants < Vowels

In Beijing Mandarin, there exists a lenition process where the retroflex obstruents /ʂ tʂʰ tʂ/ in syllable onsets variably change into a retroflex approximant [ɻ], increasing in sonority. Examples are given in (2), where a word-medial syllable with a retroflex obstruent onset (henceforth, retroflex syllable) undergoes lenition.

(2)   /pʰai **tʂʰu** swo/ → [pʰai **ɻu** swo]   'police station'
         /mei **ʂu** kwan/ → [mei **ɻu** kwan] 'art gallery'
         /ʂwei **tʂu** jy/   → [ʂwei **ɻu** jy]   'boiled fish'

Retroflex lenition mostly occurs in fast speech, and speakers' production can sometimes be gradient, where the retroflex obstruent onset is deleted completely. I will not discuss the phonetics of retroflex lenition in this paper. In (3), we see that although the same retroflex obstruent is in the same segmental (u_a) environment, it undergoes lenition in (3b) but not in (3a). This suggests that retroflex lenition is not triggered by a particular segmental environment. The tones in the examples are omitted when they are not phonologically relevant, and I will continue this practice throughout the paper.

(3)   a. /tʂʰu tʂʰa ji ʂẓ/   → [tʂʰu **tʂʰa** ji ʂẓ]   (without lenition)   'exit the tea room'
                                   → *[tʂʰu **ɻa** ji ʂẓ]   (with lenition)
             /ʂu ʂa ɻən fan/   → [ʂu **ʂa** ɻən fan]   (without lenition)   'count murderers'
                                   → *[ʂu **ɻa** ɻən fan]   (with lenition)
             /wu tʂa tɕjaŋ mjan/ → [wu **tʂa** tɕjaŋ mjan]   (without lenition)   'no fried noodles'
                                   → *[wu **ɻa** tɕjaŋ mjan] (with lenition)

         b. /tu tʂʰa tɕy tʂaŋ/ → [tu **tʂʰa** tɕy tʂaŋ]   (without lenition)   'chief of the inspection bureau'
                                   → [tu **ɻa** tɕy tʂaŋ]   (with lenition)
             /mou ʂa an fan/   → [mou **ʂa** an fan]   (without lenition)   'murderer'
                                   → [mou **ɻa** an fan]   (with lenition)
             /pau tʂa wu tʂʰaŋ/ → [pau **tʂa** wu tʂʰaŋ] (without lenition)   'explosive factory'
                                   → [pau **ɻa** wu tʂʰaŋ] (with lenition)

However, we see two examples where retroflex syllables in the same (peninitial) position can (4a) or cannot (4b) undergo lenition in different morphosyntactic structures.

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(4)   a.   /[[[pən **ʈʂʰʐ̩** ʈʂʰə]NP ʈʂu]NP/   → [pən **ɻ̩ʐ̩** ʈʂʰə ʈʂu]   'Benz owner'
                    'Benz'   'owner'
              /[[tu **ʂʐ̩**]NP [ʈʂʰwan ʂwuo]NP]NP /   → [tu **ɻ̩ʐ̩** ʈʂʰwan ʂwuo]   'urban legend'
                    'urban'   'legend'
              /[[ʈʂʐ̩ **ʈʂʐ̩**]AP ʂu]NP li]NP/   → [ʈʂʐ̩ **ɻ̩ʐ̩** ʂu li]   'in the paper book'
                    'paper'   'book' LOC

       b.   /[tə   [[**ʈʂʰʐ̩** tai]AP ʈʂən]NP]VP/   → [tə **ʈʂʰʐ̩** tai ʈʂən]   'suffer from dementia'
                    'suffer' 'dementia' 'illness'   → *[tə **ɻ̩ʐ̩** tai ʈʂən]
              /[kʰan   [[**ʂʐ̩** tɕje]NP pei]NP]VP/ → [kʰan **ʂʐ̩** tɕje pei]   'watch World Cup'
                    'watch'   'world'   'cup'   → *[kʰan **ɻ̩ʐ̩** tɕje pei]
              /[tswo [[**ʈʂʐ̩** jwan]NP ʈʂə]NP]VP/   → [tswo **ʈʂʐ̩** jwan ʈʂə]   'volunteering
                    'do'   'volunteer' 'person'   → *[tswo **ɻ̩ʐ̩** jwan ʈʂə]

Crucially, we observe that morphosyntax can affect where lenition occurs, but lenition does not occur in a fixed morphosyntactic position. I argue that retroflex lenition is conditioned by prosodic structures, which are influenced by, but not perfectly mapped from morphosyntactic structures in Beijing Mandarin. However, this is not to say lenition is inherent to certain prosodic positions. Or in other words, prosody does not directly trigger lenition. Essentially, lenition is a surface phonetic process sensitive to phonetic factors like duration, speech rate, and so on. What I propose is that the crucial factor in triggering retroflex lenition is the (short) duration of the segment. Meanwhile, phonological factors like stress and prosodic structures can affect duration. More specifically, an unstressed syllable or syllable in a prosodically weak position surfaces as phonetically short. Thus, lenition is directly conditioned by (short) duration, which can reflect prosodically weak positions. From this perspective, I use lenition as a probe to look back into the phonology from surface phonetics.

1.2 *Neutral tone*   Neutral tone is one of the lexical tones in Mandarin, often analyzed as the absence of tone. Syllables carrying neutral tones contrast in meaning with ones carrying other tones. An example is given in (5), where the two words in (5a) and (5b) only differ in the tone on the final syllable and have contrastive meanings, forming a minimal pair. In other words, neutral tone is underlying in the lexicon.

(5)   a.   [tɕje55 **faŋ214**] 'street interview'
       b.   [tɕj55 **faŋ**]   'neighbors'

Despite neutral tone being phonemic in the language, its distribution is subject to some constraints. Most neutral-tone syllables belong to functional categories (6a) or are products of reduplication like (6b). They can also be part of the lexicon (6c), where the absence of tone on the second syllable is unpredictable. Crucially, neutral-tone syllables cannot occur initially, and they rarely occur adjacent to each other. I propose these distributional constraints are justified by phonology, and specifically, neutral-tone syllables are always footed on the weak syllable of a trochee.

(6)   a.   [ʈʂʰʐ̩55 **lə**]   'eat-ASP'
       b.   [kɤ55 **kɤ**]   'brother'
       c.   [lau214 **ʂʐ̩**]   'honest'

Second, neutral-tone syllables never occur adjacent to each other in the lexicon[1], as illustrated in (7).

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[1] There are rare cases that neutral-tone syllables can be in adjacent positions. That is when they are in a derived morphosyntactic environment, where the two functional morphemes with neutral tones are adjacent, as illustrated below. These adjacent neutral tone syllables are not part of the lexicon, because they do not form a unit together.
          Ni214   chi55-**le**   **ma**?
          You   eat-ASP   POLQ
          'Did you eat?'

(7)   *[tɕje tɕje]   cf. [tɕje35 **tɕje**]   'sister'

These neutral-tone syllables are underlying in the lexicon, and they always surface bearing a neutral tone. Additionally, there is another type of syllable that can either surface with a full tone or a neutral tone in free variation. As shown in (8), although the form with a neutral-tone syllable (8a) is more frequently used, (8b) with a full-tone is also acceptable.

(8)   a. [wei35 **tɕʰyn**]   'apron'
           b. [wei35 **tɕʰyn35**]

It has been argued that the word has an underlying full-tone syllable, and the change to a neutral tone is due to it being on an unstressed position (Chen 1974). Noticeably, tone sandhi still applies although the surface environment for tone sandhi (i.e., 214 214) no longer exists, resulting in opacity. This illustrates tone sandhi applies after tone deletion.

(9)   Tone 3 Sandhi: (214) → (35) / ___ (214)
                    /ɕjau214 ma214/ → [**ɕjau35** ma214]   'small horse'

I will term this type of neutral-tone syllable as *derived*, as opposed to *underlying* neutral-tone syllables that does not have a full-tone counterpart. Both types of neutral-tone syllable will be discussed with regards to retroflex lenition.
        In the rest of the paper, I will first lay out the data illustrating the difference between full-tone retroflex syllables and neutral-tone retroflex syllables with regards to their prosodic positions and its effect in triggering lenition. Crucially, I argue that the distribution of neutral tones affects prosodic parsing and furthermore, the lenition sites. Then, I will provide an analysis in Optimality Theory to account for the lenition patterns with neutral-tone syllables, followed by discussions and future steps.

2   Data

        In words with only full-tone syllables, lenition occurs on the retroflex syllable in the medial syllable in (10b) but fails to occur on the retroflex syllable in the final position in (11b). In contrast, neutral-tone retroflex syllables can undergo lenition in either medial or final position, illustrated in (10a) and (11a). Note that the segmental context is not of relevance here as discussed earlier, and each pair of words have the same morphosyntactic bracketing.

(10)   Medial position
           a.   Neutral tone: / [ku51 **ʂʐ̩**] xwei51/ → [ku51 **ɻʐ̩** xwei51]   'story circle'
           b.   Full tone: / [tɕiŋ214 **ʂʐ̩51**] tiŋ55/ → [tɕiŋ214 **ɻʐ̩51** tiŋ55]   'police department'

(11)   Final position
           a.   Neutral tone: /pu51 [lau214 **ʂʐ̩**] / → [pu51 lau214 **ɻʐ̩**]   'not honest'
           b.   Full tone: /ta51 [tu55 **ʂʐ̩51**] /   → *[ta51 tu55 **ɻʐ̩51**] / [ta51 tu55 **ʂʐ̩51**]   'metropolitan'

Furthermore, we see when there are two adjacent retroflex syllables in the medial and final position of a trisyllabic structure, it is the medial retroflex syllable that undergoes lenition in the structure with full tones, and it is the word-final neutral-tone retroflex syllable that undergoes lenition in (5a).

(12)   a. Neutral tone
      /ɕɥe35 **tʂʐ̩55 ʂʐ̩**/   → [ɕɥe35 tʂʐ̩55 **ɻʐ̩**] / *[ɕɥe35 **ɻʐ̩55** ʂʐ̩]   'learn knowledge'
           b. Full tone
      /ta51 **tʂʰəŋ35 ʂʐ̩51**/ → [ta51 **ɻɥe**35 ʂʐ̩51] / *[ta51 tʂʰəŋ35 **ɻʐ̩51**]   'big city'

Thus, the question concerns why neutral-tone retroflex syllables can undergo lenition wherever they occur while full-tone retroflex syllables are restrained to undergo lenition in certain positions, demonstrated in (10) and (11). Furthermore, as shown in (12), when both a full-tone retroflex syllables are eligible for lenition, why is the neutral-tone retroflex syllable prioritized?

3   Analysis

3.1   *Evidence for foot structure*   Beside the requirement that a retroflex obstruent in the onset triggers lenition, there are additional positional restraints retroflex lenition obeys. First, lenition cannot occur in adjacent positions, as shown in (13)[2]. Only the first of the two retroflex syllables undergoes lenition, but never both.

(13)   /waŋ **ʂəŋ ʈʂaŋ** tɕja/ → [waŋ **ɻəŋ ɻʂaŋ** tɕja]
                                →*[waŋ **ɻəŋ ɻaŋ** tɕja]   'Governor Wang's home'
          /tɕje **ʈʂʰẓ ʈʂʰa** tɕʰjan/ → [tɕje **ʈʂʰẓ ɻa** tɕʰjan]
                                →*[tɕje **ɻẓ ɻa** tɕʰjan]   'borrow tea money'
          /**ʈʂuŋ ʈʂẓ** jwan/   → [ʈʂuŋ **ɻẓ** jwan]
                                →*[**ɻuŋ ɻẓ** jwan]   'plantation'
          /**ʈʂʰuŋ ʈʂuŋ ʂəŋ**/   → [ʈʂʰuŋ **ɻuŋ ʂəŋ**]
                                →*[**ɻuŋ ɻuŋ** ʂəŋ]
                                →*[ʈʂʰuŋ **ɻuŋ ɻəŋ**]
                                →*[**ɻuŋ ɻuŋ ɻəŋ**]   'middle schooler'

Second, lenition never occurs in initial positions, as shown in (14).

(14)   /**ʈʂaŋ** lau ʂẓ/   → [ʈʂaŋ lau ʂẓ]
                                →*[**ɻaŋ** lau ʂẓ]   'Teacher Zhang'
          /ʂaŋ tjan li/   → [ʂaŋ tjan li]
                                →*[**ɻaŋ** tjan li]   'in the shop'
          /ʈʂʰaŋ tɕʰjan pi/   → [ʈʂʰaŋ tɕʰjan pi]
                                →*[**ɻaŋ** tɕʰjan pi]   'long pencil'

I propose that these two observations taken together show that the domain lenition operates on is a binary foot, and more specifically, a trochee. The weak syllable of a trochee is unstressed and surfaces as phonetically short, and a retroflex syllable in this position can thus trigger lenition. In (13), lenition does not occur in adjacent positions is because two weak beats cannot be adjacent to each other within the same foot. In (14), lenition cannot occur initially, as a trochee never starts with a weak beat.

   Additionally, trisyllabic structures with different morphosyntactic bracketing all have the same lenition site of the medial syllable. Following the binary foot analysis, the lenition site is parsed on the weak syllable of a trochee, illustrated in (15a). There is another possibility that we posit a ternary unit for the lenition domain, where the medial syllable is stipulated to be the lenition site, schematized in (15b).

(15)   Morphosyntactic structure: [σ σ] σ / σ [σ σ] / [σ σ σ]
          a.   Binary foot analysis: ('σ **σ**) σ
          b.   Ternary foot analysis: (σ **σ** σ)

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[2] The blocking of retroflex lenition in successive syllables is not due to an effect of Obligatory Contour Principle (OCP) dissimilation constraint violation that bans two instances of /ɻ/ in neighboring syllables' onsets. /ɻ/ is a legal onset in the language, and the /ɻ-ɻ/ sequence is viable in many other examples that do not involve lenition. The below examples illustrate a set of disyllabic, trisyllabic and tetrasyllabic words with adjacent syllables with rhotic onsets.

       /**ɻəŋ ɻan**/   → [**ɻəŋ ɻan**]   'still'
       /tsẓ **ɻan ɻəŋ**/   → [tsẓ **ɻan ɻəŋ**]   'natural person'
       /sẓ **ɻan ɻə** ljaŋ/ → [sẓ **ɻan ɻə** ljaŋ]   'natural heat'

The direct argument against the ternary foot analysis is that a neutral-tone retroflex syllable can undergo lenition either in medial or final position of a trisyllabic structure, as shown in (10a) and (11b). This requires an additional stipulation that the final syllable of a ternary foot is also a possible lenition site when occupied by a neutral tone syllable. However, this fails to account for a structure like (16) (12a repeated), where a retroflex full-tone syllable is in the medial position and a retroflex neutral-tone syllable is in the final position. While it should be predicted that both syllables can undergo lenition, only the neutral-tone retroflex syllable lenites, as shown in (16).

(16)   /ɕye35 tʂʐ̩55 ʂʐ̩/   → [ɕye35 tʂʐ̩55 ɻʐ̩] / *[ɕye35 ɻʐ̩55 ɻʐ̩]   'learn knowledge'

On the contrary, the binary foot analysis can account for this since the two adjacent retroflex syllables cannot be both on the weak beat and trigger lenition. On this account, I propose that only the binary foot analysis can capture the lenition site patterns.

3.2   *OT analysis of full-tone trisyllabic structures* [3]   Trisyllabic structures with different morphosyntactic composition have the same footing, as the medial syllable is always the lenition site. Under the binary foot analysis, the medial syllable in all three structures is footed on the weak syllable of trochee, as illustrated in (15a). I propose that the constraint driving this morphosyntax-prosody mismatch is ALL-FT-LT. Its definition is given in (17).

(17)   **ALL-FT-LT**: Assign a violation for each syllable that separates the left edge of a foot from that of a prosodic word in the output. (McCarthy & Prince 1993)

The constraint driving the faithfulness between morphosyntax and prosody is MATCH, originally proposed in Selkirk (2011) and its definition is given in (18).

(18)   **MATCHWORD:** A word in syntactic constituent structure must be matched by a corresponding prosodic constituent, call it ω, in phonological representation.

However, there are two things the original MATCH constraint cannot account for deriving the prosodic structures for retroflex lenition. First, Selkirk (2011)'s MATCH constraint ensures the isomorphism between syntax and prosody, i.e., syntactic word matching prosodic word in (18). In Mandarin's case, both morphological compounds and syntactic phrases with the same structures appear to receive the same prosodic parse. As shown in (19a-b), both the medial retroflex syllables are footed on the weak beat and thus can lenite.

(19)   a. Morphological
        /[tu tʂʰa]ₙₚ tɕy]ₙₚ/   → [(ˈtɕiŋ ɻa) tɕy]_ω   'inspection bureau'
        b. Syntactic
        /[tɕjan tʂʰa]ᵥ ʂwei]ᵥₚ/ → [(ˈtɕjan ɻa) ʂwei]_ω   'go check the water'

Therefore, we need a MATCH constraint that does not differentiate morphological compounds from syntactic phrases as long as their hierarchical structures are identical. Second, we see that a phrase (i.e., [tu tʂʰa]ₙₚ in 19a and [tɕjan tʂʰa ʂwei]ᵥₚ in 19b) can either be mapped to a foot or something bigger (e.g., a prosodic word). The original MATCH constraint cannot achieve this one-to-more mapping. Thus, I propose we need an updated version of the original constraint that is only sensitive to morphosyntactic bracketing but not the specific label-matching. I term this the category-general MATCH constraint, definition given in (20). (20a) illustrates the MATCH constraint ensuring morphosyntax-prosody isomorphism, and (20b) ensures the prosody-morphosyntax isomorphism.

(20)   a. **MATCH(M-S, Π):** Assign a violation for each morphosyntactic constituent M-S that does not have a corresponding prosodic constituent π.

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[3] For a discussion of the prosodic structures for more full-tone multisyllabic structures and their lenition sites, see Wang (To appear).

b. **MATCH(Π, M-S):** Assign a violation for each prosodic constituent π that does not have a corresponding morphosyntactic constituent M-S.

Other foot well-formedness constraints are listed in (21a-b).

(21)   a. **FTBIN(σ)**: Assign a violation for each non-binary foot in the output.
        b. **Parse-σ**: Assign a violation for each unfooted syllable in the output. (McCarthy & Prince 1993)

In tableau (22), we see candidates with degenerate foot (22c) and ternary foot (22d) get eliminated due to violations in the undominated FTBIN(σ), though they satisfy PARSE-σ better. The winner (22a) satisfies ALL-FT-LT while violating MATCH(M-S, Π) and MATCH(Π, M-S), the opposite of candidate (22b). This shows the constraint ranking of ALL-FT-LT >> MATCH(M-S, Π) and MATCH(Π, M-S). Lenition sites are underlined in the underlying representation.

(22)   [tɕʰy51 [tʂʰau55 ʂʐ̩51]] → (ˈtɕʰy51 ɻau55) ʂʐ̩51   'go to grocery store'
        'go'   'grocery store'

[σ [σ σ]]	FTBIN(σ)	PARSE-σ	ALL-FT-LT	MATCH (M-S,Π)	MATCH (Π, M-S)
☞ a.[(ˈσ σ) σ]_ω		*		*	*
b. [σ (ˈσ σ)]_ω		*	*W	L	L
c. [(ˈσ) (ˈσ σ))]_ω	*W	L	*W	L	*
d. [(ˈσ σ σ)]_ω	*W	L		*	L

In the left branching trisyllabic structure in (23)[4], winner (23a) satisfies all ALL-FT-LT, MATCH(M-S, Π) and MATCH(Π, M-S) and harmonically bounds candidate (23b).

(23)   [[xu51 ʂou214]   ʂwaŋ55] → (ˈxu51 ɻou214) ʂwaŋ55   'hand cream'
        'hand protector' 'cream'

[[σ σ] σ]	FTBIN(σ)	PARSE-σ	ALL-FT-LT	MATCH (M-S,Π)	MATCH (Π, M-S)
☞ a.[(ˈσ σ) σ]_ω		*			
b. [σ (ˈσ σ)]_ω		*	*W	*W	*W

3.3   *OT analysis of underlying neutral-tone trisyllabic structures*   Regarding syllables with underlying neutral tone, we see that they can undergo lenition in either medial or final position. There can be two possible analyses to account for this: the first one is what I term the PHONETICS ACCOUNT, which predicts that neutral-tone syllables are inherently phonetically short, and thus they can lenite wherever they are. The second analysis is the PHONOLOGICAL ACCOUNT, which predicts that neutral-tone syllables are always parsed on the weak syllable of a trochee. Since it is an unstressed position, they surface as phonetically short and thus trigger lenition.

To determine which of the two analyses are correct, we examine the structure in (24), where both the medial and final positions are filled with neutral-tone retroflex syllables. Under the PHONETICS ACCOUNT, both neutral-tone retroflex syllables should be able to lenite despite their prosodic positions. However, this is not what we observe: only the medial syllable lenites. This observation supports the PHONOLOGICAL ACCOUNT, which predicts that only one of the two adjacent retroflex syllables can be footed on the weak syllable of a trochee and undergo lenition.

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[4] A flat trisyllabic structure like [σ σ σ] will also have the prosodic structure of (ˈσ σ) σ and the same violation marks as (23a). The tableau is omitted for purpose of space.

(24)   /lau214 ʂʐ̩ ʈʂə/   'honest-PROG'
       a. PHONETICS ACCOUNT: *[(ˈlau214 ɻʐ̩̍) ɻə]
       b. PHONOLOGICAL ACCOUNT: [(ˈlau214 ɻʐ̩̍) ʈʂə]

Thus, I argue that the PHONOLOGICAL ACCOUNT correctly captures the lenition patterns, and neutral-tone syllables need to always be footed on the weak syllable of a foot. This account argues that being phonetically short is a necessary yet insufficient condition to trigger lenition. In other word, a retroflex neutral-tone syllable also needs to be in an unstressed position to lenite.

The tendency for neutral-tone syllables to be footed on the unstressed syllable is captured by the WEAKNEUTRAL constraint in (25). The influence of tones on stress placement and foot structures (and vice versa) is attested cross-linguistically (de Lacy 2002, 2007a-b, a.o.). Specifically, there is a hierarchy of tonal preferences in different prosodic positions, based on tone heights. Low tones are prone to non-head position of a foot, or in other words, the distribution of low tones can affect prosodic parsing. My WEAKNEUTRAL constraint follows a similar line of reasoning that the position of neutral-tone syllables affects foot structures, and they prefer to be foot non-heads.

(25)   **WEAKNEUTRAL**: Assign a violation for each neutral-tone syllable NOT on a weak syllable of a trochee in the output.

In (26), we see that the winner (26a) satisfies WEAKNEUTRAL by having the neutral-tone syllable on the weak beat at the cost of violating ALL-FT-LT. Candidate (26b) is the opposite, violating WEAKNEUTRAL while satisfying ALL-FT-LT. This illustrates the constraint ranking: WEAKNEUTRAL >> ALL-FT-LT.

(26)   /[pu51 [lau214 ʂʐ̩]]/ → [pu51 lau214 ɻʐ̩̍]   'not honest'
           'not' 'honest'

/[pu51 [lau214 ʂʐ̩]]/	WEAKNEUTRAL	ALL-FT-LT	MATCH (M-S,Π)	MATCH (Π, M-S)
☞ a. [pu51 (ˈlau214 ɻʐ̩̍)]_ω		*		
b. [(ˈpu51 lau214) ʂʐ̩̍]_ω	*W	L	*W	*W

In the left-branching trisyllable structure with a neutral-tone in the medial position, we see the winner (27a) is a perfect winner satisfying all WEAKNEUTRAL, ALL-FT-LT and both MATCH constraints, and it thus harmonically bounds candidate (27b).

(27)   /[[ku51 ʂʐ̩] xwei51]/ → [ku51 ɻʐ̩̍ xwei51]   'story circle'
           'story' 'circle'

/[[ku51 ʂʐ̩] xwei51]/	WEAKNEUTRAL	ALL-FT-LT	MATCH (M-S,Π)	MATCH (Π, M-S)
☞ a. [(ˈku51 ɻʐ̩̍) xwei51]_ω				
b. [ku51 (ˈʂʐ̩̍ xwei51)]_ω	*W	*W	*W	*W

Furthermore, the example in (28) illustrates an example in which the medial syllable is a full-tone retroflex syllable, and the final syllable carries a neutral tone. Lenition does not occur on the medial syllable in this case, since the neutral-tone syllable needs to be footed on the final weak syllable. This makes the preceding medial retroflex syllable a stressed syllable, and thus, retroflex lenition does not occur. If lenition occurs, then it means the retroflex syllable is footed on the unstressed syllable of a trochee. The following neutral-tone syllable cannot be footed on the unstressed syllable of a trochee, violating WEAKNEUTRAL. Note that an unfooted syllable is unable to trigger lenition under current proposal.

(28)   /mai214 ʈʂʰəŋ35 tsʐ̩/ → [mai214 (ˈʈʂʰəŋ35 tsʐ̩)]
                                → *[(ˈmai214 ɻəŋ35) tsʐ̩]   'buy orange'

/[mai214 [tʂʰɔŋ35 tsẓ]]/	WEAKNEUTRAL	ALL-FT-LT	MATCH (M-S,Π)	MATCH (Π, M-S)
☞ a. [mai214 (ˈtʂʰɔŋ35 tsẓ)]ω		*		
b. [(ˈmai214 ɻəŋ35) tsẓ]ω	*W	L	*W	*W

In summary, this section illustrates that the distribution of underlying neutral-tone syllables affects prosodic parsing, as they always need to be footed on the weak syllable. Full-tone and neutral-tone syllable in the same prosodic position still contrast in strength, which instantiates the main claim of this paper that tone and prosody are independent of each other in Mandarin.

3.4 *OT analysis of derived neutral-tone trisyllabic structures*   For derived retroflex neutral-tone syllables, they can trigger lenition like their underlying counterparts all the same, except that they also have the option of surfacing as full tone. As shown in the example in (29a), we see if the derived neutral-tone syllable (tone marked in parentheses) surfaces with a neutral tone, then it needs to be footed on the weak syllable of a foot. This forces the retroflex syllable to fall on the strong beat of a foot and lenition cannot happen. On the other hand, if the retroflex syllable lenites, then that means it is footed on the weak syllable of a foot. The neutral tone needs to be restored back to a full tone, as shown in (29b).

(29)   /pu51 tʂẓ55 tau(51)/   'do not know'
        a. [pu51 (ˈtʂẓ55 tau)]
        b. [(ˈpu51 ɻẓ) tau51]

However, in the OT analysis with strict domination, only one winner (30a) can be derived. Another possible winner (30b), which is more faithful to the morphosyntactic structure but violates ALL-FT-LT, gets immediately eliminated due to the violation in ALL-FT-LT.

(30)   /[pu51 [tʂẓ55 tau]]/ → pu51 (ˈtʂẓ55 tau) 'do not know'
          'not'   'know'

/[pu51 [tʂẓ55 tau(51)]]/	WEAKNEUTRAL	ALL-FT-LT	MATCH (M-S,Π)	MATCH (Π, M-S)
☞ a. [(ˈpu51 ɻẓ) tau51]ω			*	*
b. [pu51 (ˈtʂẓ tau)]ω		*W	L	L

One way to derive optionality is to use Harmonic Grammar, where constraints are weighted (Legendre et al. 1990). Candidates with the same harmony will be of the same likelihood to surface. The crucial weighting relationship is that $\mathcal{W}$ (ALL-FT-LT) = $\mathcal{W}$ (MATCH(M-S, Π)) + $\mathcal{W}$ (MATCH(Π, M-S)). As illustrated in tableau (31), two candidates (31a) and (31b) both have the same harmony and thus can surface as winners.

(31)   /[pu51 [tʂẓ55 tau]]/ → pu51 (ˈtʂẓ55 tau) 'do not know'
          'not'   'know'

/[pu51 [tʂẓ55 tau(51)]]/	WEAKNEUTRAL 3	ALL-FT-LT 2	MATCH (M-S,Π) 1	MATCH (Π, M-S) 1	HARMONY
☞ a. [(ˈpu51 ɻẓ) tau51]ω			-1	-1	-2
☞ b. [pu51 (ˈtʂẓ tau)]ω		-1			-2

The other option is to posit that there are two kinds of underlying representations for derived neutral tone syllables. Specifically, in (32), when the input is the underlying representation with a neutral tone, then

WEAKNEUTRAL ensures that the neutral-tone syllable is footed on the weak syllable of the trochee. The preceding retroflex syllable will then be on the stressed position of a trochee, unable to trigger lenition.

(32)　　　Underlying representation 1: /[pu51 [ʈʂʐ̩55 tau]]/ → pu51 (ˈʈʂʐ̩55 tau) 'do not know'
　　　　　　　　　　　　　　　　　　　'not'　　'know'

/[pu51 [ʈʂʐ̩55 tau]]/	WEAKNEUTRAL	ALL-FT-LT	MATCH (M-S,Π)	MATCH (Π, M-S)
☞ a. [pu51 (ˈʈʂʐ̩55 tau)]ω		*		
b. [(ˈpu51 ɻʐ̩55) tau]ω	*W	L	*W	*W

In (33), when the underlying representation is with a full tone, the WEAKNEUTRAL constraint is vacuously satisfied by both candidates. Thus, the winner is the one that satisfies the next high-weighted constraint ALL-FT-LT, with the foot aligned to the left edge of the word. Under this footing, the retroflex syllable is footed on the weak syllable of a trochee, thus triggering lenition.

(33)　　　Underlying representation 2: /[pu51 [ʈʂʐ̩55 tau51]]/ → (ˈpu51 ɻʐ̩55) tau51 'do not know'
　　　　　　　　　　　　　　　　　　　'not'　　'know'

/[pu51 [ʈʂʐ̩55 tau(51)]]/	WEAKNEUTRAL	ALL-FT-LT	MATCH (M-S,Π)	MATCH (Π, M-S)
☞ a. [(ˈpu51 ɻʐ̩) tau51]ω			*	*
b. [pu51 (ˈʈʂʐ̩ tau)]ω		*W	L	L

In sum, this section shows the derived neutral-tone syllables also need to be footed on the weak beat as underlying neutral-tone syllables do. Since it is optional for them to surface as full tone, parallel OT fails to derive the optionality of multiple winners, which can be resolved in other variants of OT, such as Harmonic Grammar. An alternative analysis is that words with derived neutral-tone syllable has separate mental representations for surface forms with full tone and neutral tone. Depending on whether the surface tone is a full or neutral tone, the prosodic structures change and so do the lenition sites.

4　Theoretical implications and future directions

In this paper, I discuss the incorporation of neutral-tone syllables into the analysis of retroflex lenition in extension to the analysis in Wang (To appear). Crucially, a neutral-tone retroflex syllable can always undergo lenition, in contrast to full-tone retroflex syllables. I argue that this contrast illustrates that the distribution of neutral tones can affect prosodic parsing. More specifically, neutral-tone syllables are always on a prosodically weak position, the weak syllable of a trochee. Syllables in this unstressed position surface as phonetically short and can undergo lenition. By examining the sites of lenition, we can look deeper into the prosodic structures that underlie them. Neutral-tone retroflex syllables can lenite not purely based on their phonetic properties, but because of their prosodic positions. This tone-driven (un)stress is warranted in previous literatures on tone-prosody interaction (de Lacy 2002, 2007a-b), where low tones specifically are footed as non-heads. As a future step, it is worth looking into the comparability between neutral tone and low tone.

Second, in final positions, neutral-tone retroflex syllables can lenite although susceptible to final lengthening, contrary to the final retroflex full-tone syllable. This shows that syllables in the same prosodic positions can contrast in strength. This is an extension to the discussion in the first section, where syllables with the same tones can contrast in strength in stressed and unstressed positions. Essentially, I propose there is at least[5] a three-way contrast between the interaction of syllable strengths and prosodic positions in Beijing

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[5] The strength of an unfooted full-tone syllable and an unstressed syllable of a maximal foot still needs to be examined and incorporated into the analysis, pending further evidence.

Mandarin, as shown in the table below. '3' marks the strongest, and '1' marks the weakest syllable. A future step is to find phonetic and also phonological evidence, e.g., other phonological processes that are sensitive to different syllable strengths, to corroborate this existence of this contrast.

(34)   Syllable strength in Beijing Mandarin

	Weak syllable of a trochee	Strong syllable of a trochee
Full tone	2	3
Neutral tone	1	N/A

For theoretical implications, retroflex lenition, as a phonetic process, is indirectly conditioned by prosodic factors, which lies in the realm of phonology. Prosodic structures are conditioned by morphosyntax in Mandarin, but there is a mismatch. Tone, as both a phonetic and phonological factor, can also affect prosody. Lenition provides great avenues to study the phonetics-phonology interface, syntax-prosody interface, and showcases tone-prosody interaction in Mandarin, and furthermore, tonal languages where stress and prosody are not distinctive.

For future directions, a phonetics study is needed to examine the realization of retroflex lenition and syllables on the weak beat of the trochee. Reduced duration of segments in this position would provide phonetic-based evidence for the prosodic structures provided in this paper.

5   Conclusion

In this paper, a foot analysis is provided to account for the distribution of neutral-tone syllables in relation to lenition sites and their prosodic positions. Neutral-tone syllables are always parsed on the prosodically weak positions, i.e., the weak beat of a trochee. Constraint interactions in parallel OT can account for most of the patterns but fail to capture the optionality for structures with derived neutral-tone syllables. An alternative analysis is provided in Harmonic Grammar.

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