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Non-contrastive features and categorical patterning in Chinese diminutive suffixation: MAX[F] *or* IDENT[F]*?**

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1 Introduction

The influence of non-contrastive phonetic details such as intergestural timing, stop release burst and articulatory effort expense on phonological patterning has been discussed extensively in Browman & Goldstein (1992), Flemming (1995), Jun (1995), Kirchner (1997), Silverman (1997), Boersma (1998), Gordon (1999), Hayes (1999), Steriade (1999, 2000), Zhang (forthcoming), among others. Even though the way in which phonology incorporates phonetic factors is debatable (see Hayes & Steriade, forthcoming for an overview of the debate and §3.1.1 for more detailed discussion), the fact that there exist phonological patterns that are governed by phonetic factors seems less so. In this paper, without committing myself to any view of how phonetic factors are encoded in phonology, I present the case of Chinese retroflex suffixation in support of the relevance of non-contrastive phonetic features to categorical phonological patterning. In addition, I argue that MAXFEATURE constraints (Lombardi 1995, 1998, Casali 1996, Pulleyblank 1996, Causley 1997, Walker 1999; henceforth MAX[F]) are needed to account for the data in question.

In many northern Chinese dialects, a retroflex approximant /ɻ/ can be suffixed to a noun to indicate the diminutive or endearing meaning of the noun. In this paper, I focus on the interaction between the retroflex

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suffix and the nasal coda of the noun stem syllable to which the suffix is added.

Let us take the Beijing dialect of Mandarin as an example. In Beijing, upon /ɹ/-suffixation, the nasal coda in both /CVn/ and /CVŋ/ is lost, but a contrast of vowel nasalisation results – the vowel in /CVn+ɹ/ is realised as oral while the vowel in /CVŋ+ɹ/ is realised as nasalised (Dow 1972, 1984, Lin & Wang 1992), as shown in (1).

(1)	*Noun stem*	*Diminutive noun*	
a.	p^{h}an	p^{h}aɹ	'plate'
	ɕin	ɕiɹ	'heart'
b.	p^{h}ɑŋ	p^{h}ɑ̃ɹ	'side'
	ɕiŋ	ɕĩɹ	'star'

An aerodynamic study I conducted (§2) shows that in the stem forms, the vowel in /CVŋ/ has a significantly longer nasal flow duration than the vowel in /CVn/, indicating that the vowel is more nasalised in /CVŋ/ than /CVn/. I claim that the difference between the realisation of /CVn+ɹ/ and /CVŋ+ɹ/ reflects this difference in the stem forms.

To capture this effect in an optimality-theoretic analysis, we may consider two distinct approaches – Ident-OO[F] and Max-OO[F], both of which are based on the correspondence between two output forms – the stem form and the suffixed form (see Burzio 1994, Benua 1995, Flemming 1995, Kenstowicz 1995, Steriade 2000 for output–output correspondence). Since output–output correspondence is the only kind of correspondence relation that I am concerned with in this paper, I will use the abbreviated terms Ident[F] and Max[F] henceforth. The relevant feature here is [nasal].

Duanmu (1990: 55) contends that in the unsuffixed forms, the vowel is nasalised before a velar nasal, but not before an alveolar nasal. When the suffix /ɹ/ is added, the vowel simply maintains its nasality and orality in the two cases, respectively. The coda nasal in both cases is replaced by the /ɹ/ suffix. This analysis can translate into an Ident[F] approach if we assume that in the surface representation of the unsuffixed forms, the vowel has a [−nasal] specification before an /n/-coda, but a [+nasal] specification before an /ŋ/-coda. Therefore, the inputs for the suffixed forms are /CVn+ɹ/ and /CṼŋ+ɹ/, respectively. A highly ranked Ident[nas] constraint will ensure that the vowel surfaces as oral in /CVn+ɹ/, but nasalised in /CṼŋ+ɹ/, as shown in (2). In (2a), the winner is [CVɹ], since it does not violate either Ident[nas] or the markedness constraint against nasalised vowels. In (2b), the winner is [CṼɹ], since although it violates *V_{nas}, its rival [CVɹ] violates the higher-ranking Ident[nas].[1]

[1] As one anonymous reviewer points out, this is only one possible Ident[F] approach. Other approaches might involve the use of underspecification. These alternatives are discussed in detail in §6.

(2)

		Id[nas]	*V_{nas}
a.	/CVn+ɻ/		
☞	CVɻ		
	CṼɻ		*!
b.	/CṼŋ+ɻ/		
	CVɻ	*!	
☞	CṼɻ		*

The alternative approach – Max[F] – does not assume the categorical perception of nasalisation on the vowel. It only assumes that the aerodynamic result has the following perceptual consequence: the nasality induced by /ŋ/ is stronger than the nasality induced by /n/. In the analysis, we require a feature to be more faithfully preserved if it is perceptually more salient. To do this, we may posit two Max[F] constraints, Max[+nas]$_{strong}$ and Max[+nas]$_{weak}$, and an intrinsic ranking between these two constraints projected from phonetics – Max[+nas]$_{strong}$ ≫ Max[+nas]$_{weak}$. In Beijing, the nasality induced by /ŋ/ belongs to [+nasal]$_{strong}$, while the nasality induced by /n/ belongs to [+nasal]$_{weak}$. With the ranking Max[+nas]$_{strong}$ ≫ *V_{nas} ≫ Max[+nas]$_{weak}$, the correct pattern of Beijing is generated, as shown in (3). In the tableaux, the underlying representations for the suffixed forms are transcribed as /CṼn+ɻ/ and /CV͌ŋ+ɻ/, respectively. The different representations of nasalisation indicate the different degrees of nasalisation induced by the coda nasals and do not represent the specification of [nasal] on the vowel. In tableau (3a), the winner is [CVɻ], since it only violates the lower-ranking faithfulness constraint, while its rival [CV͌ɻ] violates the higher-ranking *V_{nas}. In tableau (3b), the winner is [CV͌ɻ], since although it violates *V_{nas}, its rival [CVɻ] violates the higher-ranking Max[+nas]$_{strong}$ by eliminating a strong nasal percept.[2]

(3)

		Max[+nas]$_{str}$	*V_{nas}	Max[+nas]$_{wk}$
a.	/CṼn+ɻ/			
☞	CVɻ			*
	CV͌ɻ		*!	
b.	/CV͌ŋ+ɻ/			
	CVɻ	*!		*
☞	CV͌ɻ		*	

I argue in this paper that the Max[F] approach is superior. The main argument comes from the factorial typologies of the constraint rankings in

[2] Besides the approach here, which directly encodes phonetic details in the constraints, there is another viable Max[F] approach, which mediates the effects of phonetics in phonology by referring to phonological segments or features that induce the phonetic differences in the constraints and positing universal rankings among them. For the case in question, the constraints and their ranking will be: Max[+nas]$_{ŋ}$ ≫ Max[+nas]$_{n}$. This approach is discussed in more detail in §3.1.1. But in either approach, the existence of grammars that are governed by phonetic details must be acknowledged.

these two approaches: the factorial typology of the MAX[F] approach displays an excellent fit with the data patterns attested in a survey of Chinese dialects, while the factorial typology of the IDENT[F] approach on the one hand predicts patterns that are unattested, and on the other hand fails to generate some attested patterns. I also claim that assuming the stem vowel to have [+nasal] specification is phonetically inappropriate.

Adopting the MAX[F] approach has two consequences for phonological theory. First, we must allow non-contrastive phonetic properties to influence phonological patterning, since in the MAX[F] approach, a non-contrastive phonetic distinction in the strength of nasal perception projects an intrinsic ranking $\text{MAX}[+\text{nas}]_{\text{strong}} \gg \text{MAX}[+\text{nas}]_{\text{weak}}$, and this ranking has phonological consequences, as the tableaux in (3) show. This position on the relation between phonology and phonetics is fundamentally different from the traditional view that phonology and phonetics are distinct, albeit closely related (Chomsky & Halle 1968, Keating 1988a, b, Cohn 1990, 1993, Zsiga 1995, 1997, *inter alia*), and therefore warrants particularly close attention. Motivating this position involves three points: (a) an analysis based on this position can capture the attested data patterns in a principled way; (b) alternative analyses that do not appeal to such a position cannot explain all the data patterns; and (c) such a position does not necessarily weaken the predictive power of phonology. I address all these points in the paper.

Second, MAX[F] constraints are necessary for featural correspondence. In McCarthy & Prince (1995)'s original conception, IDENT[F] is the only type of featural correspondence constraint. IDENT[F] requires the same specification for the feature [F] in corresponding segments in the input and the output. But the definition of IDENT[F] determines that it is only active when the segment that carries [F] is preserved in the output. If the segment is deleted, then there is no corresponding segment in the output, and IDENT[F] is vacuously satisfied, even though the feature [F] has been lost with the segment. Various researchers have pointed out that this is problematic (Lombardi 1995, 1998, Casali 1996, Pulleyblank 1996, Causley 1997, Walker 1999, *inter alia*): we often need to preserve a certain feature even when the segment that carries the feature is deleted. This calls for MAX[F] constraints, which serve exactly this purpose. The relevant feature here is [nasal] on the coda segment: when the coda segment is deleted due to higher-ranking constraints, the phonology must allow the [+nasal] feature originally carried by this segment to be preserved in the output form. Insofar as the assumption that the stem vowel is also specified for [+nasal] is either phonologically inadequate or phonetically inappropriate, and thus an IDENT[F] approach cannot be applied, we must resort to MAX[F] constraints.

The paper will proceed as follows. §2 describes the aerodynamic study of Beijing which establishes that the /ŋ/-coda induces longer vowel nasalisation than the /n/-coda. §3 gives two optimality-theoretic analyses for Beijing, using MAX[F] and IDENT[F], respectively. §§4 and 5 discuss the dialectal typology of /ɹ/-suffixation, and present arguments for a

MAX[F]-based analysis. §6 is further discussion of the MAX[F] and IDENT[F] analyses. §7 reviews two other alternative analyses to the data patterns. The first alternative appeals to the difference in vocalicness between /n/ and /ŋ/. I show that it again fails on the ground of factorial typology. The second alternative is the long-held belief among many traditional Chinese linguists: the loss of /n/ upon /ɹ/-suffixation is due to the conflict of place of articulation between these two consonants; for /ŋ/ however, given that it does not conflict with /ɹ/ in place, it is preserved in its entirety upon suffixation. I show through an EMA (Electromagnetic Articulography) experiment that this account fails on empirical grounds: the dorsal raising gesture of the velar nasal is simply not preserved in the suffixed form. §8 discusses the theoretical implications of this work for the relation between phonology and phonetics. §9 is the conclusion.

2 An aerodynamic study of Beijing Mandarin

2.1 Hypotheses and methods

In this section, I present indirect empirical evidence bearing on the hypothesis that in the unsuffixed forms in Beijing Mandarin the nasality induced by the /ŋ/-coda is perceptually more salient than the nasality induced by the /n/-coda. This hypothesis was tested through an aerodynamic experiment. Specifically, I tested whether there is a longer nasal flow duration during the vowel in /CVŋ/ than the vowel in /CVn/.

The reason why the nasal flow duration during the vowel is a good indication of the strength of nasal perception is threefold. First, the presence of the nasal flow indicates an opening of the velopharyngeal port, which is necessary for the acoustic coupling of the nasal tract with the oral tract. Such acoustic coupling is the main cue for the perception of nasality (Delattre 1954, House & Stevens 1956, House 1957, Takeuchi *et al*. 1975, Maeda 1982). Second, a longer nasal coupling during the vowel gives the vowel a stronger nasal percept. This is shown by studies by Delattre & Monnot (1968) and Whalen & Beddor (1989), who have demonstrated that with equal nasal coupling, longer vowels receive higher nasalisation ratings than shorter vowels. Third, Whalen & Beddor (1989) have also shown that with unambiguous nasality there is no effect of duration on perception. Under the assumption that nasal consonants are unambiguously nasal, we should not expect the duration of the nasal coda to affect the strength of the nasal perception. Through this chain of reasoning, we are led to infer that the nasal flow duration during the vowel in /CVn/ or /CVŋ/ can accurately indicate the relative strength of the perceived nasality induced by the nasal coda: the longer this duration, the stronger the nasal percept.

Our argument on nasal perception is admittedly indirect. However, the reasoning I propose is the only one that allows one to link the remarkable behaviour of Chinese nasals under suffixation to the phonetic differences that are easily observable between these nasals.

Another concern for the present study is the degree of nasal coupling on the vowel in /CVn/ and /CVŋ/. In Delattre & Monnot (1968) and Whalen & Beddor (1989)'s studies, the effect of duration is found under matched nasal coupling conditions (by constant formant configuration in Delattre & Monnot, and constant velopharyngeal port opening in Whalen & Beddor). For the present study, to ensure that any durational differences, if found, translate into perceptual differences, we must also show that the nasal coupling during the vowel in /CVŋ/ is at least as strong as the nasal coupling during the vowel in /CVn/. The parameter that I used to monitor this effect was the average nasal airflow (*ml/s*) during the nasalised portion of the vowel. The degree of nasal coupling is primarily determined by the size of the velopharyngeal opening (House & Stevens 1956, Abramson *et al*. 1981, Bell-Berti & Baer 1983), and nasal airflow is an indicator of the size of this opening (Benguerel 1974, Cohn 1990, 1993, Huffman 1990). But nasal airflow is also influenced by two factors other than the velopharyngeal opening – the overall glottal flow and the impedance in the oral tract. When the overall glottal flow increases, the nasal flow may increase even when the velopharyngeal opening stays the same; and when the oral impedance increases, given that more air will be forced out of the nasal tract, the nasal flow may also increase when the velopharyngeal opening stays the same. Since the overall glottal flow and oral impedance have been reported to have negligible effects in the acoustic coupling between the nasal and oral tracts (House & Stevens 1956, Bell-Berti & Baer 1983, Krakow & Huffman 1993), it is important for us to factor out their influences on the nasal flow in our study. To factor out the influence of the overall glottal flow, I simultaneously collected the oral flow and calculated the proportion of the nasal flow in the overall flow (= nasal flow + oral flow). To control for the effect of oral impedance, I used matched vowels between /CVn/ and /CVŋ/ to ensure matched oral configurations in these two environments. The nasal coda has two slight allophonic effects on the vowel quality in Beijing Mandarin: the vowel in the /__ ŋ/ context is slightly lower (Dow 1972, 1984), which will decrease the oral impedance; but the /__ ŋ/ context might also draw the tongue further back, which will increase the oral impedance. Therefore, it is reasonable to assume that these slight allophonic effects on oral impedance generally cancel each other out.

In (4), I lay out the specific hypotheses to be tested in the aerodynamic experiment on Beijing Mandarin.

(4) In the unsuffixed form:
  a. the vowel in /CVŋ/ has a longer nasal airflow duration than that in /CVn/;
  b. the proportion of the nasal airflow in the overall glottal airflow is no less during the nasalised portion of the vowel in /CVŋ/ than during the nasalised portion of the vowel in /CVn/.

As I have discussed above, if both hypotheses are true, we can safely conclude that the nasality induced by the /ŋ/-coda is perceptually more salient than the nasality induced by the /n/-coda.

Two male native speakers of Beijing Mandarin – JZ (the author) and HL – participated in the study. The test words included six pairs of /CVn/ and /CVŋ/ words. In each pair, C was a matching oral obstruent and V was a matching vowel. Nasal onsets were avoided. All words had a high level tone (1st tone). The complete word list is given in (5). '˥' indicates high level tone.

(5)

tan˥	'sheet'	taŋ˥	'crotch (of pants)'
kan˥	'dry'	kaŋ˥	'jar'
ɕin˥	'heart'	ɕiŋ˥	'star'
cɕin˥	'today'	cɕiŋ˥	'spirit'
kən˥	'root'	kəŋ˥	'thick soup'
ʈʂən˥	'true'	ʈʂəŋ˥	'argument'

The test words were read in the carrier sentence in (6). Each sentence was read with five repetitions, in randomised order.

(6) [wo ʂʷo __ ʈʂɤ kɤ tsɨ]
I say __ this measure-word character
'I say the character __ .'

Macquirer (an aerodynamic data acquisition system developed by SCICON and the UCLA Phonetics Laboratory) was used to collect the nasal flow, oral flow and audio signal of the sentences. A nasal mask and an oral mask were held by the speaker and pressed tightly around the nose and mouth when the sentences were uttered. These masks were connected to pressure transducers, and the pressures were subsequently converted to electrical signals in millivolts (*mv*). A calibration device was then used to determine the correspondence between the voltage values in *mv* and the nasal flow values in *ml/s*. An example token is given in Fig. 1.

All the recorded tokens were used, as the comparison between the vowel duration in the final and non-final repetitions yielded no significant result. The nasalised portion of the vowel was demarcated by the beginning of positive values in the nasal flow signal and the end of the vowel in the acoustic signal. The duration of the entire vowel and its nasalised portion (*D* in Fig. 1) were measured, and the proportion of the nasalised vowel duration to the entire vowel duration was calculated. The duration of the nasal coda in each token was also measured.

The average nasal airflow during the nasalised portion of the vowel was calculated using the formula in (7a). The average proportion of nasal flow in the overall flow in the nasalised portion of the vowel was calculated using the formula in (7b).

(7) a. $\bar{U}_n = \frac{1}{n}\sum_{i=1}^{n} f_i$ b. $\frac{\bar{U}_n}{U_g} = \frac{1}{n}\sum_{i=1}^{n} \frac{f_i}{f_i + g_i}$

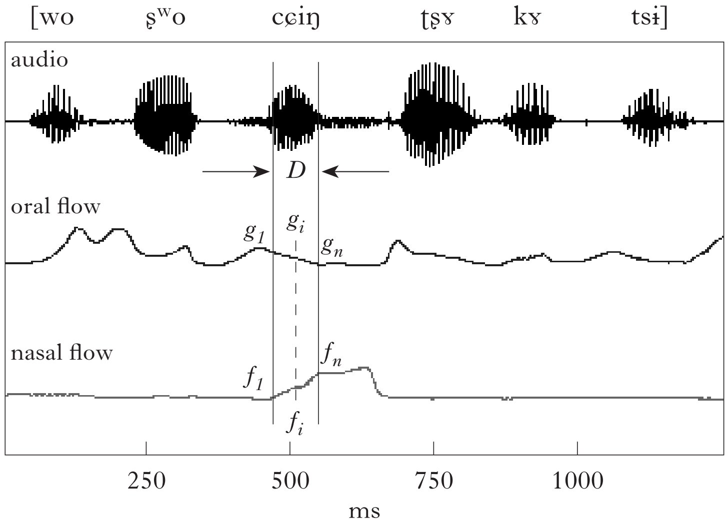


Figure 1

An example token of the aerodynamic data, with the audio signal, oral flow and nasal flow. D represents the duration of the nasalised portion of the vowel, g_1–g_n represent the recorded oral flow values, and f_1–f_n represent the recorded nasal flow values. The sampling rate for the flow measurements is 11025Hz.

The acoustic signals recorded were only used for the purpose of segmentation and duration measurements. No inference on perception was drawn from the acoustic signals, primarily due to the fact that the acoustic consequences of nasal coupling, such as the shift of formant frequencies caused by nasal formants and zeros, are difficult to measure and quantify because of the complexity of the acoustic coupling between the oral and nasal tracts (Cohn 1990, 1993, Krakow & Huffman 1993). Moreover, since an oral mask was used to collect the oral flow during the recording, the acoustic recording was not of high enough quality to do detailed spectrographic analyses.

For each subject, one-way ANOVAs with the nasal place of articulation as the independent factor were carried out for the nasal flow duration, average nasal flow, average overall flow and average nasal flow proportion, to determine the significance of the effects observed. Obviously, these tests treat subjects as a fixed effect and therefore only allow inference about these two subjects in this study. This is the inevitable limitation of any study that only has a small number of subjects (de Jong & Zawaydeh 1999, Max & Onghena 1999).

2.2 Results and discussion

The nasal flow duration during the vowel in /CVn/ and /CVŋ/ is shown in Fig. 2a. The error bar indicates one standard error. For both speakers,

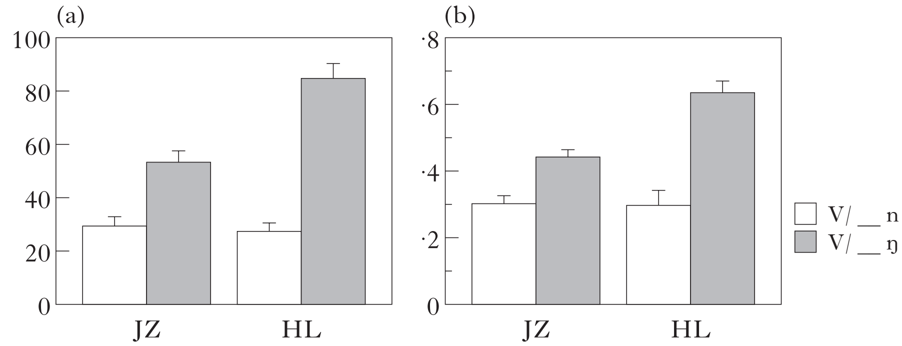


Figure 2

(a) Nasal flow duration during the vowel (ms); (b) nasalised vowel duration as a proportion of overall vowel duration.

a one-way ANOVA with nasal place as the independent factor indicates a significant effect (JZ: $F(1, 58) = 18{\cdot}759$, $p < 0{\cdot}0001$; HL: $F(1, 57) = 81{\cdot}226$, $p < 0{\cdot}0001$). Measurements and ANOVAs of the overall vowel duration in /CVn/ and /CVŋ/ indicate that for both speakers, the vowel in the /C __ ŋ/ context is significantly longer than the vowel in the /C __ n/ context (JZ: V(/__ ŋ) = 116 ms, V(/__ n) = 92 ms, $F(1, 58) = 16{\cdot}424$, $p < 0{\cdot}0005$; HL: V(/__ ŋ) = 133 ms, V(/__ n) = 109 ms, $F(1, 57) = 10{\cdot}562$, $p < 0{\cdot}005$). To factor out the effect of overall vowel duration, the proportion of the nasalisation duration to the overall duration of the vowel was calculated, and the results are shown in Fig. 2b. One-way ANOVAs with nasal place as the independent factor still indicate significant effects for both speakers (JZ: $F(1, 58) = 18{\cdot}226$, $p < 0{\cdot}0001$; HL: $F(1, 57) = 34{\cdot}665$, $p < 0{\cdot}0001$).

The duration measurements of the nasal codas yielded the following results: for JZ, the average durations for /n/ and /ŋ/ are 168 ms and 157 ms respectively, with the former significantly longer than the latter, as shown by a one-way ANOVA ($F(1, 58) = 6{\cdot}914$, $p < 0{\cdot}05$); for HL, the average durations for /n/ and /ŋ/ are 145 ms and 133 ms respectively, again with the former significantly longer than the latter, as shown by a one-way ANOVA ($F(1, 57) = 6{\cdot}009$, $p < 0{\cdot}05$). But even though the /n/-coda is significantly longer than the /ŋ/-coda, given that the nasality is unambiguous here, this durational difference does not translate into a perceptual difference according to Whalen & Beddor (1989), as I discussed in §2.1. And if we consider the duration of the nasalised portion of the vowel plus the nasal coda, it is still significantly longer for /Vŋ/ than for /Vn/ for both speakers: for JZ, 211 ms for /Vŋ/ and 197 ms for /Vn/, $F(1, 58) = 8{\cdot}752$, $p < 0{\cdot}005$; for HL, 218 ms for /Vŋ/ and 173 ms for /Vn/, $F(1, 57) = 42{\cdot}218$, $p < 0{\cdot}001$.

The average nasal flow values for the nasalised duration of the vowel in /CVn/ and /CVŋ/ are shown in Fig. 3a, and the proportion of the nasal

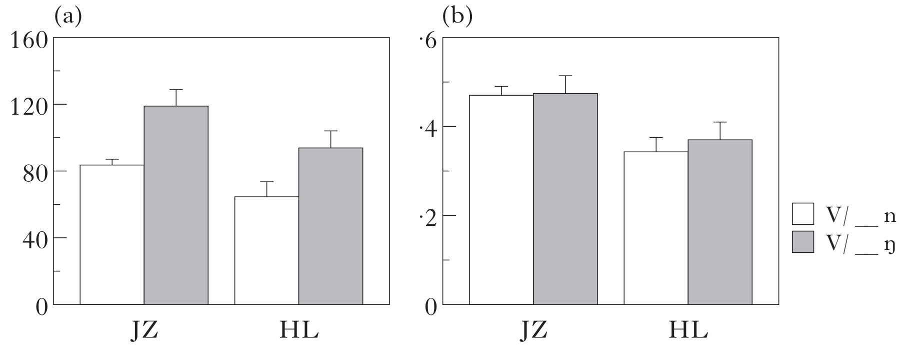


Figure 3
(a) Average nasal flow $\overline{U_n}$ (ml/s); (b) average nasal flow proportion $\overline{U_n / U_g}$.

flow to the overall glottal flow in Fig. 3b. The error bar again represents one standard error. For the average nasal flow, for both speakers, a one-way ANOVA with nasal place as the independent factor indicates a significant effect (JZ: $F(1, 58) = 11{\cdot}428$, $p < 0{\cdot}005$; HL: $F(1, 57) = 4{\cdot}636$, $p < 0{\cdot}05$). But for the average proportion of the nasal flow to the overall glottal flow, neither speaker shows any significant effect of the nasal place (JZ: $F(1, 58) = 0{\cdot}007$, $p > 0{\cdot}05$; HL: $F(1, 57) = 0{\cdot}301$, $p > 0{\cdot}05$). The lack of a significant effect in nasal flow proportion in the face of a significant effect in absolute nasal flow is apparently due to the greater overall glottal flow in the context of /C __ ŋ/ than that of /C__ n/. But I do not have an explanation as to why there is such a difference in the overall glottal flow between these two contexts.

Clearly, both of the hypotheses in (4) are supported by the experimental data. The results in Fig. 2 show that the /ŋ/-coda induces a significantly longer nasal flow duration on the vowel nucleus than the /n/-coda. The results in Fig. 3 show that during the nasalised portion of the vowel, the proportion of the nasal flow to the overall flow is no less in the /C __ ŋ/ context than in the /C __ n/ context. Under the assumption that the oral impedance during the vowel is comparable for /CVŋ/ and /CVn/, we infer from the airflow results that the velopharyngeal opening is comparable during the nasalised portion of the vowel in /CVŋ/ and /CVn/. Given that the nasalisation is significantly longer during the vowel in /CVŋ/, we infer that the nasality induced by the /ŋ/-coda is perceptually more salient than the nasality induced by the /n/-coda.

3 Two optimality-theoretic analyses for Beijing

3.1 A MAX[F] approach

3.1.1 *Universal ranking of faithfulness constraints*. In the OT literature, the role of phonetics is often captured by universal rankings of constraints governed by phonetic scales. This idea is explicitly expressed in Prince & Smolensky (1993), whose discussion of the universal peak and margin hierarchies is based on the sonority scale. Steriade (1999), in analysing cross-linguistic laryngeal neutralisation patterns, argues for a series of universally ranked licensing constraints which requires reference to perceptual cues for laryngeal features. In his account of place assimilation, Jun (1995) illustrates the necessity of universal rankings among faithfulness constraints on place features, basing the argument on the production and perception of consonants at different places.[3] Beckman (1998) identifies cases in which a wider range of phonological contrasts is attested in prosodically strong positions such as roots, stressed syllables and syllable onsets, and argues that this effect can be captured by positional faithfulness constraints IDENT-*Position*[F] and their universal rankings with the general faithfulness constraints – IDENT-*Position*[F] ≫ IDENT[F]. The argument for such universal rankings is based on the fact that these positions are either perceptually more salient (e.g. stressed) or particularly important for lexical access (e.g. root, onset).

On the surface, the case under discussion seems to be of a slightly different nature, since it is the *intrinsic* strength of a feature associated with certain segments that is relevant here: a feature is more likely to be preserved if it is carried by a segment that gives it a more salient percept. Thus, since the /ŋ/-coda induces a stronger nasal percept than the /n/-coda, the constraint requiring the preservation of the nasality of /ŋ/ is more highly ranked than the constraint requiring the preservation of the

[3] One anonymous reviewer points out that the universal ranking proposed by Jun (1995), to the effect that the dorsal place is more faithfully preserved than the labial place, which in turn is more faithfully preserved than the coronal place, is debatable. For example, Kirchner (1998), in a large survey of lenition processes, does not find asymmetries based on the place of articulation. Given Jun's universal place hierarchy, this is a surprising result. Moreover, Hume *et al*. (1999) report from perceptual data that even though the perceptual salience of stop place of articulation is similar to the phonetic salience ranking proposed by Jun, it is also dependent on vowel environment. Since the consonant place assimilation patterns are not conditioned by vowel environment, they conclude that 'phonetic salience is only one of possibly several factors influencing phonological markedness' (1999: 2072). But in fact, it is not clear that either of these works directly contradicts Jun's universal hierarchy. Since Kirchner's work concerns lenition, the directly relevant faithfulness constraints are those on voicing, continuancy, sonority, etc., therefore it does not directly bear on Jun's hierarchy, which is on place faithfulness. Hume *et al*.'s divergence from Jun is also not on the faithfulness hierarchy, but they do not regard the perceptual salience of place features to be the sole determining factor for the faithfulness hierarchy as Jun does.

nasality of /n/. But if we get at the heart of some earlier works on the perceptual effects in phonology, we see that this is only a logical extension of these earlier works. When we discuss the perception of a certain linguistic feature, we are necessarily discussing the perceptual correlates of this feature. For example, for obstruent place features, what are of perceptual relevance are the formant transitions (mainly F2 and F3) into and/or out of the adjacent vowels. Jun (1995) has argued that the formant transitions from a vowel into a stop are stronger than those from a vowel into a nasal due to the effects of nasal resonance on the formant structure, and this translates into a universal ranking between two faithfulness constraints on the place of C_1 in a C_1C_2 consonant cluster: PRES(pl(__ , [stop])C) ≫ PRES(pl(__ , [nas])C) (Jun 1995: 147). Similarly, based on the fact that a coronal stop produces a relatively small movement of the formants, its formant transitions are not as perceptible as those of a labial stop, and this translates into another universal ranking between two faithfulness constraints on the place of unreleased stops: PRES(pl(lab˥)) ≫ PRES(pl(cor˥)) (Jun 1995: 150). These cases are exactly parallel to the proposal regarding nasals here, in that formant transitions are crucial to the place feature just as the acoustic consequence of nasal coupling is crucial to the [nasal] feature. In the former, stronger formant transitions warrant a more faithful realisation of the stop place associated with it, in this case, labial stops. In the latter, the stronger acoustic consequence of nasal coupling (due to longer coupling duration) warrants a more faithful realisation of the [+nasal] feature, in this case, velar nasals.

To formalise this idea, let us suppose that in a language *L* there exist *k* contrastive segments that are specified for [+nasal]: $n_1, n_2, \ldots, n_k$. The strengths of the nasal percept induced by these *k* segments are different; let us suppose that from strongest to weakest, the order is $n_1, n_2, \ldots, n_k$. If we define the nasal percept induced by these segments to be $NP(n_1)$, $NP(n_2), \ldots,$ and $NP(n_k)$ correspondingly, then $NP(n_1) > NP(n_2) > \ldots > NP(n_k)$. I posit a family of faithfulness constraints on the nasal percept in (8a) and their universal ranking in (8b).

(8) a. $\text{MAX}[+\text{nas}]_{NP(n_i)}$ $(1 \leqslant i \leqslant k)$

If a segment *s* induces a nasal percept that is greater than or equal to $NP(n_i)$, and *s* is in the input, then [+nasal] must be in the output.

b. $\text{MAX}[+\text{nas}]_{NP(n_1)} \gg \text{MAX}[+\text{nas}]_{NP(n_2)} \gg \ldots \gg \text{MAX}[+\text{nas}]_{NP(n_k)}$.

Since the nasal percept induced by n_i is $NP(n_i)$ $(1 \leqslant i \leqslant k)$, the universal ranking in (8b) establishes an implicational hierarchy on the preservation of [+nasal] among the contrastive segments that are specified for [+nasal] in language *L*: for $1 < i \leqslant k$, if [+nasal] in n_i is preserved from the input to the output, then [+nasal] in n_{i-1} is preserved from the input to the output.

The formalisation in (8) deviates radically from traditional phonology, in that it incorporates phonetic details directly in the constraints. Naturally, we must ask the question: 'are there any alternatives that would avoid such a radical position?'. Possible alternatives outside the realm of MAX[F] are discussed later in the paper, and the conclusion will be that these alternatives do not suffice to account for the attested data patterns. But within the framework based on MAX[F], there does seem to be a viable alternative: instead of referring to the strength of the nasal percept *per se* in the constraints, we can directly refer to the nasal segments that induce the nasal percept. Therefore, the constraints are as the ones shown in (9a), with a universal ranking in (9b).

(9) a. $\text{MAX}[+\text{nas}]_{n_i}$ $(1 \leqslant i \leqslant k)$
If a segment n_i is in the input, then [+nasal] must be in the output.
b. $\text{MAX}[+\text{nas}]_{n_1} \gg \text{MAX}[+\text{nas}]_{n_2} \gg \ldots \gg \text{MAX}[+\text{nas}]_{n_k}$.

As we can see, even though the constraints themselves do not refer to the nasal percept, the universal ranking still respects the hierarchy that the [+nasal] feature of a segment that has a stronger nasal percept is more faithfully preserved than the [+nasal] feature of a segment that has a weaker nasal percept. This approach is similar in spirit to the version of phonetically driven phonology advocated in Hayes (1999), where he proposes that language learners use their knowledge of articulation and perception gained from experience and construct from it phonological constraints that refer to more or less traditional phonological representations.

Apparently, the data patterns discussed here do not bear on the choice between the two approaches in (8) and (9): whether the constraints refer to the strengths of the nasal percept or the segments that induce the different strengths of nasal percept, the implicational hierarchy – if [+nasal] is preserved in a segment with a weak nasal percept, then it is preserved in a segment with a strong nasal percept – can be formally captured. But in either case, we must acknowledge the existence of grammars that are governed by phonetic facts, either directly or filtered through phonological categories. In the analyses that follow, I opt for the more traditional approach that refers to the phonological segments, since the data patterns in question do not directly motivate the alternative approach that allows a substantially richer array of representations. But given that the rich-representation approach has been argued to be necessary in other works (e.g. Kirchner 1997, Boersma 1998, Steriade 1999, 2000, Zhang, forthcoming), it should not be taken as dismissed here.

3.1.2 *Beijing explained*. Specifically for Beijing, the relevant MAX[F] constraints are $\text{MAX}[+\text{nas}]_{ŋ}$ and $\text{MAX}[+\text{nas}]_{n}$, as defined in (10a) and (10b). And according to the phonetic results that the nasal percept induced by /ŋ/ is stronger than that induced by /n/, I posit the universal ranking in (10c).

(10) a. MAX[+nas]$_{ŋ}$
If /ŋ/ is the input, then [+nasal] must be in the output.
b. MAX[+nas]$_{n}$
If /n/ is in the input, then [+nasal] must be in the output.
c. MAX[+nas]$_{ŋ}$ ≫ MAX[+nas]$_{n}$

To account for the data pattern in Beijing, we also need to posit the faithfulness constraint in (11a) and phonotactic constraints in (11b)–(11d).

(11) a. REALISEAFFIX
Affixes must be realised.
b. *COMPLEXCODA
No complex coda is allowed.
c. *V$_{nas}$
No nasalised vowel is allowed in *non-nasal environments*.
d. TEMPLATE
The suffixed form must be one syllable.

REALISEAFFIX, in the case in question, requires the diminutive suffix to be realised in the suffixed form. This can be deemed as an OT rendition of the Affix Manifestation Principle proposed by Lin (1993). *COMPLEX CODA bans syllables with complex codas. *V$_{nas}$ bans nasalised vowels in *non-nasal environments*. Therefore we do not consider [CṼn] or [CṼ̃ŋ] to incur a violation for *V$_{nas}$, even though our phonetic study has shown that there is nasalisation on the vowel. The motivation for this lies in the perceptual nature of the dispreference for nasalised vowels: nasalisation jeopardises the perceptual salience of the vowel quality, but nasalisation affects the vowel quality less if it is expected, i.e. if a nasal environment is present, as shown by Beddor *et al*. (1986), who found that American English listeners identify the vowel height of [bṼnd] better than that of [bṼd]. This provides justification for banning a nasalised vowel only in the absence of a nasal environment in our constraint system. Templatic constraints for morphological classes have been widely used in the phonological literature (e.g. McCarthy & Prince 1986, 1993, Lin 1993). The motivation for the TEMPLATE constraint here lies in the common preference for disyllables in Chinese dialects. Since the suffixed form is usually used with another monosyllabic morpheme to form a compound word, it is preferred to be monosyllabic so that the disyllabic compound word can be generated.

In the transcription that follows in this subsection (§3.1.2), the underlying representations for the suffixed forms are again transcribed as /CṼn+ɻ/ and /CṼ̃ŋ+ɻ/, respectively.

In Beijing, *COMPLEXCODA, REALISEAFFIX and TEMPLATE are undominated. From /CṼn+ɻ/ → [CVɻ], *[CṼ̃ɻ], we infer that *V$_{nas}$ ≫ MAX [+nas]$_{n}$; from /CṼ̃ŋ+ɻ/ → [CṼ̃ɻ], *[CVɻ], we infer that MAX [+nas]$_{ŋ}$ ≫ *V$_{nas}$. The complete ranking for Beijing is shown in (12). The tableaux that generate the correct results are shown in (13).

(12) *Constraint ranking for Beijing*

*ComplexCoda, RealiseAffix, Template, Max[+nas]$_ŋ$

|

*V$_{nas}$

|

Max[+nas]$_n$

(13)

		*CompCoda	RealAff	Temp	Max[+nas]$_ŋ$	*V$_{nas}$	Max[+nas]$_n$
a.	CṼn+ɻ						
☞	CVɻ						*
	CṼnɻ	*!					
	CṼn		*!				
	CṼn.ɻ̩			*!			
	CṼ̃ɻ					*!	
b.	CṼ̃ŋ+ɻ						
☞	CṼ̃ɻ					*	
	CṼ̃ŋɻ	*!					
	CṼ̃ŋ		*!				
	CṼ̃ŋ.ɻ̩			*!			
	CVɻ				*!		

Looking at the data pattern in Beijing, we might want to entertain a slightly different approach. Since the meagre vowel nasalisation induced by /n/ in the stem is completely lost in the suffixed form, should this be interpreted as a dispersion effect (Flemming 1995)? That is, the loss of nasality in /CṼn+ɻ/ is due to the functional consideration of maintaining a better contrast between /CṼn+ɻ/ and /CṼ̃ŋ+ɻ/, not to the dispreference for nasalised vowels. This is schematised in (14).

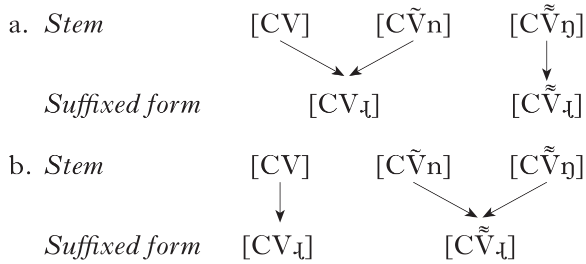
(14) *Stem* [CṼn] → [CVɻ]; [CṼ̃ŋ] → [CṼ̃ɻ]

Suffixed form [CVɻ] ······ *contrast* ······ [CṼ̃ɻ]

better than

[CṼɻ] ······ *contrast* ······ [CṼ̃ɻ]

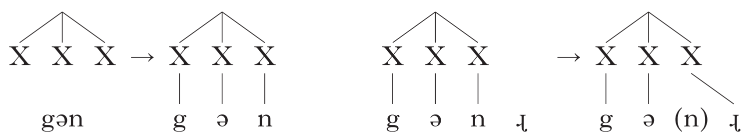
But taking into account the behaviour of open syllables upon suffixation, we find this to be an untenable position. The realisation of /CV+ɻ/ is simply [CVɻ]. Thus, by losing the nasality of /n/ completely in the suffixed form, /CVn+ɻ/ is neutralised with /CV+ɻ/. This is schematised in (15a). And since in Beijing, there are more /CV/ ~ /CVn/ pairs than /CVn/ ~ /CVŋ/ pairs, due to the incompatibility of certain vowels with /ŋ/, the attested pattern in fact causes more neutralisation in the suffixed forms than an alternative which neutralises /CṼn+ɻ/ and /CṼ̃ŋ+ɻ/ to [CṼ̃ɻ], as in (15b). A theory solely based on dispersion without the consideration of *V$_{nas}$ would then wrongly predict the alternative.

(15)


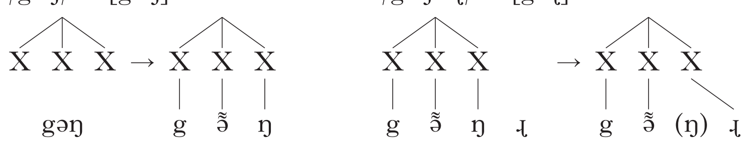
3.2 An Ident[F] approach

As mentioned in the introduction, the phonetic results discussed in §2 can also lead to the following interpretation: categorically, the vowel in the /C __ n/ context has an oral percept, but the vowel in the /C __ ŋ/ context has a nasalised percept. This is explicitly suggested in Duanmu (1990). He contends that the vowel in the unsuffixed form is oral before /n/, but nasalised before /ŋ/, as shown in (16).

(16) a. /gən/ → [gən] /gən+ɻ/ → [gəɻ]



b. /gəŋ/ → [gə͌ŋ] /gəŋ+ɻ/ → [gə͌ɻ]



In optimality-theoretic terms, this proposal amounts to an Ident[F] approach. For the case in question, the relevant constraint is Ident[nas], as defined in (17) (McCarthy & Prince 1995).

(17) Ident[nas]
Let α be a segment in the stem and β be a correspondent of α in the suffixed form. If a is [γnasal], then β is [γnasal].

This constraint requires the [nasal] specification of the vowel in the stem to be the same in the suffixed form, as Duanmu suggests.

To complete the OT analysis, we also need to assume the same constraints *ComplexCoda, RealiseAffix, Template and $*V_{nas}$ as above. Furthermore, we need another constraint that penalises the loss of the stem nasal. This is formalised in (18).

(18) MaxSeg(stem)
If α is a segment in the stem, then α must have a correspondent in the suffixed form.

*ComplexCoda, RealiseAffix and Template are still undominated. Crucially, they outrank MaxSeg(stem), since /CVn+ɹ/ → [CVɹ̃], *[CVnɹ], *[CVn], *[CVn.ɹ]. Moreover, Ident[nas] ≫ $*V_{nas}$, since /CṼ̃ŋ +ɹ/ → [CṼɹ], *[CVɹ]. The complete ranking for Beijing using Ident [nas] is shown in (19). Tableaux that generate the correct outputs are given in (20). Note that in (20a), the unsuffixed form has an oral vowel, while in (20b), the unsuffixed form has a nasalised vowel, as conceived by Duanmu (1990). And again, bear in mind that Ident[nas] is an output–output correspondence constraint, not Ident-IO(nas]. Otherwise we would predict contrastive vowel nasalisation under this ranking.

(19) *Constraint ranking for Beijing using* Ident[nas]

*ComplexCoda, RealiseAffix, Template, Ident[nas]

|

$*V_{nas}$, MaxSeg(stem)

(20)

	CVn+ɻ	*CompCoda	RealAff	Temp	Id[nas]	$*V_{nas}$	MaxSeg(stem)
a.	☞ CVɻ						*
	CVnɻ	*!					
	CVn		*!				
	CVn.ɻ			*!			
	CṼ̃ɻ				*!	*	*
b.	CṼ̃ŋ+ɻ						
	CVɻ				*!		
	CṼ̃ŋɻ	*!				*	
	CṼ̃ŋ		*!			*	
	CṼ̃ŋ.ɻ			*!		*	
	☞ CṼ̃ɻ					*	*

As shown in the tableaux, the Ident[F] approach does work for Beijing. It is similar to the Max[F] approach in that they both acknowledge the difference in vowel nasalisation between [CṼn] and [CṼ̃ŋ] and encode this difference in the grammar. Since vowel nasalisation is not a contrastive feature in the stem words in Beijing, in a sense both analyses are phonetically based. But Ident[F] makes an assumption on categorisation that Max[F] does not make, i.e. the vowel in the /C __ n/ context is categorically oral, while the vowel in the /C __ ŋ/ context is categorically nasal. In the next section, I will show that this assumption has unwanted consequences on the factorial typology of the constraints.

One of the claims of Optimality Theory is that cross-linguistic variation is accounted for by the factorial typology of the constraints. Moreover, if the correct set of constraints are used, in principle, only the data patterns that are attested should be generated in the factorial typology (Prince & Smolensky 1993). Therefore, to determine which analysis is correct in essence, and which analysis only accidentally captures the facts in Beijing, I conducted a dialectal survey on the retroflex suffixation and compared the results with two distinct factorial typologies – one based on MAX[F] and one based on IDENT[F]. The comparison indicates that MAX[F] is a superior approach, as its factorial typology generates exactly the attested patterns, while the factorial typology of IDENT[F] both overgenerates, as it generates unattested patterns, and undergenerates, as it fails to generate some attested patterns.

4 Dialectal typology and factorial typology

4.1 Dialectal typology

Nineteen dialects with two coda nasals (/n/ and /ŋ/) were included in the dialectal typology. The geographical locations of these dialects are given in a map in the Appendix. The sources of the data were mostly descriptive papers on the sounds and basic grammatical structures of the dialects studied, and the transcriptions were primarily based on impressionistic observation of the field worker. The survey focuses on the interaction between the coda nasals and the retroflex suffix. It reveals that the data patterns fall into two distinct groups: one in which [CṼn] and [CṼ̃ŋ] behave differently upon /ɹ/-suffixation, and one in which they behave identically. Throughout the discussion of the dialectal typology, I will assume that the vowel before an /ŋ/-coda is more nasalised than the vowel before an /n/-coda as in Beijing, hence the transcriptions [CṼn] and [CṼ̃ŋ].

4.1.1 /CVn/ ≠ /CVŋ/ *upon* /ɹ/*-suffixation.* Many dialects exhibit similar behaviour to Beijing; namely, upon /ɹ/-suffixation, the nasal coda in both [CṼn] and [CṼ̃ŋ] is lost. The vowel in /CṼ̃ŋ + ɹ/ is realised as nasalised while the vowel in /CṼn + ɹ/ is realised as oral. Examples from Zhengzhou (Lu 1992) and Huojia (He 1982) are given in (24). Tones are not marked in the examples, as they are not relevant to the issue in question. Occasional vowel changes induced by suffixation should also be ignored for the same reason. Other dialects which behave similarly include Changhai (Li 1981), Juxian (Shi 1995), Harbin (Yin 1995), Wulumuqi (Zhou 1994), Xiangcheng (Liu 1993) and Muping (Luo 1995).

(21) a. *Zhengzhou* (Lu 1992)

/CṼn + ɹ/ → [CVɹ]	/pãn + ɹ/ → [paɹ]	'work'
	/tʂə̃n + ɹ/ → [tʂəɹ]	'a while'
/CṼ̃ŋ + ɹ/ → [CṼ̃ɹ]	/pã̃ŋ + ɹ/ → [pã̃ɹ]	'side'
	/sĩ̃ŋ + ɹ/ → [siə̃̃ɹ]	'star'

b. *Huojia* (He 1982)

/CṼ + ɹ/ → [CVɹ]	/pʰãn + ɹ/ → [pʰɐɹ]	'plate'
	/tɕĩn + ɹ/ → [tɕiəɹ]	'tip'
/CṼ̃ŋ + ɹ/ → [CṼ̃ɹ]	/pã̃ŋ + ɹ/ → [pã̃ɹ]	'side'
	/də̃̃ŋ + ɹ/ → [də̃̃ɹ]	'lamp'

In a few other dialects, the /ɹ/-suffix cannot merge with [CṼ̃ŋ] to form a rhotacised syllable as in Beijing. Rather, it is realised as a separate syllable following the stem, leaving the stem unchanged. But when the stem is [CṼn], the realisation of the suffixed form is monosyllabic as in Beijing. The /ɹ/-suffix replaces /n/. Mancheng, a dialect spoken in Hebei Province, is a dialect of this sort (Chen 1988). As seen in the examples in (22), this dialect prohibits the /ɹ/-suffix from overlapping with [CṼ̃ŋ], but not with [CṼn]. Note that the vowel in [CṼn] is left non-nasalised while the nasal coda is deleted upon /ɹ/-suffixation.

(22) *Mancheng* (Chen 1988)

/CṼn + ɹ/ → [CVɹ]	/mə̃n + ɹ/ → [məɹ]	'door'
	/pʰãn + ɹ/ → [pʰɐɹ]	'plate'
/CṼ̃ŋ + ɹ/ → [CṼ̃ŋ.ɹ̩]	/iɑ̃̃ŋ + ɹ/ → [iɑ̃̃ŋ.ɹ̩]	'sheep'
	/ɕĩ̃ŋ + ɹ/ → [ɕĩ̃ŋ.ɹ̩]	'apricot'[4]

Anqing, a dialect spoken in Anhui Province, behaves similarly to Mancheng, except that the vowel in [CṼn] becomes clearly nasalised when the nasal coda is deleted upon /ɹ/-suffixation (Hao 1982).

(23) *Anqing* (Hao 1982)

/CṼn + ɹ/ → [CṼ̃ɹ]	/pãn + ɹ/ → [pã̃ɹ]	'plank'
	/tɕʰiẽn + ɹ/ → [tɕʰiẽ̃ɹ]	'before'
/CṼ̃ŋ + ɹ/ → [CṼ̃ŋ.ɹ̩]	/nõ̃ŋ + ɹ/ → [nõ̃.ɹ̩]	'coop'

In this section, we have seen three different patterns of interaction between coda nasals and the /ɹ/-suffix. One generalisation underlies all these patterns: the nasality associated with /ŋ/ is always more faithfully preserved than the nasality associated with /n/. The difference is shown either by nasalisation of the vowel in /CṼ̃ŋ + ɹ/, but not in /CṼn + ɹ/, or by simply requiring the /Ṽ̃ŋ/ rhyme to remain intact upon /ɹ/-suffixation. The opposite situation, where the nasality of /n/ is more prominently preserved than that of /ŋ/, is not attested.

4.1.2 /CVn/ = /CVŋ/ *upon* /ɹ/-suffixation. Dialects in which [CṼn] and [CṼ̃ŋ] behave identically in the suffixation process are also attested. A number of dialects do not have nasalisation on the stem vowel in either

[4] In the transcription given by the original field worker, the suffixed form of [CṼ̃ŋ] is [CṼŋ.ŋəɹ] (the nasalisation on the vowel is, again, my conjecture), not [CṼŋ.ɹ̩], as given here. But from my own experience with a closely related Hebei dialect, Shunping (Sun 1998, personal communication), the suffixed form of [CṼŋ] sounds more like [CṼŋ.ɹ̩] than [CṼŋ.ŋəɹ]. The choice between [CṼŋ.ɹ̩] and [CṼŋ.ŋəɹ] does not affect the basics of the following analyses. But lower-ranked constraints need to be assumed for [CṼŋ.ŋəɹ], e.g. IDENT[long], DEP(ə). Thus I opt for [CṼŋ.ɹ̩] for both simplicity and possibly phonetic accuracy.

/CṼn+ɻ/ or /CṼ̃ŋ+ɻ/. Liaocheng (Zhang 1995), Chengdu (Yuan 1989), Nanjing (Liu 1997), Yinchuan (Gao & Zhang 1997) and Miyang (Li 1996) are cases of this sort. Data from Liaocheng, Chengdu and Miyang are given in (24). Even though the vowel alternation is different among these dialects, and the retroflex suffix in Miyang is a lateral, the basic pattern regarding the interaction between the coda nasals and the suffix is the same. In all these dialects, both nasals – /n/ and /ŋ/ – completely disappear upon suffixation.

(24) a. *Liaocheng* (Zhang 1995)

/CṼn+ɻ/ → [CVɻ]	/ĩn+ɻ/ → [ieɻ]	‘sound’
	/uə̃n+ɻ/ → [ueɻ]	‘lines’
/CṼ̃ŋ+ɻ/ → [CVɻ]	/pã̃ŋ+ɻ/ → [pɐɻ]	‘side’
	/ĩ̃ŋ+ɻ/ → [iəɻ]	‘shadow’

b. *Chengdu* (Yuan 1989)

/C(V$_1$)Ṽ$_2$n+ɻ/ → [C(V$_1$)əɻ]	/pãn+ɻ/ → [pəɻ]	‘class’
	/tɕiãn+ɻ/ → [tɕiəɻ]	‘item’
/C(V$_1$)Ṽ̃$_2$ŋ+ɻ/ → [C(V$_1$)əɻ]	/kə̃̃ŋ+ɻ/ → [kəɻ]	‘thick soup’
	/tsə̃̃ŋ+ɻ/ → [tsuəɻ]	‘cup’

c. *Miyang* (Li 1996)

/CṼn+ɭ/ → [CVɭ]	/pãn+ɭ/ → [pɜɭ]	‘plank’
	/piɛ̃n+ɭ/ → [piɜɭ]	‘edge’
/CṼ̃ŋ+ɭ/ → [CVɭ]	/pã̃ŋ+ɭ/ → [pɜɭ]	‘stick’
	/pĩ̃ŋ+ɭ/ → [piɜɭ]	‘soldier’

On very rare occasions, the vowels in both /CṼn/ and /CṼ̃ŋ/ become clearly nasalised upon suffixation. Only one case of this sort was found in the typological survey – Jiyuan (He 1981, cited in Lin 1993). Lin (1993) argues that the /ɻ/-suffix in Jiyuan is a feature bundle [−back, +round]. Examples of the correspondence between the stem rhyme and the diminutive rhyme in Jiyuan are given in (25). Clearly, whether the stem has an /n/-coda or an /ŋ/-coda, the diminutive rhyme is nasalised.[5]

(25) *Jiyuan* (He 1981)

stem rhyme	*diminutive rhyme*
ə̃n, ə̃̃ŋ	ə̃̃ɥ
ĩn, ĩ̃ŋ	ĩ̃ɥ
ũn, ũ̃ŋ	ũ̃ɥ
ỹn, ỹ̃ŋ	ỹ̃ɥ

Since the diminutive suffix here is a feature bundle [−back, +round], not the segment /ɻ/, a word on the justification for including this dialect is in order. The justification is twofold. First, the diminutive suffix, even when realised as /ɻ/, has been treated as floating features by some researchers (e.g. Wang 1993, 1997). Therefore, the feature-bundle analysis

[5] He (1981) also documents that the diminutive rhymes for /an/ and /aŋ/ are [ø] and [æ̃], respectively. The lack of nasalisation for the diminutive rhyme for /an/ is considered accidental by Lin (1993) and enforced by a feature configuration constraint *[−hi, −bk, +rd, +nas]. I adopt this view here.

of the diminutive suffix is not necessarily peculiar to Jiyuan. Second, the choice between a feature bundle and a segment does not affect the evaluation of the proposed constraints in any essential way. For example, the full realisation of the feature bundle in the coda position will incur *ComplexCoda violations, just like [nɹ] and [ŋɹ], since this feature bundle obviously does not agree in place with all the possible codas; and granting these features a syllabic segment in its own right violates Template, just like [CṼn.ɹ̩] and [CṼ̃ŋ.ɹ̩].

Finally, in two dialects in the survey, Guiyang (Li 1997) and Xinjiang (Hou & Wen 1993), the /ɹ/-suffix cannot merge with either [CṼn] or [CṼ̃ŋ] to form a rhotacised syllable. The suffix must be realised as a separate syllable in both cases. Examples from these dialects are given in (26).

(26) a. *Guiyang* (Li 1997)
/CṼn + ɹ/ → [CṼn.ɹ̩] /pʰãn + ɹ/ → [pʰãn.ɹ̩] 'plate'
/CṼ̃ŋ + ɹ/ → [CṼ̃ŋ.ɹ̩] /fã̃ŋ + ɹ/ → [fã̃ŋ.ɹ̩] 'house'

b. *Xinjiang* (Hou & Wen 1993)
/CṼn + ɹ/ → [CṼn.ɹ̩] /ɕĩn + ɹ/ → [ɕĩn.ɹ̩] 'heart'
/CṼ̃ŋ + ɹ/ → [CṼ̃ŋ.ɹ̩] /ɕĩ̃ŋ + ɹ/ → [ɕĩ̃ŋ.ɹ̩] 'star'

Therefore, three patterns in which [CṼn] behaves identically to [CṼ̃ŋ] are attested in the survey. In the first two patterns, both /n/ and /ŋ/ are deleted, but one results in nasalisation of the stem vowel (Jiyuan) and the other does not (Liaocheng). In the last pattern, the diminutive suffix must be realised as a separate syllable following either [CṼn] or [CṼ̃ŋ] (Guiyang).

		Data pattern	*Example dialect*
CṼn≠CṼ̃ŋ	a.	/CṼn+ɹ/ → [CVɹ] /CṼ̃ŋ+ɹ/ → [CṼ̃ɹ]	Beijing
	b.	/CṼn+ɹ/ → [CVɹ] /CṼ̃ŋ+ɹ/ → [CṼ̃ŋ.ɹ̩]	Mancheng
	c.	/CṼn+ɹ/ → [CṼ̃ɹ] /CṼ̃ŋ+ɹ/ → [CṼ̃ŋ.ɹ̩]	Anqing
CṼn=CṼ̃ŋ	d.	/CṼn+ɹ/ → [CVɹ] /CṼ̃ŋ+ɹ/ → [CVɹ]	Liaocheng
	e.	/CṼn+F/ → [CṼ̃$_F$] /CṼ̃ŋ+F/ → [CṼ̃$_F$]	Jiyuan
	f.	/CṼn+ɹ/ → [CṼn.ɹ̩] /CṼ̃ŋ+ɹ/ → [CṼ̃ŋ.ɹ̩]	Guiyang

[Table I. Summary of dialectal typology.]

	Output pattern	*Constraint ranking*
a.	/CṼn+ɻ/ → [CVɻ] /CṼ̃ŋ+ɻ/ → [CṼ̃ɻ]	Template, Max[+nas]$_{\text{ŋ}}$ ≫ *V$_{nas}$ ≫ Max[+nas]$_{n}$
b.	/CṼn+ɻ/ → [CVɻ] /CṼ̃ŋ+ɻ/ → [CṼ̃ŋ.ɻ̩]	Max[+nas]$_{\text{ŋ}}$, *V$_{nas}$ ≫ Template ≫ Max[+nas]$_{n}$
c.	/CṼn+ɻ/ → [CVɻ] /CṼ̃ŋ+ɻ/ → [CVɻ]	Template, *V$_{nas}$ ≫ Max[+nas]$_{\text{ŋ}}$, Max[+nas]$_{n}$
d.	/CṼn+ɻ/ → [CṼ̃ɻ] /CṼ̃ŋ+ɻ/ → [CṼ̃ɻ]	Template, Max[+nas]$_{\text{ŋ}}$, Max[+nas]$_{n}$ ≫ *V$_{nas}$
e.	/CṼn+ɻ/ → [CṼn.ɻ̩] /CṼ̃ŋ+ɻ/ → [CṼ̃ŋ.ɻ̩]	*V$_{nas}$, Max[+nas]$_{\text{ŋ}}$, Max[+nas]$_{n}$ ≫ Template

[Table II. Factorial typology: Max[F].]

4.1.3 *Summary*. In the dialectal typology, six distinct patterns of behaviour are attested. They are summarised in Table I. In (e), I use F to represent the feature bundle for Jiyuan. Since the nasalisation of /ŋ/ is either more prominently preserved than that of /n/, as shown in §4.1.1, or is equally preserved as that of /n/, as shown in §4.1.2, we conclude that all the attested patterns observe the following implicational hierarchy: if the nasalisation of /n/ is preserved, then the nasalisation of /ŋ/ is preserved at least as faithfully. A correct analysis should capture this generalisation. In the next subsection, we consider the factorial typologies of the Max[F] approach and the Ident[F] approach, and see which one captures this generalisation and exhibits a closer match with the attested patterns.

4.2 Factorial typology

4.2.1 *The* Max[F] *approach*. The constraints involved in the Max[F] analysis are listed again in (27).

(27) a. Max[+nas]$_{\text{ŋ}}$ d. RealiseAffix
b. Max[+nas]$_{n}$ e. Template
c. *ComplexCoda f. *V$_{nas}$

Before we proceed, we should recognise that there are three conditions that constrain the factorial typology. First, since complex codas are banned in virtually all Chinese dialects, *ComplexCoda is ranked as invariably undominated. Second, since the dialects in question are the ones *with* the retroflex suffix, the RealiseAffix constraint is ranked as invariably undominated. These two conditions in fact simplify our factorial typology from a six-constraint set to a four-constraint set. The last condition is the universal ranking MAX[+nas]$_{\text{ŋ}}$ $\gg$ MAX[+nas]$_{\text{n}}$.

The factorial typology of the four constraints MAX[+nas]$_{\text{ŋ}}$, MAX[+nas]$_{\text{n}}$, TEMPLATE and *V$_{\text{nas}}$, taking into account the universal ranking MAX[+nas]$_{\text{ŋ}}$ $\gg$ MAX[+nas]$_{\text{n}}$, was computed using the optimality-theory software developed by Bruce Hayes at UCLA. All possible rankings considered, five distinct patterns were generated, as summarised in Table II. All rankings assume that *COMPLEXCODA and REALISEAFFIX are on the top tier of the hierarchy. Consequently, candidates that violate these constraints are not considered.

The data pattern in Table IIa is that of Beijing. The ranking that generates Table IIa is exactly the ranking we posited for Beijing in (12). To recapitulate the gist of the argument, the highly ranked TEMPLATE prevents Beijing from having disyllabic outputs for the suffixed form; MAX[+nas]$_{\text{ŋ}}$ $\gg$ *V$_{\text{nas}}$ ensures the [+nasal] feature for /ŋ/ is preserved in the form of vowel nasalisation; and *V$_{\text{nas}}$ $\gg$ MAX[+nas]$_{\text{n}}$ guarantees the loss of nasality for the /n/-coda. Tableaux that generate the correct outputs were given in (13).

The data pattern in Table IIb, /CṼn+ɻ/ → [CVɻ], /CṼ̃ŋ+ɻ/ → [CṼ̃ŋ.ɻ̩], is that of Mancheng (cf. (22)). The constraint hierarchy that accounts for this pattern is MAX[+nas]$_{\text{ŋ}}$, *V$_{\text{nas}}$ $\gg$ TEMPLATE $\gg$ MAX[+nas]$_{\text{n}}$. The ranking *V$_{\text{nas}}$, TEMPLATE $\gg$ MAX[+nas]$_{\text{n}}$ ensures that no nasal feature is preserved in the suffixed form of /CVn/; the ranking MAX[+nas]$_{\text{ŋ}}$, *V$_{\text{nas}}$ $\gg$ TEMPLATE ensures that disyllabicity is the only way to preserve the [+nasal] feature of /ŋ/ and at the same time not violate *V$_{\text{nas}}$. Implementing this constraint hierarchy, the tableaux in (28) give the analysis for Mancheng.[6] Notice that the last candidate in both tableaux does not violate *V$_{\text{nas}}$ even though there is nasalisation on the vowel. This is because the vowel is in the environment of a nasal coda.

(28)

	CṼn+ɻ	MAX[+nas]$_{\text{ŋ}}$	*V$_{\text{nas}}$	TEMP	MAX[+nas]$_{\text{n}}$
a.	☞ CVɻ				*
	CṼɻ		*!		
	CṼn.ɻ̩			*!	
b.	CṼ̃ŋ+ɻ				
	CVɻ	*!			
	CṼ̃ɻ		*!		
	☞ CṼ̃ŋ.ɻ̩			*	

[6] We must assume that the constraint IDENT[syll] is lowly ranked in this grammar in order for [CṼ.ɻ̩] to emerge as the winner for (28b). Adding this constraint to the factorial typology will not generate any more data patterns, since all the patterns that observe the universal ranking MAX[+nas]$_{\text{ŋ}}$ $\gg$ MAX[+nas]$_{\text{n}}$ have already been generated (except for /CṼn+ɻ/ → [CṼɻ] and /CṼ̃ŋ+ɻ/ → [CṼ̃ŋ.ɻ̩], but see the explanation below). Nor will it obliterate any data patterns, since we can simply place it at the bottom of any of the hierarchies under discussion, so that it will have no effect on the outputs of the grammar.

The data pattern in Table IIc, /CṼn + ɻ/ → [CVɻ], /CV͌ŋ + ɻ/ → [CVɻ], is that of Liaocheng (cf. (24a)). The constraint hierarchy that accounts for this pattern is: Template, *V$_{\text{nas}}$ ≫ Max[+nas]$_{\text{ŋ}}$, Max [+nas]$_{\text{n}}$. With a low ranking of both the nasal faithfulness constraints and a high ranking of Template and *V$_{\text{nas}}$, the nasal feature is lost for both [CṼn] and [CV͌ŋ] in the suffixed form, rendering [CVɻ] as the output for both. The tableaux that generate the correct results for dialects like Liaocheng are given in (29).

(29)

	CṼn+ɻ	Temp	*V$_{\text{nas}}$	Max[+nas]$_{\text{ŋ}}$	Max[+nas]$_{\text{n}}$
a.	☞ CVɻ				*
	CV͌ɻ		*!		
	CṼn.ɻ̩	*!			
b.	CV͌ŋ+ɻ				
	☞ CVɻ			*	
	CV͌ɻ		*!		
	CV͌ŋ.ɻ̩	*!			

The data pattern in Table IId, /CṼn + ɻ/ → [CV͌ɻ], /CV͌ŋ + ɻ/ → [CV͌ɻ], is that of Jiyuan (cf. (25)). The slight complication here is that the diminutive suffix in Jiyuan is not exactly /ɻ/, but a feature bundle [−back, +round]. But, as we argued in §4.1.2, this does not affect the core of the analysis. The tableaux in (30) show that by ranking *V$_{\text{nas}}$ at the bottom of the hierarchy, we generate nasalised vowels for both /CṼn + F/ and /CV͌ŋ + F/. Again, F represents the feature bundle, and the surface realisation of the feature bundle is represented as F subscript to the vowel, or as syllabic F if the feature bundle projects its own syllabic segment.

(30)

	CṼn+F	Temp	Max[+nas]$_{\text{ŋ}}$	Max[+nas]$_{\text{n}}$	*V$_{\text{nas}}$
a.	CV$_{\text{F}}$			*!	
	☞ CV͌$_{\text{F}}$				*
	CṼn.F̩	*!			
b.	CV͌ŋ+F				
	CV$_{\text{F}}$		*!		
	☞ CV͌$_{\text{F}}$				*
	CV͌ŋ.F̩	*!			

The data pattern in Table IIe, /CṼn + ɻ/ → [CṼn.ɻ̩], /CV͌ŋ + ɻ/ → [CV͌ŋ.ɻ̩], is that of Guiyang (cf. (26a)). The ranking *V$_{\text{nas}}$, Max[+nas]$_{\text{ŋ}}$, Max[+nas]$_{\text{n}}$ ≫ Template ensures that the nasality of both /ŋ/ and /n/ must be preserved, and the only way to preserve it is to have disyllabic suffixed forms with the nasal coda fully preserved, since without the nasal coda, a nasalised vowel will violate the $*V_{nas}$ constraint. The tableaux that illustrate the analysis are given in (31).

(31) a.

CṼn+ɻ	$*V_{nas}$	MAX[+nas]$_{ŋ}$	MAX[+nas]$_{n}$	TEMP
CVɻ			*!	
CṼ̃ɻ	*!			
☞ CṼn.ɻ̩				*

b.

CṼ̃ŋ+ɻ	$*V_{nas}$	MAX[+nas]$_{ŋ}$	MAX[+nas]$_{n}$	TEMP
CVɻ		*!		
CṼ̃ɻ	*!			
☞ CṼ̃ŋ.ɻ̩				*

Therefore, all the patterns generated by the factorial typology are attested in real languages. Of course, another question that should be asked is whether there are attested data patterns that are not generated by the factorial typology. The answer is 'yes' here, and the data pattern is Anqing, given in (23). In this dialect, upon suffixation, [CṼn] loses its nasal coda and nasalises the vowel, but [CṼ̃ŋ] stays intact, and the suffix is realised as a separate syllable. The reason why this is not generated by the factorial typology is as follows: in both /CṼn+ɻ/ and /CṼ̃ŋ+ɻ/, the [+nasal] feature is preserved, indicating high ranking of MAX[+nas]$_{ŋ}$ and MAX[+nas]$_{n}$. But the means of [+nasal] preservation is different, which creates a ranking paradox: /CṼn+ɻ/ is realised as [CṼ̃ɻ], not [CṼn.ɻ̩], indicating TEMPLATE ≫ $*V_{nas}$, but /CṼ̃ŋ+ɻ/ is realised as [CṼ̃ŋ], not [CṼ̃ɻ], indicating $*V_{nas}$ ≫ TEMPLATE.

The problem lies in the evaluation of the nasal faithfulness constraints. The fact is that there *is* a difference in the form of preservation. For /CṼ̃ŋ+ɻ/, the entire nasal segment is preserved in the output; but for /CṼn+ɻ/, the nasal is only preserved as nasalisation on the vowel. The former is obviously a more faithful rendition of the input nasal. Therefore, we can make the following modification to the evaluation of the nasal faithfulness constraints: the constraints are only satisfied when the nasal itself is fully preserved in the suffixed form. They receive one violation if the nasality is only preserved on the vowel, and they receive two violations if the nasality is completely lost. This is illustrated in (32).

(32)

Stem	*Stem+suffix*	MAX[+nas]$_{n}$	
[CṼN]	[CṼN]		
[CṼN]	[CṼ]	*	
[CṼN]	[CV]	**	(N = n or ŋ)

The following ranking arguments can be given for Anqing. For /CṼn+ɻ/, since the nasal vowel wins over the oral vowel, MAX[+nas]$_{n}$ ≫ $*V_{nas}$, and since the nasal vowel wins over the disyllabic form, TEMPLATE ≫ MAX[+nas]$_{n}$. For /CṼ̃ŋ+ɻ/, since the disyllabic form wins over both of the monosyllabic forms, MAX[+nas]$_{ŋ}$ ≫ TEMPLATE. The complete constraint ranking for Anqing is given in (33). The tableaux in (34) generate the correct results for Anqing.[7]

(33) MAX[+nas]$_{ŋ}$ ≫ TEMPLATE ≫ MAX[+nas]$_{n}$ ≫ *V$_{nas}$

(34)

	CṼn+ɻ	MAX[+nas]$_{ŋ}$	TEMP	MAX[+nas]$_{n}$	*V$_{nas}$
a.	CVɻ			**!	
	☞ CṼ̃ɻ			*	*
	CṼn.ɻ̩		*!		
b.	CṼ̃ŋ+ɻ				
	CVɻ	*!*			
	CṼ̃ɻ	*!			*
	☞ CṼ̃ŋ.ɻ̩		*		

Under the new interpretation of the MAX[+nas]$_{n}$ constraints, the rest of the factorial typology emerges unchanged. This was checked using the OT software. The Anqing pattern is the only one not generated by the previous factorial typology since all other patterns that observe the universal ranking MAX[+nas]$_{ŋ}$ ≫ MAX[+nas]$_{n}$ have already been generated. It does not obliterate any previously generated patterns either. This can be checked against tableaux (13) and (28)–(31). Minimal modification to the ranking of MAX[+nas]$_{ŋ}$ is needed in some cases, e.g. Beijing in (13). This is because if the winner for /CṼ̃ŋ+ɻ/ is [CṼ̃ɻ], MAX[+nas]$_{ŋ}$ can no longer be ranked as undominated, as it is violated by the winner. But placing it right below the other undominated constraints will still generate the correct outputs.

To summarise, the data patterns generated by the factorial typology exhibit a good match with reality. All patterns generated by the factorial typology are attested in real languages. The only case that is not generated by the factorial typology but is attested can be accounted for with the same constraints, with only a slight modification to the means of evaluation.

The six attested patterns, recapitulated in (35), observe the following implicational hierarchy: if the nasalisation of /n/ is preserved, then the nasalisation of /ŋ/ is preserved at least as faithfully. Moreover, these are *all* the possible patterns that observe this implicational hierarchy. The factorial typology of the MAX[F] approach generates exactly these patterns, due to the universal ranking MAX[+nas]$_{ŋ}$ ≫ MAX[+nas]$_{n}$. When relevant markedness constraints intervene between these two constraints, the nasalisation of /ŋ/ is more faithfully preserved than that of /n/, as in (35a, b, e). When no other constraint intervenes between these two constraints, the nasalisation of /ŋ/ and /n/ is preserved (or not preserved) identically, as in (35c, d, f). The opposite pattern, where the nasality of /n/ is more prominently preserved than that of /ŋ/, is not attested, nor is it generated

[7] We again assume that IDENT[syll] is ranked at the bottom of the hierarchy.

by the factorial typology, since the universal ranking Max[+nas]$_{ŋ}$ ≫ Max[+nas]$_{n}$ forbids it.

(35) a. /CṼn+ɻ/ → [CVɻ] /CṼ͌ŋ+ɻ/ → [CṼ͌ɻ]
b. /CṼn+ɻ/ → [CVɻ] /CṼ͌ŋ+ɻ/ → [CṼ͌ŋ.ɻ̩]
c. /CṼn+ɻ/ → [CVɻ] /CṼ͌ŋ+ɻ/ → [CVɻ]
d. /CṼn+ɻ/ → [CṼ͌ɻ] /CṼ͌ŋ+ɻ/ → [CṼ͌ɻ]
e. /CṼn+ɻ/ → [CṼ͌ɻ] /CṼ͌ŋ+ɻ/ → [CṼ͌ŋ.ɻ̩]
f. /CṼn+ɻ/ → [CṼn.ɻ̩] /CṼ͌ŋ+ɻ/ → [CṼ͌ŋ.ɻ̩]

4.2.2 *The* Ident[F] *approach.* We turn now to the factorial typology of the Ident[F] approach. The constraints involved in the Ident[F] analysis are summarised in (36).

(36) a. Ident[nas] d. RealiseAffix
b. MaxSeg(stem) e. Template
c. *ComplexCoda f. *V$_{nas}$

The basic assumption under the Ident[F] analysis is that the vowel before an /n/-coda is [−nasal], while the vowel before an /ŋ/-coda is [+nasal]. Let us take this for granted for now and interpret it as an undominated constraint VN, as defined in (37). It penalises a [+nasal] specification for the vowel before a coda /n/ and a [−nasal] specification for the vowel before a coda /ŋ/. To encode the [nasal] specification on the vowel, in this subsection the inputs for the suffixed forms are transcribed as /CVn+ɻ/ and /CṼ͌ŋ+ɻ/.

(37) VN

Vn	Vŋ
|	|
[−nas]	[+nas]

Again, we assume *ComplexCoda and RealiseAffix to be undominated, and only compute the factorial typology of the other four constraints. And crucially, since the vowel in the /C __ ŋ/ context is specified for [+nasal], it has in a way acquired an independent status regarding nasality from the coda nasal. Therefore I consider it more appropriate to assign a violation for *V$_{nas}$ to [CṼ͌ŋ] in this analysis, even though [Ṽ͌] is in a nasal environment here. All rankings considered, four distinct data patterns are generated, as summarised in Table III.

Two problems can be immediately observed from this factorial typology. First, although patterns Table IIIa–c are attested (Beijing, Liaocheng and Guiyang, respectively), Table IIId is not, nor can it be considered an accidental gap. As a result of the high ranking of VN and *V$_{nas}$ and the low ranking of Template, this language preserves /n/ fully, but deletes /ŋ/ completely. This is exactly the situation that is systematically missing in the dialectal survey – the nasalisation of /n/ is more prominently preserved than that of /ŋ/. The Max[F] analysis correctly

	Output pattern	*Constraint ranking*
a.	/CVn+ɻ/ → [CVɻ] /CṼ̃ŋ+ɻ/ → [CṼ̃ɻ]	TEMPLATE, IDENT[nas] ≫ *V_{nas}, MAXSEG(stem)
b.	/CVn+ɻ/ → [CVɻ] /CṼ̃ŋ+ɻ/ → [CVɻ]	TEMPLATE, *V_{nas} ≫ IDENT[nas], MAXSEG(stem)
c.	/CVn+ɻ/ → [CVn.ɻ̩] /CṼ̃ŋ+ɻ/ → [CṼ̃ŋ.ɻ̩]	IDENT[nas], MAXSEG(stem) ≫ TEMPLATE, *V_{nas}
d.	/CVn+ɻ/ → [CVn.ɻ̩] /CṼ̃ŋ+ɻ/ → [CVɻ]	*V_{nas} ≫ IDENT[nas], MAXSEG(stem) ≫ TEMPLATE

[Table III. Factorial typology: IDENT[F].]

predicts this, while the IDENT[F] analysis misses this generalisation. The tableaux that illustrate the derivation of this unattested output pattern are given in (38). Notice that in (38b), the candidate [CṼ̃ŋ.ɻ̩] violates *V_{nas}, due to the [+nasal] specification of the vowel.

(38) a.

CVn+ɻ	VN	*V_{nas}	MAXSEG(stem)	ID[nas]	TEMP
CVɻ			*!		
☞ CVn.ɻ̩					*
CṼ̃ɻ		*!	*		

b.

CṼ̃ŋ+ɻ	VN	*V_{nas}	MAXSEG(stem)	ID[nas]	TEMP
☞ CVɻ			*	*	
CVŋ.ɻ̩	*!				*
CṼ̃ŋ.ɻ̩		*!			*
CṼ̃ɻ		*!	*		

Second, the factorial typology fails to generate [CṼ̃ɻ] as a possible output for /CVn+ɻ/. But as we have seen, Jiyuan and Anqing exhibit this data pattern. The reason why [CṼ̃ɻ] is never generated for /CVn+ɻ/ is because nothing is gained by violating IDENT[nas] and *V_{nas} – MAXSEG(stem) is still violated, just as in [CVɻ].

Therefore, we conclude that although the IDENT[F] approach seems to work for Beijing, it suffers from lack of generality when extended to other dialects. The factorial typology of the constraints produces unattested patterns and cannot generate some attested patterns. On these grounds, I claim that MAX[F] is a superior approach. The IDENT[F] analysis makes the assumption that the vowel in the /C __ n/ context is categorically oral, and the vowel in the /C __ ŋ/ context is categorically nasal. The IDENT[nas] constraint then requires the correspondence of this feature between the stem and the suffixed form. As a consequence, the vowel in /CVn/ is never able to receive nasalisation, despite the loss of the nasal. But obviously, the pressure is for the output to preserve the nasal feature in *some* form, not for total featural identity between suffixed and unsuffixed forms. Therefore MAX[F], rather than IDENT[F], is a more appropriate type of constraints for the data in question.

5 Dialectal typology and factorial typology for one nasal coda

Some Chinese dialects have only one nasal coda. This nasal coda is usually /ŋ/ (Chen 1972, Zee 1985). Historical /n/ is either completely lost or manifested as vowel nasalisation. In the latter case, nasalisation on vowels is contrastive. What do the MAX[F] and IDENT[F] analyses predict in these situations? How do the predictions match up with attested patterns? To preview the findings, the factorial typology of MAX[F] only predicts patterns in which the nasality of the /ŋ/ is preserved at least as faithfully as that of /**Ṽ̃**/ (I use boldface to indicate contrastive vowel nasalisation), if we take into account the universal ranking $\text{MAX}[+\text{nas}]_{ŋ} \gg \text{MAX}[+\text{nas}]_{\tilde{\tilde{V}}}$, with the assumption that the nasal percept of a nasal stop is stronger than that of a nasalised vowel. The dialectal typology shows that only these patterns are attested. The factorial typology of IDENT[F], however, cannot generate some attested patterns.

In a MAX[F] approach, we again assume *COMPLEXCODA and REALISE AFFIX to be undominated. Moreover, in the seven dialects I have consulted, none allows disyllabic diminutive forms. Given that only a limited number of dialects have one nasal coda, I consider this to be an accidental gap and assume TEMPLATE to be undominated as well.

Let us first tackle the simpler case, in which the historical /n/ is completely lost. Therefore the factorial typology only involves two constraints – $\text{MAX}[+\text{nas}]_{ŋ}$ and $*V_{nas}$. It generates two simple patterns, as in Table IV.

	Output pattern	*Constraint ranking*
a.	/CṼ̃ŋ+ɹ/ → [CVɹ]	$*V_{nas} \gg \text{MAX}[+\text{nas}]_{ŋ}$
b.	/CṼ̃ŋ+ɹ/ → [CṼ̃ɹ]	$\text{MAX}[+\text{nas}]_{ŋ} \gg *V_{nas}$

[Table IV. Factorial typology for one nasal coda.]

Both of these patterns are attested in real languages. Pattern Table IVa is instantiated by Changzhi (Hou 1985), as shown in (39a), and pattern Table IVb is instantiated by Pingyao (Hou 1989), as shown in (39b).[8]

[8] In Pingyao, the suffixed form of [Cĩŋ] is [Ciɹ], without the nasalisation on the vowel. This in fact fits in the perceptually based MAX[F] analysis. Perceptual experiments (Lintz & Sherman 1961, Ali *et al*. 1971, Brito 1975) have shown that 'low vowels are more likely to elicit nasal percepts than are nonlow vowels in the same contexts' (Beddor 1993: 178). This could be due to the relatively lower velum position in the production of low vowels (Fritzell 1969, Ohala 1971, Clumeck 1976,

(39) a. *Changzhi* (Hou 1985)

/CV + ɻ/ → [CVɻ]	/pa + ɻ/ → [paɻ]	'grip, handle'
	/tsu + ɻ/ → [tsuəɻ]	'person concerned'
/CṼ̃ŋ + ɻ/ → [CVɻ]	/jã̃ŋ + ɻ/ → [jaɻ]	'shape'
	/pʰĩ̃ŋ + ɻ/ → [pʰiəɻ]	'bottle'

b. *Pingyao* (Hou 1989)

/CV + ɻ/ → [CVɻ]	/mɑ + ɻ/ → [mɑɻ]	'horse'
	/y + ɻ/ → [yɻ]	'fish'
/CṼ̃ŋ + ɻ/ → [CṼ̃ɻ]	/jɑ̃̃ŋ + ɻ/ → [jɑ̃̃ɻ]	'eye'
	/pʰə̃̃ŋ + ɻ/ → [pʰẽ̃ɻ]	'washbasin'

For dialects with one nasal coda and phonemic nasalisation, we need to decide whether /N/ or /**Ṽ̃**/ induces a stronger nasal percept. Apparently, the acoustic consequences of the nasal tract are weakened by the presence of an open oral tract: the nasal formants are blurred by the oral formants, the open oral tract contributes antiformants to the nasal formant structure and these antiformants are different from the antiformants in a nasal stop. Moreover, nasalised vowels do not benefit from the nasal murmur that is present in nasal stops. Thus we can reasonably infer that a nasal stop yields a better nasal perception than a nasalised vowel. Therefore, we arrive at the universal ranking for MAX[+nas]$_{\text{ŋ}}$ and MAX[+nas]$_{\tilde{\tilde{\text{V}}}}$ shown in (40).

(40) MAX[+nas]$_{\text{ŋ}}$ ≫ MAX[+nas]$_{\tilde{\tilde{\text{V}}}}$

Again, bear in mind that the MAX[+nas] constraints here are MAX-OO[+nas] constraints. They require the [+nasal] feature in the stem to be preserved in the suffixed form, both of which are output representations. The phonemic status of vowel nasalisation requires the constraint ranking MAX-IO[+nas] ≫ *V$_{\text{nas}}$, but there is no predetermined ranking between MAX-OO[+nas] and *V$_{\text{nas}}$.

Taking into account this universal ranking, we compute the factorial typology of three constraints: MAX[+nas]$_{\text{ŋ}}$, MAX[+nas]$_{\tilde{\tilde{\text{V}}}}$ and *V$_{\text{nas}}$. Three data patterns are generated, as shown in Table V. I again use boldface /**Ṽ̃**/ to indicate phonemic vowel nasalisation and /Ṽ̃/ to indicate phonetic nasalisation. Therefore /**Ṽ̃**/ occurs in open syllables and /Ṽ̃/ before a coda /ŋ/. There is no vowel nasalisation contrast before a nasal coda.

The factorial typology only generates data patterns in which the nasalisation of /ŋ/ is at least as faithfully preserved as the nasalisation of /**Ṽ̃**/. This is the direct result of the universal ranking of MAX[+nas]$_{\text{ŋ}}$ ≫ MAX[+nas]$_{\tilde{\tilde{\text{V}}}}$. When no other constraint is ranked between them,

Henderson 1984). Cross-linguistically, the Pingyao pattern is not uncommon. Various studies have shown that low vowels are more likely to be nasalised in historical changes (Chen 1972, Ohala 1975, Ruhlen 1978, Hombert 1986). This might be taken as a stronger case for referring to nasal percepts directly in phonology, since the cut-off point here (/ŋ/-coda except in [+high, +front] contexts) cannot be easily expressed by using traditional phonological categories.

	Output pattern	*Constraint ranking*
a.	/C**Ṽ̃**+ɹ/ → [CVɹ]	Max[+nas]$_{ŋ}$ ≫ *V$_{nas}$ ≫ Max[+nas]$_{Ṽ̃}$
	/CṼ̃ŋ+ɹ/ → [CṼ̃ɹ]	
b.	/C**Ṽ̃**+ɹ/ → [CVɹ]	*V$_{nas}$ ≫ Max[+nas]$_{ŋ}$, Max[+nas]$_{Ṽ̃}$
	/CṼ̃ŋ+ɹ/ → [CVɹ]	
c.	/C**Ṽ̃**+ɹ/→ [CṼ̃ɹ]	Max[+nas]$_{ŋ}$, Max[+nas]$_{Ṽ̃}$ ≫ *V$_{nas}$
	/CṼ̃ŋ+ɹ/ → [CṼ̃ɹ]	

[Table V. Factorial typology for one nasal coda and phonemic vowel nasalisation.]

/C**Ṽ̃** + ɹ/ and /CṼ̃ŋ + ɹ/ exhibit identical behaviour; when the phonotactic constraint *V$_{nas}$ is ranked in between, /C**Ṽ̃** + ɹ/ loses the nasalisation but /CṼ̃ŋ + ɹ/ preserves the nasality by vowel nasalisation.

The result of the dialectal survey matches the factorial typology perfectly. These three patterns are exactly the patterns that are attested. Jinan (Qian 1995) and Xuzhou (Li 1985) have pattern Table Va, Northern Shouguang (Zhang 1996) and Xi'an (Wang 1997) have pattern Table Vb and Xinzhou (Wen 1985) has pattern Table Vc. Examples from Jinan, Northern Shouguang and Xinzhou are given in (41).

(41) a. *Jinan* (Qian 1995)

/CV + ɹ/ → [CVɹ]	/fa + ɹ/ → [faɹ]	'method'
	/pʰɛ + ɹ/ → [pʰɛɹ]	'tablet'
/C**Ṽ̃** + ɹ/ → [CVɹ]	/pʰ**ã̃** + ɹ/ → [pʰɛɹ]	'plate'
	/pʰ**ẽ̃** + ɹ/ → [pʰeɹ]	'(wash) basin'
/CṼ̃ŋ + ɹ/ → [CṼ̃ɹ]	/ʐã̃ŋ + ɹ/ → [ʐã̃ɹ]	'pulp'
	/ɕĩ̃ŋ + ɹ/ → [ɕiə̃̃ɹ]	'star'

b. *Northern Shouguang* (Zhang 1996)

/CV + ɹ/ → [CVɹ]	/pa + ɹ/ → [pʌɹ]	'scar'
	/ku + ɹ/ → [kuɹ]	'drum'
/C**Ṽ̃** + ɹ/ → [CVɹ]	/p**æ̃̃** + ɹ/ → [pəɹ]	'plank'
	/i**ə̃̃** + ɹ/ → [iɭ]	'sound'
/CṼ̃ŋ + ɹ/ → [CVɹ]	/tʰã̃ŋ + ɹ/ → [tʰʌɹ]	'candy'
	/fə̃̃ŋ + ɹ/ → [fʌɹ]	'wind'

c. *Xinzhou* (Wen 1985)

/CV + ɹ/ → [CVɹ]	/tsʰɑ + ɹ/ → [tsʰɐɹ]	'branch of a tree'
	/kɛ + ɹ/ → [kəɹ]	'brother'
/C**Ṽ̃** + ɹ/ → [CṼ̃ɹ]	/ŋ**ɑ̃̃** + ɹ/ → [ŋɐ̃̃ɹ]	'crow'
	/tɕy**ɑ̃̃** + ɹ/ → [tɕyɐ̃̃ɹ]	'curl'
/CṼ̃ŋ + ɹ/ → [CṼ̃ɹ]	/fə̃̃ŋ + ɹ/ → [fɐ̃̃ɹ]	'bee'
	/miə̃̃ŋ + ɹ/ → [miɐ̃̃ɹ]	'tomorrow'

How does the factorial typology of Ident[F] do? We observe that it cannot account for Jinan and Xuzhou, which exhibit the data pattern:

/C**V͌**+ɻ/→[CVɻ], /CV͌ŋ+ɻ/→[CV͌ɻ]. If we again consider the stem with an /ŋ/-coda to have a nasalised vowel, then the proposal runs into a ranking paradox. /C**V͌**+ɻ/→[CVɻ], *[CV͌ɻ], requires that $*V_{nas}$ ≫ IDENT[nas], but /CV͌ŋ+ɻ/→[CV͌ɻ], *[CVɻ], requires the exact opposite: IDENT[nas] ≫ $*V_{nas}$. These are shown in the mini-tableaux in (42). In the transcriptions here, /V͌/ in /CV͌ŋ/ indicates a [+nasal] specification.

(42) a.

C**V͌**+ɻ	$*V_{nas}$	ID[nas]
☞ CVɻ		*
CV͌ɻ	*!	

b.

CV͌ŋ+ɻ	ID[nas]	$*V_{nas}$
CVɻ	*!	
☞ CV͌ɻ		*

In summary, the factorial typology and dialectal survey regarding dialects with only one nasal coda further support the MAX[F] analysis. The phonetically based universal ranking $\text{MAX}[+\text{nas}]_{ŋ} \gg \text{MAX}[+\text{nas}]_{\tilde{\tilde{V}}}$ predicts that if the nasalisation of /**V͌**/ is preserved, then the nasalisation of /ŋ/ is preserved as well, and this is exactly what is observed. The factorial typology of IDENT[F] again fails to match up with the attested patterns.

6 Further discussion of MAX[F] and IDENT[F]

6.1 IDENT[F]'s alternative approaches to dialectal variation

The approach I discussed in the previous sections is only one of the approaches that IDENT[F] can take. In the following subsections, I discuss three other alternatives to the dialectal variation within the realm of IDENT[F] and show that none of them can account for the attested data patterns in a satisfactory way.

6.1.1 *Two other categorical* IDENT[F] *approaches.*

6.1.1.1 *Language-specific* [nasal] *specification.* The first categorical IDENT[F] alternative is to assume that different dialects may have different [nasal] specifications for the vowel in nasal-closed syllables. For example, in Beijing, the vowel in the /C__n/ context is [−nasal], while the vowel in the /C__ŋ/ context is [+nasal]. A high-ranking IDENT[nas] constraint ensures that /CVn+ɻ/→[CVɻ] and /CVŋ+ɻ/→[CV͌ɻ]. In Liaocheng, the vowels in both the /C__n/ and /C__ŋ/ contexts are [−nasal]. High-ranking IDENT[nas] ensures that [CVɻ] is the suffixed form for both /CVn/ and /CVŋ/. Jiyuan is just the opposite of Liaocheng, with the vowels specified for [+nasal] in both the /C__n/ and /C__ŋ/ contexts. High-ranking IDENT[nas] therefore ensures that [CṼ̃$_F$] is the winner for both /CṼ̃n+F/ and /CṼ̃ŋ+F/.

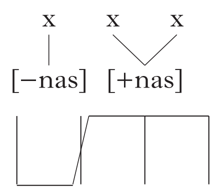
Even though this alternative seems to fare better than the previous IDENT[F] approach in that it is able to generate patterns in which vowel nasalisation appears in the alveolar nasal case, three objections can still be raised against it. First, it assumes the undominated ranking of IDENT[nas]. But if IDENT[nas] participates in the factorial typology, unattested data patterns would be generated, as shown in §4.2.2. Second, it still does not account for Jinan and Xuzhou, whose data pattern is /CṼ̃+ɹ/→[CVɹ], /CṼ̃ŋ+ɹ/→[CṼ̃ɹ]. The ranking paradox in (42) still exists. Third, in order to account for the different [nasal] specification for the vowels across dialects, it must assume that these dialects differ in the phonetic realisation of the vowel before nasal codas, as the threshold for perceiving a [+nasal]/[−nasal] distinction, if it exists, should be the same across the speakers of different dialects. Lacking phonetic data on dialects other than Beijing, we cannot verify whether this assumption is valid. But given that the MAX[F] approach does not have to rely on unmotivated assumptions, this constitutes one reason why the IDENT[F] approach is less attractive. Moreover, as it is shown in §6.1.1.3, even its assumption for Beijing does not seem to hold up under close phonetic scrutiny.

6.1.1.2 *Underspecification*. The second categorical alternative is underspecification, i.e. allowing the vowel before one or both of the nasal codas to be underspecified for the feature [nasal]. But this move does not seem to gain us any new ground either: it still has all the problems of a full-specification IDENT[F] analysis. First, its factorial typology still generates unattested patterns such as /CVn+ɹ/→[CVn.ɹ], /CṼ̃ŋ+ɹ/→[CVɹ], under the assumption that the vowel is underspecified for [nasal] in the context of /C__n/, and specified as [+nasal] in the context of /C__ŋ/. The argument is the same as the tableaux in (38), where the vowel is [−nasal] before /n/ and [+nasal] before /ŋ/. Second, the data pattern of Jinan and Xuzhou, /CṼ̃+ɹ/→[CVɹ], /CṼ̃ŋ+ɹ/→[CṼ̃ɹ], is still left unaccounted for. This is because in order for a nasalised vowel to surface in the suffixed form, the vowel in the context of /C__ŋ/ must be specified as [+nasal]. And given that the phonemic vowel must be specified as [+nasal] as well, the situation is exactly the same as in (42). Third, to account for the presence of vowel nasalisation in the alveolar nasal case in some of the dialects, we must still resort to the [+nasal] specification for the vowel in the /C__n/ context, which makes the language-specific phonetic assumption that need not be made in an MAX[F] approach. Finally, as I will show in §6.1.1.3, a [+nasal] specification for the vowel in the /C__ŋ/ context is phonetically inappropriate.

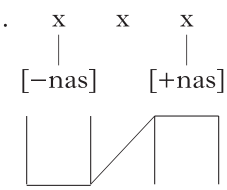
6.1.1.3 *The* [+nasal]/[−nasal] *distinction in* IDENT[F]. Although, as claimed, both the MAX[F] and IDENT[F] approaches are phonetically based, they differ in how much phonetic detail they endorse. The MAX[F] approach simply compares the perceptual salience of two realisations of a feature and bases the ranking on this phonetic comparison, without any assumptions about the relation between perceptual salience and phonological representations. The Ident[F] approach, on the other hand, assumes the categorical specification of [−nasal] for the vowel in [CṼn] and [+nasal] for the vowel in [CṼ̃ŋ]. Thus the output–output correspondence is based on phonological comparison, even though the [nasal] feature values for the vowels are specified through phonetic evidence.

One question to ask at this point is, what does the listener do? Does he simply perceive the nasality to be stronger in one environment than the other, or categorically perceive [+nasal] and [−nasal] for the vowel? Given the aerodynamic data, we can make certain inferences on the speaker's specification of the [nasal] feature on the vowel. Cohn (1990) has argued that if the vowel before a nasal is specified as [+nasal], we would expect to see the nasal flow pattern as in (43a). If the nasalisation is simply a phonetic anticipatory effect, we would expect to see the pattern as in (43b).

(43) a.



b.



Looking at the nasal flow trace for /cɕiŋ/ shown in Fig. 1, we observe that its amplitude increases gradually, as in pattern (43b). Moreover, the average duration of positive nasal flow is only 45–65% of the duration of the entire vowel in [CṼ̃ŋ], as shown in Fig. 2. Thus if we adopt Cohn (1990)'s criterion, we infer that the vowel in the /C__ŋ/ context is most likely not specified for [+nasal], but acquires its nasality through coarticulation with the /ŋ/-coda. From this we conclude that assuming the vowel in the /C__ŋ/ context to be [+nasal] is unwarranted. Given that the [+nasal] specification for the vowel in the unsuffixed form is the prerequisite for this vowel to surface as nasalised in the suffixed form in any categorical version of the Ident[F] approach, I conclude that the categorical Ident[F] approach is also phonetically unsound.

6.1.2 *A gradient* Ident[F] *approach.* With the failure of the two categorical Ident[F] approaches, we may want to consider a gradient Ident[F] approach. In this approach, what is in correspondence is not the categorical feature [±nasal], but the amount of nasality. For example, we may consider constraints of the forms Ident[nas]$_{(\text{V/\_ŋ})}$ and Ident[nas]$_{(\text{V/\_n})}$, which require identity on the amount of nasality during the vowel between the stem and the suffixed form. Based on the fact that the /ŋ/-coda induces stronger nasality than the /n/-coda, we may posit a universal ranking between these constraints: Ident[nas]$_{(\text{V/\_ŋ})}$ ≫ Ident[nas]$_{(\text{V/\_n})}$. Similarly to the Max[F] approach, ranking *V_{nas} between these two constraints will produce the data pattern for Beijing (cf. (3)).

This move is in the spirit of Steriade (2000), in that it requires uniformity within the paradigm with regard to a non-contrastive phonetic feature. And the mechanism through which the /n–ŋ/ asymmetry in the suffixed form is derived is the same as that proposed for Max[F] – a universal constraint ranking based on phonetic facts. Thus we must acknowledge that this move makes the Ident[F] approach essentially the same as the Max[F] one. But one problem still remains – the data pattern in Jinan and Xuzhou: /C**Ṽ̃**+ɻ/ → [CVɻ], /CṼ̃ŋ+ɻ/ → [CṼ̃ɻ] (cf. (41a)). Under normal circumstances, we would expect a phonemic nasal vowel [**Ṽ̃**] to have more nasality than the vowel in [Ṽ̃ŋ]. Thus we should posit the universal ranking Ident[nas]$_{\tilde{\tilde{v}}}$ ≫ Ident[nas]$_{(V/\_\_ŋ)}$. Under this ranking, we would only predict patterns in which the nasality of [C**Ṽ̃**] is more prominently preserved than that of [CṼ̃ŋ]. But the data pattern in Jinan and Xuzhou is just the opposite.

6.2 Max[F] *vs*. Ident[F]

From the above discussion, I conclude that no version of the Ident[F] approach can capture all the data patterns in a satisfactory way, and Max[F] constraints are needed on both typological and phonetic grounds, as they make better predictions in their factorial typology and make fewer assumptions in the phonetic realisation of nasalisation.

Support for the need for Max[F] constraints can be found in Lombardi (1995, 1998), Casali (1996), Pulleyblank (1996), Causley (1997) and McCarthy & Prince (1999). For example, Casali (1996) shows that resolving hiatus by coalescence can only receive a satisfactory analysis by referring to Max[F] constraints. Lombardi (1995, 1998) provides a twofold argument for Max[F] from Japanese coda neutralisation, intensified adverbs and verb paradigms. On the one hand, Ident[F] requires too strict a correspondence relation, since it penalises the alteration of both '+' and '−' values of the feature, and it prevents features from moving around. Lombardi (1998) shows that in Japanese verb paradigms, the correct analysis should only penalise the loss of [+voice] feature, and it should allow the [+voice] feature to be realised on a different segment than the underlying one. On the other hand, Ident[F] posits too loose a correspondence relation, since it receives no violation if the whole segment is deleted. Casali (1996) shows that if Ident[F] is the only type of featural correspondence constraints, vowel elision will always be a more harmonic option in hiatus resolution, and vowel coalescence should never be attested. But coalescence is observed many times in a cross-linguistic survey.

This raises two questions that I will not be able to answer in this paper: 'do we need Ident[F] at all?' and 'in Beijing and other dialects where both Ident[F] and Max[F] generate the correct output, do we have evidence that the speaker uses one or the other?'. Lombardi (1995) has made some headway in showing that it is possible to replace Ident[F] with

Max[F] and Dep[F] in the analysis of voicing assimilation; Pater (1995) argues for both Ident[+F] and Ident[−F] constraints which seem to achieve equivalent effects to Max[F] and Dep[F]. These works hint at the possibility of eliminating Ident[F] constraints. But without carrying the paper further afield, I simply acknowledge the question and hope to unveil the answer in future research.

7 Two other alternatives

7.1 The vocalicness of /ŋ/[9]

House (1957), Trigo (1988), Ohala & Ohala (1993), among other researchers, have demonstrated that back nasals are more vocalic than front nasals. House (1957) shows that listeners are more likely to confuse /ŋ/ with /**V͌**/ than either /m/ or /n/. Ohala & Ohala (1993) give two main reasons for this phenomenon. First, the further back the oral constriction is, the higher the antiformants contributed by the closed oral tract are. These high antiformants only have a small perceptual effect. Therefore the perceptually dominant resonances of a velar nasal will be mostly contributed by the pharyngeal-nasal cavity, which will make it sound similar to a nasalised vowel. Second, back consonants are produced by the relatively massive tongue dorsum, which gives them a slower transition, and hence a less abrupt spectral change, to the neighbouring vowels. This also makes them less consonantal than consonants produced by the lips or tongue tip.

Intuitively, this fact may provide an alternative explanation to the asymmetry between /ŋ/ and /n/ in the attested data patterns: /CV͌ŋ+ɹ/ tends to surface with a nasalised vowel since in the stem form the vowel and the /ŋ/-coda are already blended together with a blurry boundary; /CṼn+ɹ/ tends to surface with an oral vowel since in the stem form there is a clear boundary between the vowel and the /n/ coda. But this intuition turns out to be extremely difficult to capture formally. One possible way to formalise the idea is to appeal to constraint conjunction (Hewitt & Crowhurst 1996, Crowhurst & Hewitt 1997). Let us consider /ŋ/ to be [+vocalic], /n/ to be [−vocalic] and both /ŋ/ and /n/ to be [+nasal]. Then we can propose two conjoined Max-OO[F] constraints holding between the stem and the suffixed form: Max[+voc]&Max[+nas] and Max[−voc]&Max[+nas], requiring the preservation of the features for /ŋ/ and /n/, respectively. These constraints are satisfied only if both of the conjoined constraints are satisfied. With the familiar *ComplexCoda, RealiseAffix, Template and $*V_{nas}$ at play, the ranking in (44) generates the data pattern for Beijing.

[9] Thanks to an anonymous reviewer for pointing out this alternative to me.

(44) *ComplexCoda, RealiseAffix, Template

|

Max[+voc]&Max[+nas], Max[−voc]&Max[+nas]

|

$*V_{nas}$

(45) a.

CṼn+ɻ	*Comp Coda	RealAff	Temp	Max[+voc]& Max[+nas]	Max[−voc]& Max[+nas]	$*V_{nas}$
☞ CVɻ					*	
CṼnɻ	*!					
CṼn		*!				
CṼn.ɻ			*!			
CṼ̃ɻ					*	*!
b. CṼ̃ŋ+ɻ						
☞ CṼ̃ɻ						*
CṼ̃ŋɻ	*!					
CṼ̃ŋ		*!				
CṼ̃ŋ.ɻ			*!			
CVɻ				*!		

The tableaux in (45) illustrate the working of the constraint ranking. In (45a), the winner [CVɻ] ties with its closest rival [CṼ̃ɻ] on Max[−voc]&Max[+nas], since even though [CṼ̃ɻ] preserves the nasality of /n/, it still violates the conjoined constraint Max[−voc]&Max[+nas], due to the violation of Max[−voc]. But [CVɻ] does not violate $*V_{nas}$, while [CṼ̃ɻ] does. In (45b), the winner [CṼ̃ɻ] satisfies Max[+voc]&Max[+nas] by preserving both the vocalicness and nasality of /ŋ/ on the vowel, while its closest rival [CVɻ] violates the conjoined constraint by violating Max[+nas].

Therefore, this alternative does account for the data pattern in Beijing. But from tableau (45a), we immediately observe a problem for generalising this account to other attested patterns: in the case of /CṼn+ɻ/, the constraint violations for the candidate [CṼ̃ɻ] are a superset of those for [CVɻ]. This implies that [CṼ̃ɻ] will never emerge as the winner under any ranking of the constraints in this approach. But this pattern is attested in two of the dialects in the typology: Anqing (cf. (23)) and Jiyuan (cf. (25)). Moreover, since there is no *a priori* justification for any universal ranking between Max[+voc]&Max[+nas] and Max[−voc]&Max[+nas], there is no mechanism in this approach that prevents the nasality of /n/ to be more faithfully preserved than the nasality of /ŋ/. In fact, two such patterns can be generated by these constraints, as shown in Table VI. I

	Output pattern	*Constraint ranking*
a.	/CṼn+ɹ/ → [CṼn.ɹ̩] /C$\tilde{\tilde{V}}$ŋ+ɹ/ → [CVɹ]	*ComplexCoda, RealiseAffix, Max[−voc]&Max[+nas], *V_{nas} ≫ Template ≫ Max[+voc]&Max[+nas]
b.	/CṼn+ɹ/ → [CṼn.ɹ̩] /C$\tilde{\tilde{V}}$ŋ+ɹ/ → [C$\tilde{\tilde{V}}$ɹ]	Max[−voc]&Max[+nas], Max[+voc]&Max[+nas] ≫ Template ≫ *V_{nas}

[Table VI. Two problematic predictions in the factorial typology for the conjoined constraints Max[−voc]&Max[+nas], Max[+voc]&Max[+nas].]

therefore conclude that this alternative does not provide a satisfactory account for the range of variations observed in the dialectal survey.[10]

7.2 An articulatorily based alternative for Beijing

From an articulatory point of view, /n/ is coronal, while /ŋ/ is dorsal. Since the retroflex suffix /ɹ/ is also coronal, it conflicts with /n/, but not with /ŋ/. Is it possible that the phonological differences between /n/ and /ŋ/ are caused by their difference in place of articulation?

This line of reasoning has been assumed in the works of many Chinese scholars, notably Lin (1982) and Wang & He (1985). It is also pursued in Wang (1993, 1997) in feature-geometric terms. But two questions remained unanswered in this articulatorily based approach. First, since the place features and the manner features of a segment are independent, why does the loss of the place feature [+coronal] of /n/ incur the loss of the manner feature [+nasal] as well? Second, this approach implies that upon suffixation, the /ŋ/-coda keeps its place feature as well as the manner

[10] As one anonymous reviewer points out, it is possible that the vocalicness of the coda nasals plays an auxiliary role in helping the language learner posit two distinct and universally ranked constraints on the preservation of the nasal feature: Max$[+nas]_{ŋ}$ ≫ Max$[+nas]_{n}$. The reviewer also suggests that, if this is correct, then it will pose a problem for the direct approach of phonetics in phonology (Max$[+nas]_{NP(ŋ)}$ ≫ Max$[+nas]_{NP(n)}$, cf. §3.2.1), since it cannot easily incorporate multiple influences of this sort in the analysis. But my intuition is that the difference in vocalicness between the two nasals is relevant to the data patterns in question only if the following two conditions are met: first, it contributes to nasal perception *per se*; second, the vocalicness of /ŋ/ increases its nasal perception, or the (non-)vocalicness of /n/ decreases its nasal perception, or both. There are presumably other differences between /n/ and /ŋ/, but apparently not all of them contribute to the data patterns under discussion. The argument is again based on the factorial typology: if all differences between /n/ and /ŋ/ were allowed to influence the data pattern, then the factorial typology of the analysis would surely explode, since the strength of the nasal perception would not be the sole factor, but one of many that could come into play. If this reasoning is right, then the direct approach still holds up. Not only so, it is in fact more restrictive and accurate than the other approach, since it only allows those differences between /n/ and /ŋ/ that have an effect on nasal perception in a certain direction to influence the data pattern.

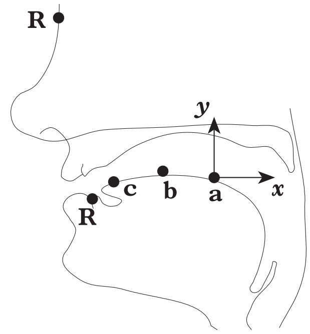


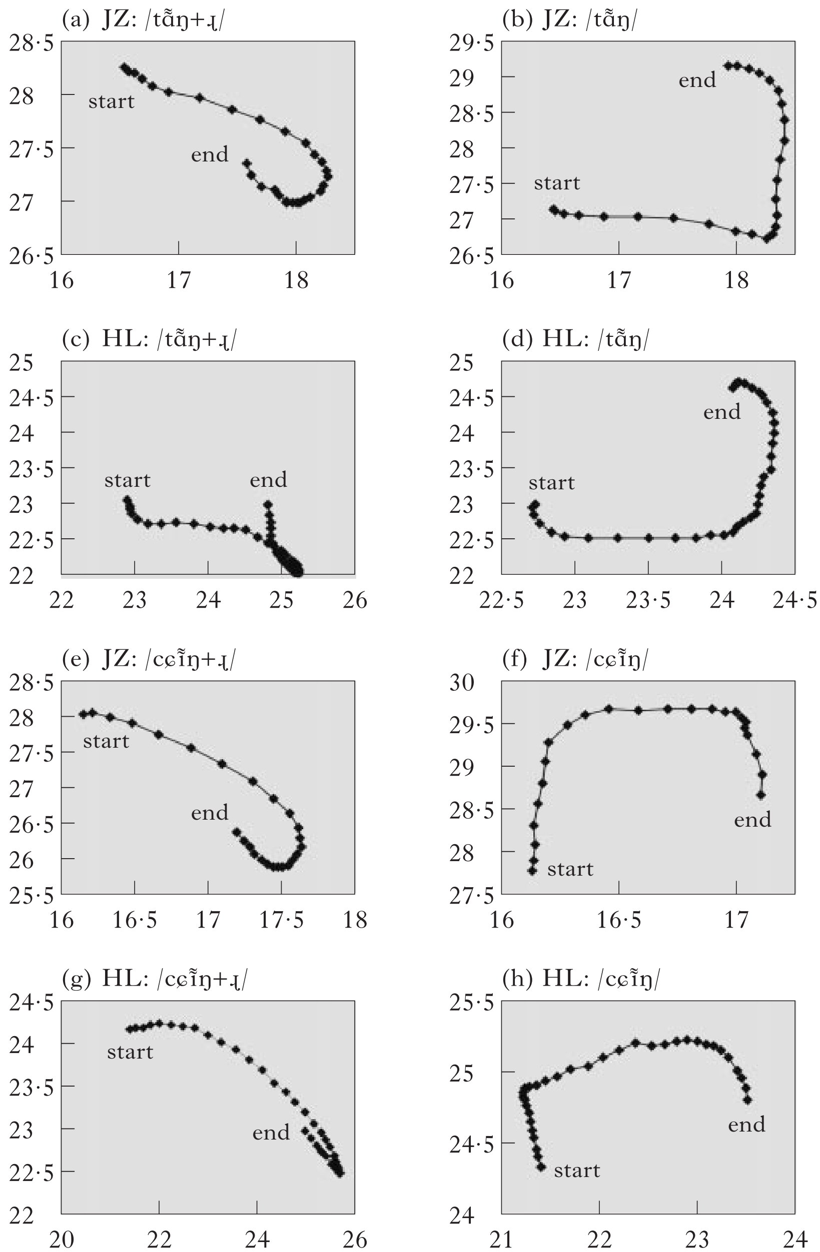
Figure 4
Schematic of receiver coil placement in the EMA study.

feature [+nasal]. This conflicts with the usual claim that the only trace of the /ŋ/-segment is the nasalisation on the vowel. Is there empirical support for this?

To address the first question, Wang (personal communication) suggests that the loss of the two features must be related and this effect can be achieved representationally. But even if we can justify the claim that the loss of the nasal feature is related to the loss of the place feature, we are still left with the empirical question – is the place gesture of /ŋ/ actually preserved in the suffixed form?

To answer this question, an EMA (Electromagnetic Articulography) study was conducted on the same two speakers – JZ and HL – in the Phonetics Laboratory of UCLA. EMA is a system that transduces movements of the tongue, lips, jaw and teeth during the process of speech utilising an inductive measurement principle based on the physical law that the electromagnetic field strength in a receiver is inversely proportional to the cube of the distance from a transmitter. The system employs three transmitter coils placed equidistant from one another so that they generate a symmetric alternating electromagnetic field at different frequencies. A number of receiver coils are placed on the articulators of the subject. The induced voltages on the sensors provide a measure of the accurate position of the sensors over time.

Three receiver coils were placed from the tip to the back of the subject's tongue to collect movement data. The distance between each pair of coils was about 2·5 cm. Two reference coils were also placed on the bridge of the nose and between the lower incisors. The placement of the receiver coils is shown schematically in Fig. 4. The speech material was the same as that used in the aerodynamic experiment described in §2.1 – six pairs of [CṼn] and [CṼ̃ŋ] with matching onsets and vowels, read in the same carrier sentence. Each sentence was read with five repetitions. The


(a) JZ: /tã̃ŋ+ɻ/
start
end
(b) JZ: /tã̃ŋ/
end
start
(c) HL: /tã̃ŋ+ɻ/
start
end
(d) HL: /tã̃ŋ/
end
start
(e) JZ: /cɕĩ̃ŋ+ɻ/
start
end
(f) JZ: /cɕĩ̃ŋ/
end
start
(g) HL: /cɕĩ̃ŋ+ɻ/
start
end
(h) HL: /cɕĩ̃ŋ/
end
start

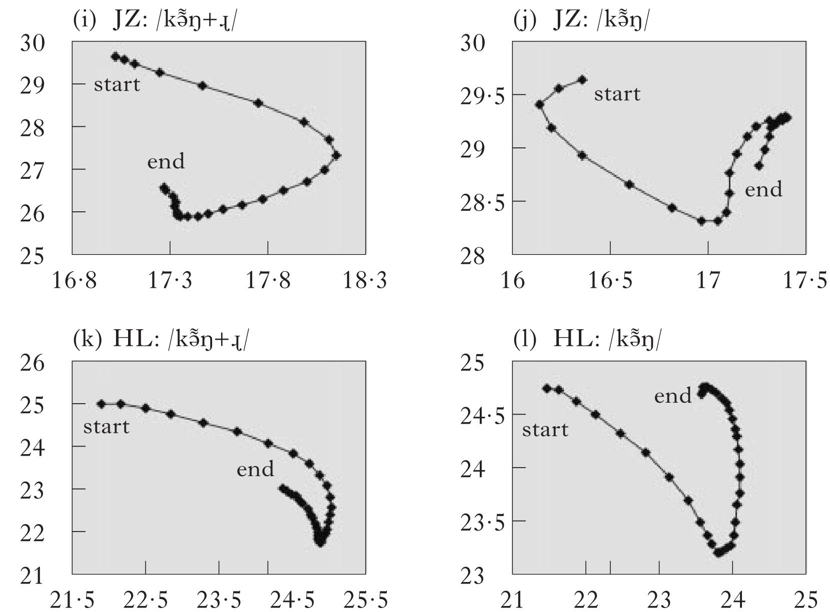


Figure 5

EMA results for the /ŋ/ cases (suffixed and unsuffixed). The values on the *x* and *y* axes are in centimetres.

movement data were sampled at 500 Hz for JZ and 250 Hz for HL. Since the dorsal movement responsible for the velar articulation is primarily indicated by the backmost coil on the tongue (coil (a)), I focus on the position data of this coil here. For both speakers, the position results of this coil during the rhyme portion of the five tokens of each target word were pooled together, and an *x*–*y* movement graph was generated. As shown in Fig. 4, an increase in the *x*-value indicates a dorsal retraction movement, and an increase in the *y*-value indicates a dorsal raising movement. The graphs in Fig. 5 are dorsal movement results for the two speakers for the suffixed and unsuffixed forms of [tã̃ŋ˥] 'crotch (of pants)', [ɕĩ̃ŋ˥] 'spirit' and [kə̃̃ŋ˥] 'thick soup'. The other words exhibit similar patterns to these. The values on the *x* and *y* axes are in centimetres.

As we can see from the graphs, for the [CṼ̃ŋ] syllables the suffixed form and the unsuffixed form do not share any similarities in terms of their dorsal movement trajectories. Especially obvious is that the dramatic dorsal raising movement (for the /ŋ/-closure) in the unsuffixed forms is almost completely missing in the suffixed forms. The short raising at the end of every suffixed form here is also present in the suffixed forms for [CṼn], as can be seen from the data for [tãn+ɻ], [ɕən+ɻ] and [kə̃n+ɻ] for the two speakers given in Fig. 6. Comparing the cases in

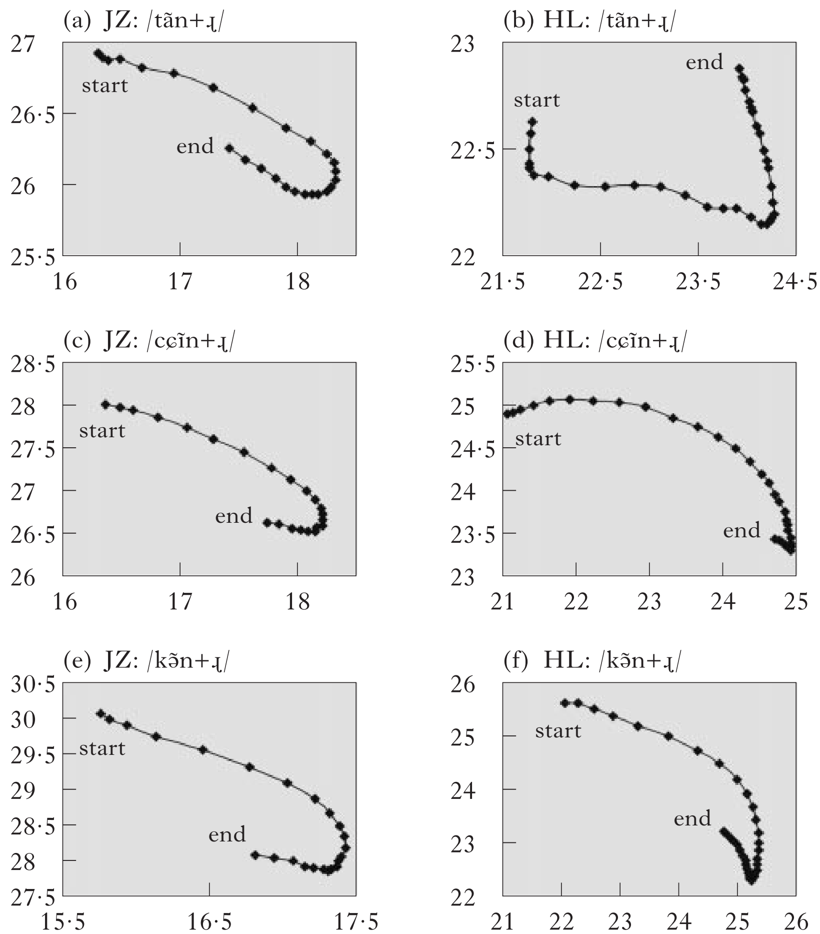


Figure 6

EMA results for the /n/ cases (suffixed). The values on the *x* and *y* axes are in centimetres.

Fig. 5 with the /ɻ/-suffix and Fig. 6, we can see that their dorsal movements have a very similar trajectory. Therefore, the short raising observed at the end of /CṼ̃ŋ + ɻ/ is likely to be the result of retroflexion, not the vestige of the dorsal raising in the unsuffixed form [CṼ̃ŋ].[11]

[11] We may notice that in all the cases, there is considerable dorsal backing movement. This may have been due to the inaccurate set up of the *x*–*y* coordinate system by the EMA data processing program. From a rough visual estimate of the recorded movements of the receiver coils, a clockwise rotation of around 15°–25° of the reported graphs in Figs. 5 and 6 may have been necessary. In that case, the actual backing movement would be considerably smaller than what is shown in the graphs, but the degree of lowering would be greater.

In conclusion, the EMA study shows that the place feature of /ŋ/ is *not* preserved in the suffixed forms. This result invalidates Wang's proposal to link the presence or absence of the nasality to the presence or absence of the place feature of the nasal, since the result shows that the velar nasal, just as the alveolar nasal, loses its place of articulation in the process of /ɹ/-suffixation as well, and thus should not behave any differently from the alveolar nasal.

Hence we refute this articulatorily based alternative for Beijing on empirical grounds. The assumption on which the alternative analysis is based – /ŋ/ maintains its place of articulation upon /ɹ/-suffixation – is factually incorrect.

8 Theoretical implications for phonology *vs*. phonetics

On considering various alternatives to the MAX[F] analysis, including different versions of IDENT[F], an account that appeals to the vocalicness of the velar nasal and an articulatorily based account, we are led to conclude that the MAX[F] analysis is superior to the others in that its factorial typology makes the most accurate cross-dialectal predictions, and its phonetic basis is also more sound.

In the MAX[F] approach, a non-contrastive phonetic distinction in the strength of nasal perception projects an intrinsic ranking $\text{MAX}[+\text{nas}]_{\eta} \gg \text{MAX}[+\text{nas}]_{n}$ (or $\text{MAX}[+\text{nas}]_{\text{strong}} \gg \text{MAX}[+\text{nas}]_{\text{weak}}$), and this ranking has phonological consequences. As I mentioned in the introductory section of the paper, allowing non-contrastive phonetic differences as such to play a role in phonological patterning requires rethinking of the widely held belief that phonology and phonetics are distinct entities. When demonstrating the necessity of such an approach by showing that it captures the attested data patterns in the principled way, and that the alternatives that do not appeal to gradient phonetics cannot account for all the data patterns, we must also show that the position on the relation between phonology and phonetics taken here does not necessarily weaken the predictive power of phonology.

Let us first consider the issue of contrast. If phonetic details can be included in phonological representations, how do phonological contrasts emerge from the ultra-rich representations? After all, along a phonetic dimension, only a small number of contrasts will emerge in any given language. Flemming (1995) and Kirchner (1997) provide a similar answer to this question: in the grammar, there exists a class of constraints that enforces the minimum auditory distinction between two contrasting sounds – MINDIST in Flemming (1995), POLAR in Kirchner (1997). These constraints are perceptually driven, and they serve the purpose of restricting the number of contrasts allowable on a given phonetic dimension. With these constraints at play, it is now possible to include necessary phonetic details in phonology, with the understanding that differences based on these phonetic details will not be rendered contrastive by the grammar.

There is also the question 'how much phonetic detail can the OT constraints refer to?'. For the case under discussion, the question is 'how big must the nasality difference be in order for two universally ranked MAX[+nas] constraints to be projected?'. My position here is that as long as the difference between two kinds of nasality can be safely perceived by the listener, it may have phonological effects by way of universally ranked constraints projected from this difference. At first sight, this position seems particularly dangerous, since just noticeable differences along any phonetic dimension are usually much smaller than any phonetic differences that are known to exert influence on phonological patterning. Therefore, this approach might face the problem of vast overgeneration. But the overgeneration problem might not be as serious as we think, for the following two reasons. First, just noticeable differences in psychoacoustic studies are usually elicited under extreme conditions in which the subject's only task is to listen to one particular difference in controlled environments. But the perception of actual speech requires the listener to perform multiple tasks simultaneously. We therefore should expect the just noticeable differences in real speech to be considerably higher than those elicited in psychoacoustic experiments. For example, this has been shown for the perception of pitch ('t Hart 1981, 't Hart *et al*. 1990). Therefore, the constraints projected from audible phonetic differences in real speech should be much more sparsely distributed than they are if they are projected from just noticeable differences in psychoacoustic experiments. Second, with more detailed phonetic studies, we may realise that many patterns that seemed to be overgenerated by the factorial typology of a phonetically rich system are in fact attested. A growing body of phonetic literature has shown that many phonetic processes that were thought to be universal exhibit cross-linguistic variations, and these variations are not random – they usually tie into the system of contrast in the language in question (Magen 1984, Keating 1988a, b, Keating & Cohn 1988, Manuel 1990, Flemming 1997). It is thus possible that there is a better match between the patterns predicted by the factorial typology and the attested patterns than we originally thought.[12]

[12] An anonymous reviewer points out that the degree of nasalisation on vowels is in fact attested to be contrastive in some languages. For example, in Palantla Chinantec, Merrifield (1963) reports that there is a contrast between lightly nasalised and heavily nasalised vowels, and Ladefoged (1971: 34) and Ladefoged & Maddieson (1996: 299) confirm the validity of this claim through aerodynamic and spectrographic observations. In Acehness, Durie (1985), following Catford (1977), suggests that there is a contrast between lightly nasal and heavily nasal consonants. These cases provide additional support for the role of such phonetic distinction in phonological patterning. But based on these facts, the reviewer also surmises that there is unlikely to be more than two degrees of nasalisation affecting the phonology. There are in fact no counterexamples to this claim, to the best of my knowledge. If this is indeed the case, the hypothesis that the system proposed here must make and subsequently test is that listeners cannot reliably distinguish more than two degrees of nasalisation in running speech – this is the only scenario in which no over-

Finally, acknowledging the effects of non-contrastive phonetic properties on phonological patterning, let us consider the possible ways in which phonetics can be encoded in phonology. As I discussed in §3.1.1, we can entertain at least two options. The first one is to encode phonetic properties directly in the grammar, e.g. $\textsc{Max}[+\text{nas}]_{\text{strong}} \gg \textsc{Max}[+\text{nas}]_{\text{weak}}$. The other is to mediate the phonetics through universal ranking of constraints that only refer to phonological categories, e.g. $\textsc{Max}[+\text{nas}]_{\text{ŋ}} \gg \textsc{Max}[+\text{nas}]_{\text{n}}$. For this paper, whose main purpose is to show the *existence* of phonetic effects on phonology, the data patterns do not distinguish between these two options, and I opted for the more conventional second approach. But given that there *are* works that illustrate the necessity for the less conventional first approach, such as Kirchner (1997), Boersma (1998), Steriade (1999, 2000) and Zhang (forthcoming), and that taking this stance does not necessarily vitiate the predictive power of phonology, as I hope the previous discussion has shown, it might well be the case that the data patterns discussed in this paper should be treated in this less conventional approach too.

The observation that non-contrastive phonetic details can influence phonological patterning is certainly not new. The same point has been made in an extensive literature. For example, Jun (1995)'s Production Hypothesis states that the faithfulness of a feature in the grammar is positively correlated with strength of its acoustic cues. Silverman (1997) shows that the non-contrastive timing of laryngeal features governs their phonological distribution. Kirchner (1997) and Zhang (forthcoming) observe that the non-contrastive prosodic final lengthening influences the pattern of vowel centralisation and contour tone distribution, respectively. More relevantly, Steriade (2000) specifically shows that non-contrastive details such as the duration of consonantal constriction and linguo-palatal contact are relevant in the evaluation of paradigmatic uniformity.

The theoretical contributions of this work to the relation between phonology and phonetics are twofold. First, it presents a case in which the influence of phonetics on phonology is clearly established by both experimental data and a survey of phonological patterns, and provides a formal approach to capture this influence. Second, it is an extension to Steriade (2000)'s proposal on the relevance of non-contrastive features to paradigm uniformity. Her notion of paradigm uniformity can be construed as IDENT-OO[non-contrastive features]. But the MAX[F]-based analysis here does not require the identical realisation of such features. It simply requires the preservation of such features *somewhere* in the output form.

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generation will result from the factorial typology. If, on the other hand, future research does discover cases with more than two degrees of nasalisation affecting phonology, then these cases constitute even stronger arguments for the role of purely phonetic distinctions in phonological patterning, since it is unlikely that we will find three degrees of nasalisation contrasting in any language.

9 Conclusion

I have illustrated the following points in this paper. In Beijing, an /ŋ/-coda induces a significantly longer nasal flow duration in the preceding vowel than an /n/-coda. It is this non-categorical, non-contrastive phonetic difference that leads to the categorical difference in phonological patterning between [CṼn] and [C$\tilde{\tilde{\mathrm{V}}}$ŋ] upon /ɹ/-suffixation. In an optimality-theoretic grammar, this is captured by the universal ranking MAX[+nas]$_{ŋ}$ ≫ MAX[+nas]$_{n}$. This analysis is supported by the close match between the factorial typology of the constraints proposed and a dialectal survey. To motivate the encoding of phonetic properties in the grammar, various other approaches that do not appeal to this position are considered. Approaches based on IDENT[F] are inferior since their factorial typology on the one hand fails to generate all the attested patterns, on the other hand generates patterns that are systematically missing in a comprehensive dialectal survey. The alternative that appeals to the vocalicness of the velar nasal fails on the same ground. An articulatorily based analysis, however, is refuted on phonetic grounds: the dorsal place of articulation of /ŋ/ is not preserved in the suffixed form, just like the coronal place of articulation of /n/, *contra* Wang (1993, 1997, personal communication)'s claim.

Theoretically, this paper further establishes the relationship between non-contrastive phonetic features and categorical phonological patterning, and illustrates that using phonetically based universal ranking is a profitable way to capture such relations. Moreover, MAX[F] must be a relevant type of featural correspondence constraints, as it is needed to explain patterns in which a feature is preserved in the output even though its carrying segment is lost, without having to resort to phonetically unmotivated feature specification. In the meantime it also makes factually more accurate predictions. The relevance of non-contrastive phonetic details to paradigmatic uniformity can be expressed not only through identity mapping, but also through less stringent preservation mapping.

REFERENCES

Abramson, Arthur S., Patrick W. Nye, Janette B. Henderson & Charles W. Marshall (1981). Vowel height and the perception of consonantal nasality. *JASA* **70**. 329–339.

Ali, Latif, Tanya Gallagher, Jeffrey Goldstein & Raymond Daniloff (1971). Perception of coarticulated nasality. *JASA* **49**. 538–540.

Beckman, Jill (1998). *Positional faithfulness*. PhD dissertation, University of Massachusetts, Amherst.

Beckman, Jill, Laura Walsh Dickey & Suzanne Urbanczyk (eds.) (1995). *Papers in Optimality Theory*. Amherst: GLSA.

Beddor, Patrice Speeter (1993). The perception of nasal vowels. In Huffman & Krakow (1993). 171–196.

Beddor, Patrice Speeter, Rena Arens Krakow and Louis M. Goldstein (1986). Perceptual constraints and phonological change: a study of nasal vowel height. *Phonology Yearbook* **3**. 197–217.

Appendix

Figure 7
Geographic locations of the 26 dialects included in the survey.

Bell-Berti, Fredericka & Thomas Baer (1983). Velar position, port size, and vowel spectra. *Proceedings of the 11th International Congress on Acoustics*. Vol. 4. 19–21.

Benguerel, Andre-Pierre (1974). Nasal airflow patterns and velar coarticulation in French. In Gunnar Fant (ed.) *Speech communication : Proceedings of the Speech Communication Seminar*. Vol. 2. Stockholm: Almqvist & Wiksell. 105–112.

Benua, Laura (1995). Identity effects in morphological truncation. In Beckman *et al*. (1995). 77–136.

Boersma, Paul (1998). *Functional phonology : formalizing the interactions between articulatory and perceptual drives*. The Hague: Holland Academic Graphics.

Brito, Gêlda, A. (1975). The perception of nasal vowels in Brazilian Portuguese: a pilot study. In Ferguson *et al*. (1975). 49–66.

Browman, Catherine & Louis Goldstein (1992). Articulatory phonology: an overview. *Phonetica* **49**. 155–180.

Burzio, Luigi (1994). *Principles of English stress*. Cambridge: Cambridge University Press.

Casali, Roderic F. (1996). *Resolving hiatus*. PhD dissertation, UCLA.

Catford, John C. (1977). *Fundamental problems in phonetics*. Bloomington: Indiana University Press.

Causley, Trisha (1997). Identity and featural correspondence: the Athapaskan case. *NELS* **27**. 93–105.

Chen, Matthew (1972). *Nasals and nasalisation in Chinese : explorations in phonological universals*. PhD dissertation, UCB.

Chen, Shujing (1988). Hebei Mancheng fangyan de tedian. [Idiosyncrasies of the Mancheng dialect of Hebei province.] *Fangyan* [*Dialects*] **88**. 103–112.

Chomsky, Noam & Morris Halle (1968). *The sound pattern of English*. New York: Harper & Row.

Clumeck, Harold (1976). Patterns of soft palate movements in six languages. *JPh* **4**. 337–351.

Cohn, Abigail C. (1990). *Phonetic and phonological rules of nasalization*. PhD dissertation, UCLA. Distributed as *UCLA Working Papers in Phonetics* **76**.

Cohn, Abigail C. (1993). Nasalisation in English: phonology or phonetics. *Phonology* **10**. 43–81.

Crowhurst, Megan & Mark Hewitt (1997). *Boolean operations and constraint interactions in Optimality Theory*. Available as ROA-229 from the Rutgers Optimality Archive.

de Jong, Kenneth & Bushra Adnan Zawaydeh (1999). Stress, duration, and intonation in Arabic word-level prosody. *JPh* **27**. 3–22.

Delattre, Pierre (1954). Les attributs acoustiques de la nasalité vocalique et consonantique. *Studia Linguistica* **8**. 103–109.

Delattre, Pierre & Michel Monnot (1968). The role of duration in the identification of French nasal vowels. *International Review of Applied Linguistics in Language Teaching* **6**. 267–288.

Dow, Francis D. M. (1972). *An outline of Mandarin phonetics*. Canberra: Australian National University Press.

Dow, Francis D. M. (1984). *An introduction to the pronunciation of Chinese*. Edinburgh: Department of Chinese, University of Edinburgh.

Duanmu, San (1990). *A formal study of syllable, tone, stress and domain in Chinese languages*. PhD dissertation, MIT.

Durie, Mark (1985). *A grammar of Acehness on the basis of a dialect of North Aceh*. Dordrecht: Foris.

Ferguson, Charles A., Larry M. Hyman & John J. Ohala (eds.) (1975). *Nasálfest: papers from a symposium on nasals and nasalization*. Stanford: Language Universals Project, Stanford University.

Flemming, Edward (1995). *Auditory representations in phonology*. PhD dissertation, UCLA.

Flemming, Edward (1997). Phonetic optimization: compromise in speech production. In V. Miglio & B. Morén (eds.) *University of Maryland Working Papers in Linguistics* **5**. *Selected Phonology Papers from the Hopkins Optimality Theory Workshop 1997/University of Maryland Mayfest 1997*. 72–91.

Fritzell, Björn (1969). The velopharyngeal muscles in speech: an electromyographic and cineradiographic study. *Acta Otolaryngolica*. Suppl. **50**.

Gao, Baotai & Ansheng Zhang (1997). *Yinchuan hua yindang*. [*A record of the Yinchuan dialect*.] Shanghai: Shanghai Jiaoyu Zhubanshe [Shanghai Education Press].

Gordon, Matthew (1999). The process specific nature of weight: the case of contour tone restrictions. *WCCFL* **17**. 235–249.

Hao, Ning (1982). Anqing fangyan cihui. [The vocabulary of the Anqing dialect.] *Fangyan* [*Dialects*] **82**. 297–313.

't Hart, Johan (1981). Differential sensitivity to pitch distance, particularly in speech. *JASA* **69**. 811–821.

't Hart, Johan, René Collier & Antonie Cohen (1990). *A perceptual study of intonation: an experimental-phonetic approach to speech melody*. Cambridge: Cambridge University Press.

Hayes, Bruce (1999). Phonetically driven phonology: the role of Optimality Theory and inductive grounding. In Michael Darnell, Edith Moravscik, Frederick Newmeyer, Michael Noonan & Kathleen Wheatly (eds.) *Functionalism and formalism in linguistics*. Vol. 1: *General papers*. Amsterdam: Benjamins. 243–285.

Hayes, Bruce, Robert Kirchner & Donca Steriade (eds.) (forthcoming). *The phonetic basis of phonology*. Cambridge: Cambridge University Press.

Hayes, Bruce & Donca Steriade (forthcoming). Phonetics in phonology: an introduction. In Hayes *et al*. (forthcoming).

He, Wei (1981). Jiyuan fangyan jilüe. [A brief record of the Jiyuan dialect.] *Fangyan* [*Dialects*] **81**. 5–26.

He, Wei (1982). Huojia fangyan yunmu de fenlei. [The rhyme categories of the Huojia dialect.] *Fangyan* [*Dialects*] **82**. 22–36.

Henderson, Janette B. (1984). *Velopharyngeal function in oral and nasal vowels : a cross-language study*. PhD dissertation, University of Connecticut.

Hewitt, Mark & Megan Crowhurst (1996). Conjunctive constraints and templates in Optimality Theory. *NELS* **26**. 101–116.

Hombert, Jean-Marie (1986). The development of nasalized vowels in the Teke language group (Bantu). In Koen Bogers, Harry van der Hulst & Maarten Mous (eds.) *The phonological representation of suprasegmentals*. Dordrecht: Foris. 359–379.

Hou, Jingyi (1985). *Changzhi fangyan zhi*. [A record of the Changzhi dialect.] Beijing: Yuwen Chubanshe [The Philology Press].

Hou, Jingyi (1989). *Jinyu yanjiu*. [Studies of the Jin dialects.] Tokyo University of Foreign Studies: Institute for the Study of Languages and Cultures of Asia and Africa.

Hou, Jingyi & Duanzheng Wen (1993). *Shanxi fangyan diaocha yanjiu baogao*. [*Research reports on Shanxi dialects*.] Taiyuan, China: Shanxi Gaoxiao Lianhe Chubanshe [The Joint Press of Shanxi Universities].

House, Arthur S. (1957). Analog studies of nasal consonants. *Journal of Speech and Hearing Disorders* **22**. 190–204.

House, Arthur S. & Kenneth N. Stevens (1956). Analog studies of the nasalisation of vowels. *Journal of Speech and Hearing Disorders* **21**. 218–232.

Huffman, Marie K. (1990). *Implementation of nasal : timing and articulatory landmarks*. PhD dissertation, UCLA. Distributed as *UCLA Working Papers in Phonetics* **75**.

Huffman, Marie K. & Rena A. Krakow (eds.) (1993). *Nasals, nasalization, and the velum*. San Diego: Academic Press.
Hume, Elizabeth, Keith Johnson, Misun Seo & Georgios Tserdanelis (1999). A cross-linguistic study of stop place perception. In John J. Ohala, Yoko Hasegawa, Manjari Ohala, Daniel Granville & Ashlee C. Bailey (eds.) *Proceedings of the 14th International Congress of Phonetic Sciences*. Berkeley: Department of Linguistics, UCB. 2069–2072.
Jun, Jongho (1995). *Perceptual and articulatory factors in place assimilation: an Optimality Theoretic approach*. PhD dissertation, UCLA.
Keating, Patricia A. (1988a). The phonology–phonetics interface. In Frederick J. Newmeyer (ed.) *Linguistics: the Cambridge survey*. Vol. 1: *Linguistic theory: foundations*. Cambridge: Cambridge University Press. 281–302.
Keating, Patricia A. (1988b). Underspecification in phonetics. *Phonology* **5**. 275–292.
Keating, Patricia A. & Abigail Cohn (1988). Cross-language effects of vowels on consonant onsets. *JASA* **84**. Suppl. 1. S84.
Kenstowicz, Michael (1995). Base-Identity and uniform exponence: alternatives to cyclicity. Available as ROA-103 from the Rutgers Optimality Archive.
Kirchner, Robert (1997). Contrastiveness and faithfulness. *Phonology* **14**. 83–111.
Kirchner, Robert (1998). *An effort-based approach to consonant lenition*. PhD dissertation, UCLA.
Krakow, Rena A. & Marie K. Huffman (1993). Instruments and techniques for investigating nasalization and velopharyngeal function in the laboratory: an introduction. In Huffman & Krakow (1993). 3–59.
Ladefoged, Peter (1971). *Preliminaries to linguistic phonetics*. Chicago: Chicago University Press.
Ladefoged, Peter & Ian Maddieson (1996). *The sounds of the world's languages*. Cambridge, Mass. & Oxford: Blackwell.
Li, Bing (1981). Changhai fangyan de erhua yu ziwei. [The 'er' and 'zi' suffixes of the Changhai dialect.] *Fangyan* [*Dialects*] **81**. 93–103.
Li, Lan (1997). *Guiyang hua yindang*. [*A record of the Guiyang dialect*.] Shanghai: Shanghai Jiaoyu Zhubanshe [Shanghai Education Press].
Li, Shen (1985). *Xuzhou fangyan zhi*. [A record of the Xuzhou dialect.] Beijing: Yuwen Chubanshe [The Philology Press].
Li, Yuming (1996). Miyang fangyan de erhua ji erhua shanyin. [The 'er' suffix and the 'er' tap in the Miyang dialect.] *Fangyan* [*Dialects*] **96**. 302–305.
Lin, Tao (1982). Beijinghua erhuayun geren duyin chayi wenti. [Speaker differences in the pronunciation of 'er' rhymes in Beijing Chinese.] *Yuwen Yanjiu* [*Philology Research*] **1982:2**. 9–14.
Lin, Tao & Lijia Wang (1992). *Yuyinxue jiaocheng*. [A course in phonetics.] Beijing: Beijing Daxue Chubanshe [Beijing University Press].
Lin, Yen-Hwei (1993). Degenerate affixes and templatic constraints: rhyme change in Chinese. *Lg* **69**. 649–682.
Lintz, Lois Brien & Dorothy Sherman (1961). Phonetic elements and perception of nasality. *Journal of Speech and Hearing Research* **4**. 381–396.
Liu, Danqing (1997). *Nanjing hua yindang*. [*A record of the Nanjing dialect*.] Shanghai: Shanghai Jiaoyu Zhubanshe [Shanghai Education Press].
Liu, Songhao (1993). Xiangcheng fangyan yinxi. [The sound system of the Xiangcheng dialect.] *Fangyan* [*Dialects*] **93**. 284–294.
Lombardi, Linda (1995). Why place and voice are different: constraint interactions and feature faithfulness in Optimality Theory. Available as ROA-105 from the Rutgers Optimality Archive.
Lombardi, Linda (1998). Evidence for MaxFeature constraints from Japanese. Available as ROA-247 from the Rutgers Optimality Archive.

Lua, Jiawen (1992). *Zhengzhou fangyan zhi*. [*A record of the Zhengzhou dialect*.] Beijing: Yuwen Chubanshe [The Philology Press].

Luo, Futeng (1995). Muping fangyan cidian yinlun. [Introduction to the *Muping dialect dictionary*]. *Fangyan* [*Dialects*] **95**. 1–16.

McCarthy, John & Alan Prince (1986). *Prosodic morphology*. Ms, University of Massachusetts, Amherst & Brandeis University.

McCarthy, John & Alan Prince (1993). *Prosodic Morphology I: constraint interaction and satisfaction*. Ms, University of Massachusetts, Amherst & Rutgers University.

McCarthy, John & Alan Prince (1995). Faithfulness and reduplicative identity. In Beckman *et al*. (1995). 249–384.

McCarthy, John & Alan Prince (1999). Faithfulness and identity in Prosodic Morphology. In René Kager, Harry van der Hulst & Wim Zonneveld (eds.) *The prosody–morphology interface*. Cambridge: Cambridge University Press. 218–309.

Maeda, Shinji (1982). Acoustic cues for vowel nasalization: a stimulation study. *JASA* **72**. Suppl. 1. S102.

Magen, Harriet (1984). Vowel-to-vowel coarticulation in English and Japanese. *JASA* **75**. Suppl. 1. S41.

Manuel, Sharon Y. (1990). The role of contrast in limiting vowel-to-vowel coarticulation in different languages. *JASA* **88**. 1286–1298.

Max, Ludo & Patrick Onghena (1999). Some issues in the statistical analysis of completely randomized and repeated measures designs for speech, language, and hearing research. *Journal of Speech and Hearing Research* **42**. 261–270.

Merrifield, W. R. (1963). Palantla Chinantec syllable types. *Anthropological Linguistics* **5**. 1–16.

Ohala, John J. (1971). Monitoring soft palate movements in speech. *Project on Linguistic Analysis Reports* **13**. J01–J015.

Ohala, John J. (1975). Phonetic explanations for nasal sound patterns. In Ferguson *et al*. (1975). 289–316.

Ohala, John J. & Manjari Ohala (1993). The phonetics of nasal phonology: theorems and data. In Huffman & Krakow (1993). 225–249.

Pater, Joe (1995). Austronesian nasal substitution and other *NC effects. Available as ROA-92 from the Rutgers Optimality Archive.

Prince, Alan & Paul Smolensky (1993). *Optimality Theory: constraint interaction in generative grammar*. Ms, Rutgers University & University of Colorado, Boulder.

Pulleyblank, Douglas (1996). Neutral vowels in Optimality Theory: a comparison of Yoruba and Wolof. *Canadian Journal of Linguistics* **41**. 295–347.

Ruhlen, Merritt (1978). Nasal vowels. In Joseph H. Greenberg (ed.) *Universals of human language*. Vol. 2: *Phonology*. Stanford: Stanford University Press. 203–241.

Qian, Zengyi (1995). Jinan fangyan cidian yinlun. [Introduction to the *Jinan dialect dictionary*.] *Fangyan* [*Dialects*] **95**. 242–256.

Shi, Mingyuan (1995). *Juxian fangyan zhi*. [*A record of the Juxiang dialect*.] Beijing: Yuwen Chubanshe [The Philology Press].

Silverman, Daniel (1997). *Phasing and recoverability*. New York: Garland.

Steriade, Donca (1999). Phonetics in phonology: the case of laryngeal neutralization. *UCLA Working Papers in Linguistics: Papers in Phonology* **3**. 25–146.

Steriade, Donca (2000). Paradigm uniformity and the phonetics–phonology boundary. In Michael Broe & Janet Pierrehumbert (eds.) *Papers in laboratory phonology V: acquisition and the lexicon*. Cambridge: Cambridge University Press. 313–334.

Sun, Jingtao (1998). *A phonological analysis of the retroflex suffixation in Shunping (Gaoyupu) Mandarin*. Paper presented at NACCL-10/IACL-7.

Takeuchi, S., H. Kasuya & K. Kido (1975). On the acoustic correlate of nasality. *Journal of the Acoustical Society of Japan* **31**. 298–309.

Trigo, Loren (1988). *On the phonological behavior and derivation of nasal glides*. PhD dissertation, MIT.

Walker, Rachel (1999). *Esimbi vowel height shift : implications for faith and markedness*. Available as ROA-336 from the Rutgers Optimality Archive.

Wang, Junhu (1997). *Xi'an hua yindang*. [*A record of the Xi'an dialect*.] Shanghai: Shanghai Jiaoyu Zhubanshe [Shanghai Education Press].

Wang, Lijia & Ningji He (1985). Beijinghua erhuayun de tingbian shiyan he shengxue fenxi. [The perceptual and acoustic studies of Beijing 'er' rhymes.] In Tao Lin & Lijia Wang (eds.) *Beijing yuyin shiyan lu*. [*A collection of phonetic studies on Beijing Chinese*.] Beijing: Beijing University Press. 27–71.

Wang, Zhijie (1993). *The geometry of segmental features in Beijing Mandarin*. PhD dissertation, University of Delaware.

Wang, Zhijie (1997). Erhuayun de tezheng jiagou. [The feature geometry of r-rhymes.] *Zhongguo Yuwen* [Chinese Philology] **1997**. 2–10.

Wen, Duanzheng (1985). *Xinzhou fangyan zhi*. [*A record of the Xinzhou dialect*.] Beijing: Yuwen Chubanshe [The Philology Press].

Whalen, D. H. & Patrice S. Beddor (1989). Connections between nasality and vowel duration and height: elucidation of the Eastern Algonquian intrusive nasal. *Lg* **65**. 457–486.

Yin, Shichao (1995). Harbin fangyan cidian yinlun. [Introduction to the *Harbin dialect dictionary*.] *Fangyan* [*Dialects*] **95**. 17–25.

Yuan, Jiahua (1989). *Hanyu fangyan gaiyao*. [*An overview of Chinese dialects*.] 2nd edn. Beijing: Wenzi Gaige Chubanshe [Writing-System Reformation Press].

Zee, Eric (1985). Sound change in syllable final nasal consonants in Chinese. *Journal of Chinese Linguistics* **13**. 291–330.

Zhang, Hequan (1995). *Liaocheng fangyan zhi*. [*A record of the Liaocheng dialect*.] Beijing: Yuwen Chubanshe [The Philology Press].

Zhang, Jie (forthcoming). The role of language-specific durational patterns in contour tone distribution. In Hayes *et al*. (forthcoming).

Zhang, Shuzheng (1996). Shandong Shouguang beibu fangyan de erhua. [The 'er' suffix of the Northern Shouguang dialect of Shandong.] *Fangyan* [*Dialects*] **96**. 298–301.

Zhou, Lei (1994). Wulumuqi fangyan cidian yinlun. [Introduction to the *Wulumuqi dialect dictionary*.] *Fangyan* [*Dialects*] **94**. 241–251.

Zsiga, Elizabeth (1995). An acoustic and electropalatographic study of lexical and postlexical palatalization in American English. In Bruce Connell & Amalia Arvaniti (eds.) *Phonology and phonetic evidence : papers in laboratory phonology IV*. Cambridge: Cambridge University Press. 282–302.

Zsiga, Elizabeth (1997). Features, gestures, and Igbo vowels: an approach to the phonology–phonetics interface. *Lg* **73**. 227–274.