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# Beijing Mandarin nasalization upon r-suffixation is phonologized: A nasometry study

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**Abstract:** In Beijing Mandarin, r-suffixation is a diminutive formation process that adds a rhotic suffix, which typically overwrites syllable-final nasal codas. Previous work by Zhang [Phonology 17, 427–478 (2000)] used nasal airflow data to argue that the categorical preservation of nasality in suffixed /CVŋ + ɹ/ as opposed to /CVn + ɹ/ is driven by salient differences in nasalization in the stem. A nasometry study revealed no significant nasalance difference between CVn and CVŋ stems, contradicting previous aerodynamic evidence. Nevertheless, a significant nasalization contrast remained in r-suffixed forms. These findings suggest that the alternation is reanalyzed as phonological instead of a reflection of phonetic differences in vowel nasalance in the stem. © 2026 Author(s). All article content, except where otherwise noted, is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND) license (<https://creativecommons.org/licenses/by-nc-nd/4.0/>).

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## 1. Introduction

In Beijing Mandarin, a rhotic suffix is used to derive diminutives, a process commonly known as *erhua*, henceforth r-suffixation. Regardless of lexical tone or stem vowel, r-suffixation overwrites nasal codas, neutralizing /CVn + ɹ/ and /CV + ɹ/. Despite the neutralization, previous research claimed that a different contrast is created: /CVŋ + ɹ/ is realized with a nasalized vowel, rendering it contrastive in nasalization from other syllable types (Zhang, 2000; Lee, 2005; Duanmu, 2007). This pattern is shown in Table 1.

Since vowel nasalization is not otherwise lexically contrastive in Beijing Mandarin, the source of the nasal contrast in r-suffixed forms is an enduring puzzle. In a phonological account of this phenomenon, Zhang (2000) attributes this pattern to output-output correspondence (Benuea, 1997), arguing that a higher degree of coarticulatory nasalization in CVŋ stems motivates its categorical preservation after r-suffixation. When nasality is preserved on the vowel, the r-suffixed form resembles its stem form to a greater degree. More recently, Fu (2022) extends the correspondence by comparing Beijing with Liaoning Mandarin, where the contrast between CVn and CV stems is maintained after r-suffixation. Fu argues that alternations in the r-suffixed forms are driven by a formal pressure to preserve the total number of lexical contrasts present in the stem forms (Flemming, 1995).

A crucial implication of the correspondence analysis is that non-phonemic phonetic salience can drive categorical feature preservation. In other words, low-level coarticulatory cues triggered by different nasal codas are robust enough to result in phonological patterns that are explicitly encoded in the grammar. This reflects a broader coarticulatory path to sound change, wherein the perceptual salience of nasal cues shown by nasal airflow duration provides the basis for formal phonological patterning (Whalen and Beddor, 1989; Beddor, 1993, 2009).

The nasometry data reported in the current study challenges the assumption that the nasal contrast in r-suffixation is tied to phonetic cues in the stem. Our results show that, contra the aerodynamic findings of Zhang (2000), there is no difference in nasalance between CVn and CVŋ stem forms, which suggests that the pattern has become a fully phonologized alternation. We begin by reviewing the Zhang (2000) study in detail before presenting the specific goals of our study.

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Table 1. Beijing Mandarin r-suffixation pattern.

| Type | Stem | Type      | Suffixed | Orthography | Gloss    |
|------|------|-----------|----------|-------------|----------|
| CV   | pa   | /CV + ɿ/  | pa.ɿ     | 把           | “handle” |
| CVn  | pan  | /CVn + ɿ/ | pa.ɿ     | 半           | “half”   |
| CVŋ  | paŋ  | /CVŋ + ɿ/ | pɑ.ɿ     | 棒           | “stick”  |

### 1.1 Zhang study

Zhang (2000) used an aerodynamic experiment to investigate the role of non-contrastive phonetic salience in Beijing Mandarin nasal-final stems. He compared the degree of anticipatory nasalization in vowel-nasal sequences across two primary conditions: words containing an alveolar nasal coda (CVn) and words containing a velar nasal coda (CVŋ). The distinction Zhang drew between the alveolar condition ([pan] “half”) and the velar condition ([paŋ] “stick”) is based on the differing airflow duration of the nasal consonants, which induce a longer airflow on the vowel preceding velar codas than the alveolar ones. Therefore, Zhang argued that the more perceptually salient nasalization in the velar condition is preserved upon suffixation ([pɑ.ɿ], “stick.DIM”). Thus, on the basis of aerodynamic evidence, Zhang (2000) made a theoretical claim that the categorical phonological patterning in r-suffixation is sensitive to non-contrastive phonetic differences in the stem.

We observe some shortcomings for the Zhang (2000) study. First, the study has only two speakers, making it unclear that the effects of nasal airflow proportion will be replicable in a larger sample. Second, Zhang (2000) does not examine the r-suffixed forms to confirm the claimed distinction in their nasalization. Zhang relies on the assumption that the phonetic differences in the stem are sufficient to explain the categorical split in the derivative forms. This reflects Zhang’s core theoretical stance that the nasalization contrast in r-suffixed forms is a direct result of output-output correspondence, which forces resemblance between morphologically-related forms.

To address these concerns, the present study aims to replicate and extend Zhang (2000) using nasometry, which allows for the separate recording and measurement of the nasal and oral channels (Bressmann, 2021). Using nasometry, we directly evaluate whether the coarticulatory nasalization differences found by Zhang (2000) are robust enough to serve as the ground for the nasalization contrast after r-suffixation (Fig. 1).

### 1.2 Current study

We present a nasometric study of Beijing Mandarin r-suffixation by directly measuring nasalance in both stem and suffixed forms. The investigation is guided by two research questions:

First, is there a significant difference in nasalance between the two types of suffixed forms (/CVn + ɿ/ vs /CVŋ + ɿ/) as claimed in the literature? Second, is there a significant difference in nasalance between the stem forms (CVn vs CVŋ), showing the same pattern as the nasal airflow data in Zhang (2000), thus supporting a phonetics-based explanation of the phonological pattern?

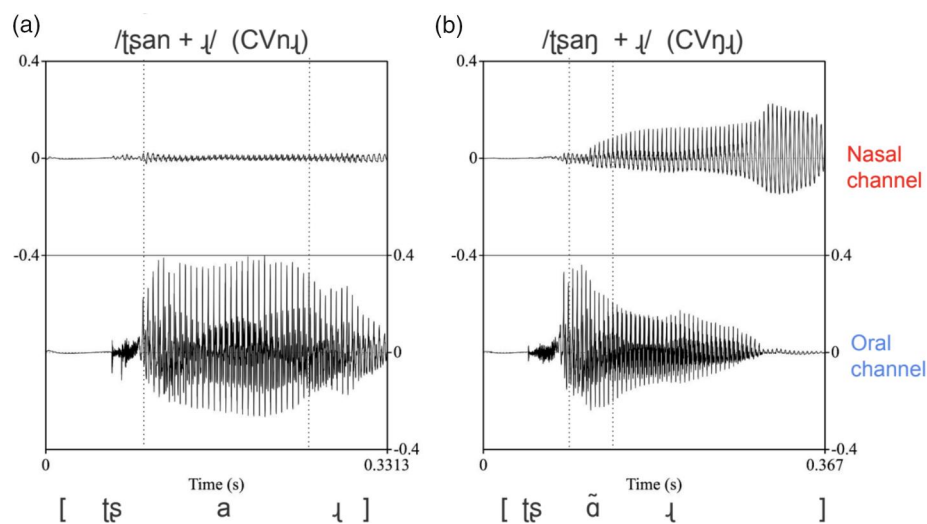


Fig. 1. Sample target items. (a) /CVn + ɿ/ target item with no nasalization. (b) /CVŋ + ɿ/ target item with nasalization.

For the first question concerning the r-suffixed forms, we hypothesize that we would find significantly more nasalization on /CVŋ + ɿ/ rhymes than /CVn + ɿ/ ones. This prediction is based on ample descriptive and experimental literature reporting a salient contrast in vowel nasalization in this environment [see [Dow \(1972\)](#), [Lin and Wang \(1992\)](#), [Zhang \(2000\)](#), and [Lee \(2005\)](#), among others]. Verifying this contrast is a necessary baseline before examining the potential phonetic source of this phonological contrast.

The second research question evaluates the synchronic phonetic grounding of the nasalization contrast upon r-suffixation. A finding of significantly greater nasalance in /CVŋ/ stems compared to /CVn/ stems would be consistent with the aerodynamic results of [Zhang \(2000\)](#), supporting the theory that gradient phonetic “pressure” motivates categorical preservation. Conversely, an absence of difference between these stem types would contradict the salience-driven model, indicating that the phonological pattern is not governed by sub-phonemic nasalization in the base form. More broadly, this research question is a test of the theoretical claim that non-contrastive phonetic details serve as an active driver of phonological patterning.

## 2. Methods

Procedures for data collection were approved by the New York University Institutional Review Board. Adopting the methodological framework established by [Bellavance et al. \(2024\)](#), independent oral and nasal acoustic signals were obtained via nasometry, which served as the basis for a generalized additive model ([Wood, 2017](#)).

### 2.1 Participants

We recruited 12 native speakers of Beijing Mandarin who lived in the New York City area at the time (ten female and two male). Two other participants were excluded from the final dataset because their nasalance values were consistently high even in bare CV forms. All participants lived in Beijing from birth through age 18 and attended all primary and secondary schooling there without interruption. No participants reported a history of speech, language, or hearing disorders. All participants had some degree of interaction with American English and resided in New York City at the time of the study but still report regularly speaking Mandarin. Each participant provided informed consent and was compensated \$15 in gift cards for their time. The experiment lasted around 30 min.

### 2.2 Data collection

Recording sessions took place in a soundproof booth at New York University using a handheld Glottal Enterprises nasometer (NAS-1 SEP Clinic; Glottal Enterprises Incorporated, Syracuse NY). This device uses a sound-attenuating plate equipped with dual USB directional microphones to isolate nasal and oral acoustic signals. To ensure a tight and comfortable seal, one of three interchangeable plate sizes was selected for each participant. Participants held the device perpendicular to their face, maintaining firm contact on their cheeks and upper lip to ensure channel separation. The resulting oral and nasal signals were captured on a laptop using Praat with the audio sampled at 44.1 kHz ([Boersma and Weenink, 2023](#)). Throughout the process, an experimenter observed the participant to ensure that the plate stayed stable.

During the experiment, participants were asked to read 96 sentences presented in standard orthography at a normal speech rate. The target items consisted of 24 noun stems: eight CV, eight CVn, and eight CVŋ, with onsets from three manners of articulation: stops, affricates, and fricatives. Each stem was presented with and without the r-suffix, resulting in a total of 48 target items. All target items had high (55) tone and monophthongal low vowel nucleus /a/ [e.g., /tʃaŋ/ (55)]. The other 48 items were fillers containing varying nuclei and tones [e.g., /p<sup>h</sup>ən/ (35)].

Stimulus items were randomly embedded in six naturalistic frame sentences in written Chinese (e.g., “The word \_\_\_\_ is written incorrectly in the book.”). To control for potential coarticulatory effects on nasalance, we constructed the sentences so that the Chinese characters meaning “the word” naturally followed the stimulus item in every sentence. The r-suffix was cued using standard orthography (the character 儿), which is typically pronounced as [ɿ] in isolation. To ensure a casual register conducive to r-suffixation, this character was also included elsewhere in the frame sentences where appropriate. A full list of the frame sentences and stimuli is available in the [supplementary material](#).

### 2.3 Analyses

For the stem forms, the pre-nasal vowel (V) and the nasal were segmented separately; in contrast, the entire rhyme (VR) was segmented for the suffixed forms, since a clear demarcation between the vowel and the rhotic coda was not possible. Praat scripts were used to extract information for both target segments, i.e., V and VR. To quantify the degree of nasalization, nasal and oral amplitudes (root mean square pressure) were measured at 50 equidistant timepoints per interval ([Bellavance et al., 2024](#)). Data processing and analyses were conducted using R ([R Core Team, 2021](#)), where nasalance was then calculated as the ratio of nasal amplitude to total amplitude [ $A_{nasal}/(A_{oral} + A_{nasal})$ ] for each of the 50 time intervals ([Carignan, 2018](#)).

Statistical analysis was twofold. First, mean nasalance values over the entire interval were analyzed using a linear mixed-effects regression (LMER) using the lme4 package ([Bates et al., 2015](#)). Second, to track the nasalance over the entire course of the rhyme, we built a generalized additive mixed-effects model (GAMM) using the bam() function from

the `mgcv` package (Wood, 2017). We used restricted maximum likelihood estimation, which adopts an empirical Bayesian approach to determine smoothing parameters. This framework is particularly appropriate for capturing non-parametric, non-linear relationships in time-series phonetic data by using “smooth terms.”

Our model included *syllable type* and *onset type* as fixed effects. To capture the non-linear relationship, we included a smooth term for *timepoint* by *syllable type* and a smooth term for *timepoint* by *onset type*. Onset type was included as a control variable to factor out potential coarticulatory effects from the preceding consonant, ensuring that the differences in nasalance are driven by the places of articulation of the codas. Random intercepts for *word* and *speaker* were included. Finally, to directly test the difference between alveolar and velar nasal coda conditions, we used the `get_difference()` function from the `tidygam` package (Coretta, 2024) to calculate smooth difference functions. This allowed us to identify the exact time windows where the nasalance significantly diverged. We confirmed the model's robustness by assessing the number of knots relative to the estimated degrees of freedom for each smooth term (Sóskuthy, 2017). Checks for concavity and model residuals also indicated that the model was suitable for interpretation (Wood, 2017; Tomaschek et al., 2018).

### 3. Results

To evaluate the mean nasalance over the rhyme interval, we conducted a LMER. Regarding the first research question, we found a difference in nasalance between the two suffixed types ( $\beta = 0.34$ , standard error = 0.016,  $p < 0.0001$ ), with /CVŋ + ɿ/ exhibiting significantly higher nasalance than /CVn + ɿ/, while the latter showed no difference from the baseline /CV + ɿ/. This confirms the expected direction of the contrast and corroborates the robustness of the phonological pattern in modern Beijing Mandarin. The GAMM smooth difference analysis in Fig. 2 reveals that the significantly higher nasalance in /CVŋ + ɿ/ persists throughout the rhyme instead of only in the vowel.

With regard to stem forms, our results contradicted the phonetic difference in vowel nasalization found by Zhang (2000). LMER analysis showed no significant difference in mean nasalance between CVn and CVŋ stems ( $\beta = 0.02$ ,  $p = 0.38$ ). In fact, the timecourse data in Fig. 3 show a significant, albeit small, difference in the opposite direction: the smooth difference function identifies a temporal window (timepoints 18–35) where CVŋ actually exhibits significantly lower nasalance than CVn.

Taken together, our findings suggest that the nasalization contrast in Beijing Mandarin r-suffixation is a phonological alternation that lacks a direct phonetic correlate in stem vowel nasalization. By refuting the claim that velar codas induce stronger non-contrastive phonetic differences in the stem than their alveolar counterparts, we show that the pattern is not currently motivated by phonological correspondence with differences in the degree of nasalization in the stem.

### 4. Discussion

The current study aimed to revisit and extend the aerodynamic study of Zhang (2000) by measuring both stem and r-suffixed forms to find whether non-contrastive phonetic cues inform phonological differences. Nasometry provides a closer estimate of the percept of nasality. Because the model used by Zhang (2000) relies specifically on the perceptual strength of the nasal cue, nasometry is especially appropriate for evaluating the salience-based account.

First, our results verified that there is a robust nasalization contrast in r-suffixed forms as claimed in the literature. We also found that the nasalization difference persists across the entire rhyme. However, contra Zhang (2000), no phonetic difference was found in the nasalization of stem vowels to cue the categorical difference in their r-suffixed forms.

As shown in Fig. 2, nasalance in the suffixed forms increased as a gradient “cline,” which Cohn (1990) identifies as a profile for phonetic rather than phonological nasalization. While this profile does occur in the stem forms that have a trigger in the nasal coda, nasalization in the suffixed form, with the absence of a nasal coda, cannot be explained by

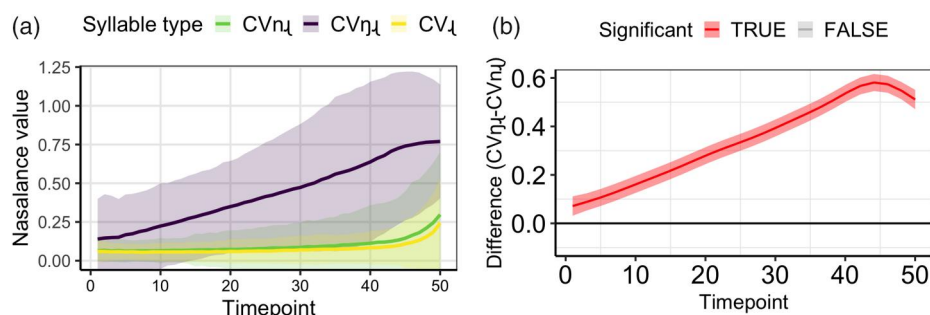


Fig. 2. (a) Time-course nasalance by r-suffixed syllable types, with non-nasal /CV + ɿ/ stems as a baseline. (b) Smooth function differences between /CVn + ɿ/ and /CVŋ + ɿ/. Red ribbons indicate temporal windows where the difference is statistically significant.

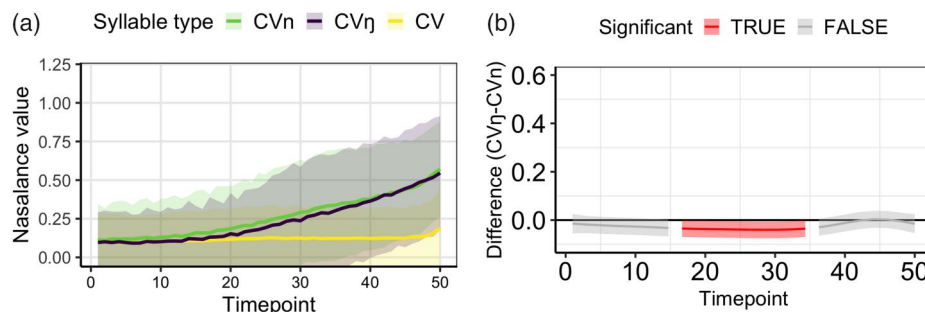


Fig. 3. (a) Time-course nasalance between stem syllable types, with non-nasal CV stems as a baseline. (b) Smooth function differences between CVn and CVŋ. Red ribbons indicate temporal windows where the difference is statistically significant.

phonetic coarticulation. We argue that the nasalization in the /CVŋ + ɿ/ form can only be accounted for by phonological specification, which is phonetically realized on the vowel and following rhotic.

Our results contrasted with the nasal airflow data of Zhang (2000): There is even some evidence that CVn nuclei have more nasalance than CVŋ nuclei. The effect occurs during a short window, and the difference is small ( $\beta = -0.04$ ); thus, this effect may not be robust in a larger sample. Nevertheless, salience-driven explanations of r-suffixation, even if there is a phonetic difference in stem forms, are at odds with the phonological outcome.

A possible explanation for the contradiction of our results and those of Zhang (2000) is sound change. Given the over two-decade gap between the two studies, it is possible that the nasal alternation in the r-suffixed forms caused by gradient phonetic differences in nasal airflow previously observed has since been reanalyzed as a categorical pattern. This grammar shift, characterized by the disappearance of the phonetic precursor while the phonological contrast persists in the r-suffixed forms, represents a classic case of phonologization (Hyman, 1976). In a similar vein, the longitudinal study of Kang and Han (2013) shows that for tonogenesis in Seoul Korean, the relative weighting of acoustic cues shifted significantly over time. Therefore, our comparison with Zhang (2000) may suggest that Beijing Mandarin has undergone a period of cue-reduction in the stem, phonologizing the r-suffixation nasalization contrast.

## 5. Limitations

The limitations in this study involve the phonetic, lexical, and sociolinguistic scope of our data. By focusing exclusively on low vowel rhymes to replicate Zhang (2000), we did not include mid vowel rhymes, which exhibit allophonic vowel qualities in stem forms and maintains a three-way contrast in r-suffixed forms (Lin, 2007). Additionally, we did not control for word frequency or perceived naturalness of the target items. The sociolinguistic context of the variable was also not explored, though r-suffixation in Beijing is known to index social class and construct specific linguistic personas (Zhang, 2008).

Finally, while the absence of precise age data prevents a direct comparison with previous age cohorts, our participant pool consisted primarily of undergraduate and graduate students. This demographic likely reflects a more recent generational stage of Beijing Mandarin than the speakers in the study of Zhang (2000), providing a snapshot of a more advanced stage of phonologization of the nasalization contrast.

## 6. Conclusion

Our study investigated the phonetic grounding of the vowel nasalization contrast in Beijing Mandarin r-suffixation, specifically evaluating the claim that the pattern is driven by non-contrastive nasality salience in the stem form (Zhang, 2000). Using nasometry, we did not find that CVŋ stems exhibited significantly higher nasalance than CVn stems. However, a robust nasalization contrast remained in the suffixed forms, where nasalization in /CVŋ + ɿ/ was present throughout the rhyme. While gradient phonetic salience may have served as the diachronic source of the phonological contrast, our results are consistent with the complete phonologization of this pattern. These novel findings demonstrate that the synchronic data of Beijing Mandarin provide no evidence for phonological sensitivity to non-contrastive phonetic cues.

## Supplementary Material

See [supplementary material](#) for a comprehensive list of the 96 stimuli used in the experiment. It includes the IPA transcriptions, orthographic representations, and the specific carrier sentences for each trial.

## Author Declarations

### Conflict of Interest

The authors have no conflicts to disclose.

### Ethics Approval

Data collection for this study was approved by the New York University Institutional Review Board.

### Data Availability

The data that support the findings of this study are openly available in OSF at <https://osf.io/cr2ms/>.

### References

- Bates, D., Mächler, M., Bolker, B., and Walker, S. (2015). "Fitting linear mixed-effects models using lme4," *J. Stat. Soft.* 67(1), 1–48.
- Beddor, P. S. (1993). "The perception of nasal vowels," in *Phonetics and Phonology: Nasals, Nasalization, and the Velum*, Vol. 5, edited by M. K. Huffman and R. A. Krakow (Academic Press, Cambridge, MA), pp. 171–196.
- Beddor, P. S. (2009). "A coarticulatory path to sound change," *Language* 85(4), 785–821.
- Bellavance, S. R., Eads, A., Katson, A., Álvarez Retamales, J., McCollum, A., Mitra, A., and Davidson, L. (2024). "Vowel nasalization does not cue ambisyllabicity in American English nasals: Evidence from nasometry," *JASA Express Lett.* 4(7), 070001.
- Benua, L. (1997). "Transderivational identity: Phonological relations between words," Ph.D. thesis, University of Massachusetts, Amherst, MA.
- Boersma, P., and Weenink, D. (2023). "Praat: Doing phonetics by computer [computer program], version 6.3.18," <https://www.praat.org/> (Last viewed July 31, 2026).
- Bressmann, T. (2021). "Nasometry," in *Manual of Clinical Phonetics*, 1st ed., edited by M. J. Ball (Routledge, Oxfordshire, England), pp. 322–338.
- Carignan, C. (2018). "Using ultrasound and nasalance to separate oral and nasal contributions to formant frequencies of nasalized vowels," *J. Acoust. Soc. Am.* 143(5), 2588–2601.
- Cohn, A. (1990). "Phonetic and phonological rules of nasalization," Ph.D. thesis, UCLA, Los Angeles.
- Coretta, S. (2024). "tidygam: Tidy prediction and plotting of generalised additive models, r package version 1.0.0," <https://github.com/stefanocoretta/tidygam> (Last viewed July 31, 2026).
- Dow, F. D. M. (1972). *An Outline of Mandarin Phonetics* (Australian National University, Canberra).
- Duanmu, S. (2007). *Oxford Linguistics The Phonology of Standard Chinese*, 2nd ed. (Oxford University Press, Oxford).
- Flemming, E. S. (1995). "Auditory representations in phonology," Ph.D. thesis, UCLA, Los Angeles.
- Fu, B. (2022). "Contrast preservation in Mandarin r-suffixation: A comparative study of Beijing and Liaoning dialects," *Glossa* 7(1), 5801.
- Hyman, L. M. (1977). "Phonologization," in *Linguistic Studies offered to Joseph Greenberg*, edited by A. Juillard (Alma Libri, Saratoga, CA), pp. 407–418.
- Kang, Y., and Han, S. (2013). "Tonogenesis in early contemporary Seoul Korean: A longitudinal case study," *Lingua* 134, 62–74.
- Lee, W.-S. (2005). "A phonetic study of the 'er-hua' rimes in Beijing Mandarin," in *Proceedings of Interspeech 2005*, pp. 1093–1096.
- Lin, T., and Wang, L. (1992). *Yuyin Xue Jiaocheng (A Course in Phonetics)* (Peking University Press, Beijing).
- Lin, Y.-H. (2007). *The Sounds of Chinese* (Cambridge University Press, Cambridge).
- R Core Team (2021). *R: A Language and Environment for Statistical Computing* (R Foundation for Statistical Computing, Vienna, Austria).
- Sóskuthy, M. (2017). "Generalised additive mixed models for dynamic analysis in linguistics: A practical introduction," [arXiv:1703.05339](https://arxiv.org/abs/1703.05339).
- Tomaschek, F., Hendrix, P., and Baayen, R. H. (2018). "Strategies for addressing collinearity in multivariate linguistic data," *J. Phonetics* 71, 249–267.
- Whalen, D. H., and Beddor, P. S. (1989). "Connections between nasality and vowel duration and height: Elucidation of the eastern Algonquian intrusive nasal," *Language* 65, 457–486.
- Wood, S. N. (2017). *Generalized Additive Models: An Introduction with R*, 2nd ed. (Chapman and Hall, London).
- Zhang, J. (2000). "Non-contrastive features and categorical patterning in Chinese diminutive suffixation: Max[F] or Ident[F]?" *Phonology* 17(3), 427–478.
- Zhang, Q. (2008). "Rhotacization and the 'Beijing Smooth Operator': The social meaning of a linguistic variable," *J. Sociolinguist.* 12(2), 201–222.