Dynamic insights into incomplete neutralisation in Beijing Mandarin: retroflex suffixation and rime merger through GAMM analyses

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Background

Incomplete neutralisation (IN): phonologically neutralised categories yield phonetically non-neutralising outputs

Beijing retroflex suffixation (BRS): a prominent feature in Beijing Mandarin speech, non-syllabic retroflex suffix ɻ, transcribed **[ə˞]** or **[ɻ]**; originally diminutive, now often semantically bleached.

- **Monophthongal open rimes (V or GV):**
  - The suffix is attached directly to *non-front vowels*.
  - **[ə]** is inserted between *front vowels* (**[i, y, e]**) and the suffix.
- **Diphthongal and nasal-coda rimes (VX or GVX):**
  - *Front and alveolar* post-nuclear segments, i.e. **[i, n]**, are deleted.
  - *Back (rounded) and velar* post-nuclear segments (**[u, ŋ]**) leave a trace of lip-rounding or nasality.

Previous empirical study found complete merger for suffixed low-nuclear rimes, e.g. [a–ai–an], as prediectd by the pattern above; but some rimes that are expected to be non-contrastive, e.g. [i-ie-in], after suffixation remain distinguishable, pointing to potential IN.

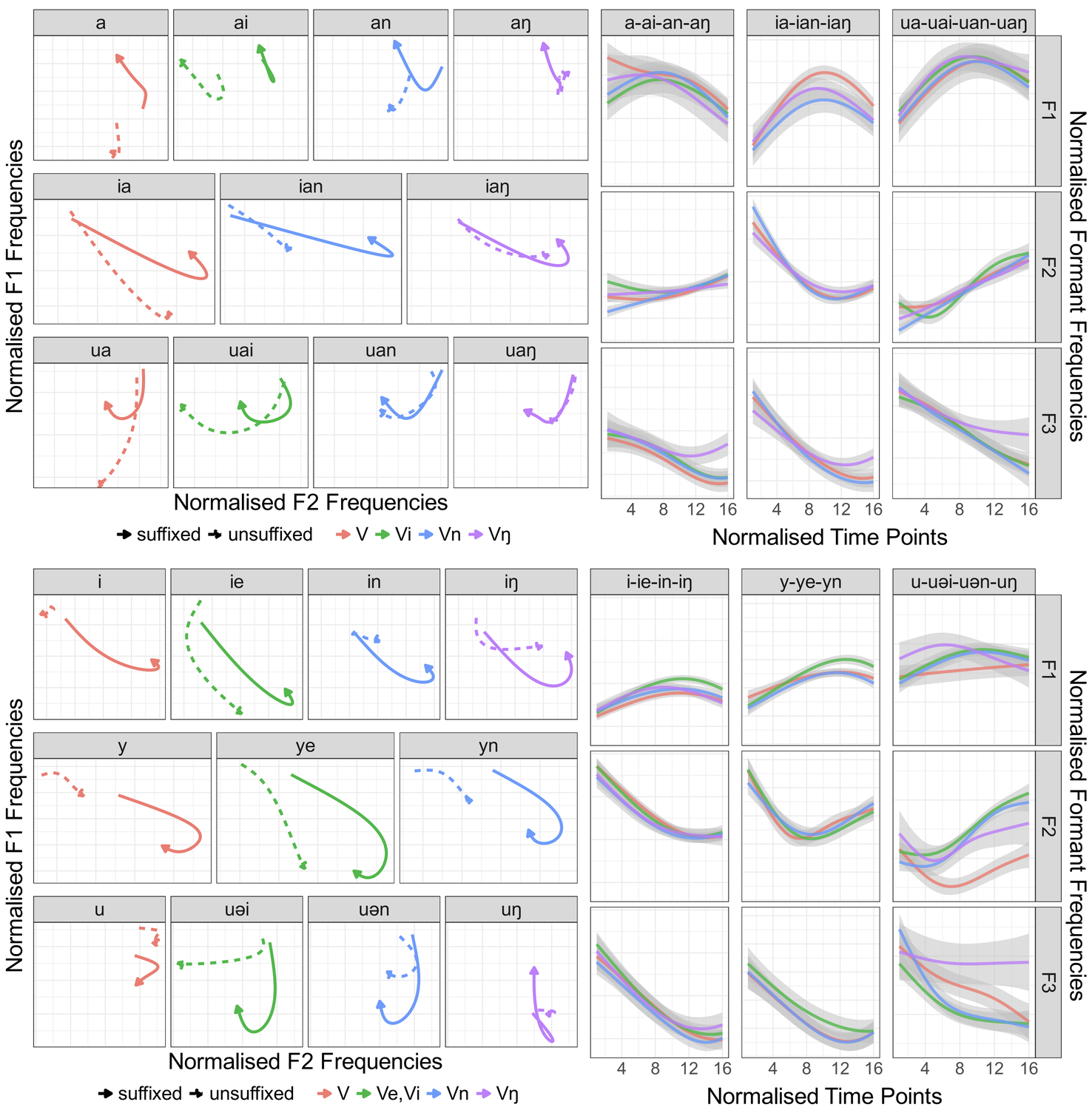
Experimental Design

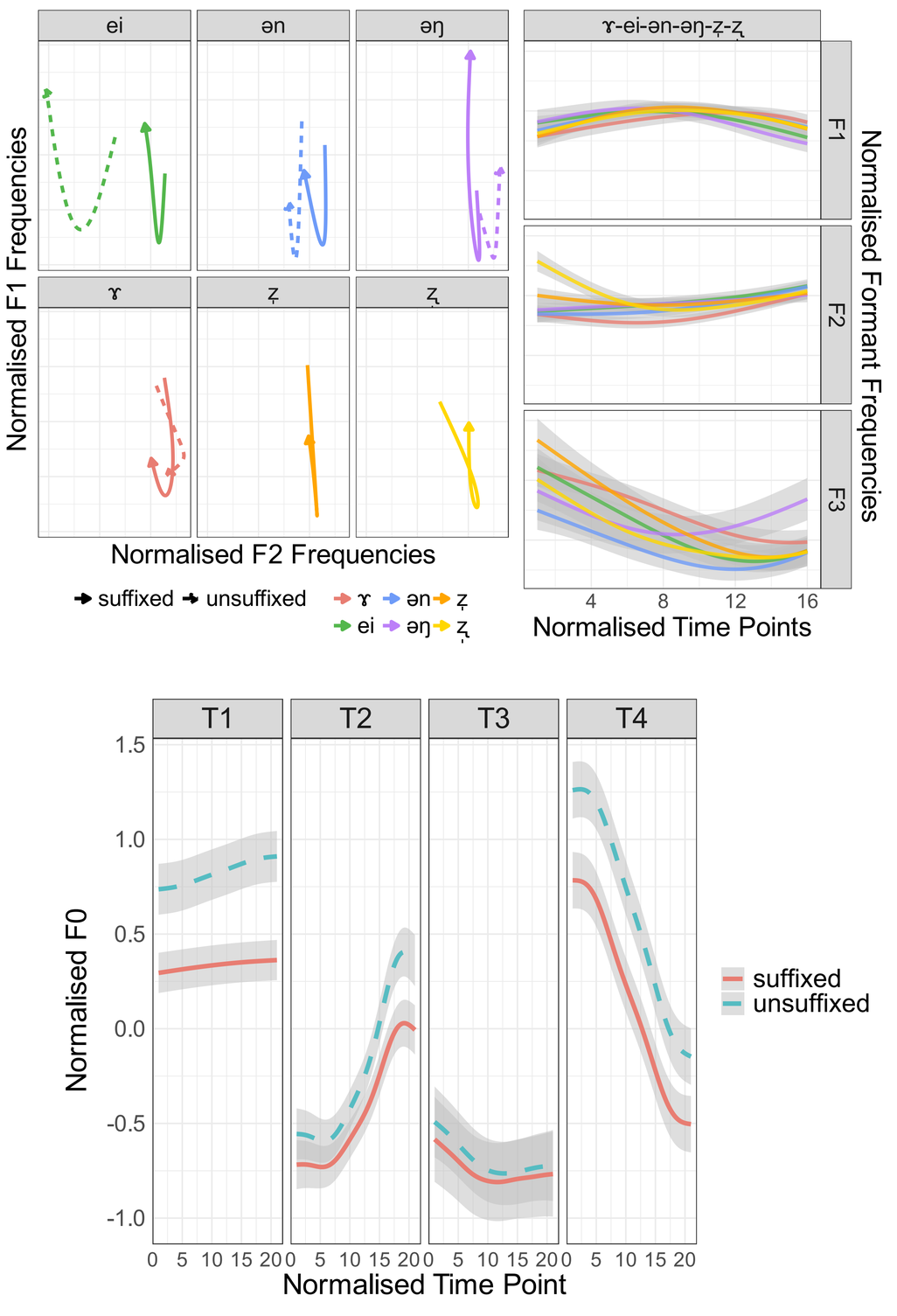
- 11 Beijing Mandarin **(BM)** native speakers (7f, 4m; aged 21–25).
- 1 token was selected for each rime×tone condition; in total 34×4 = 136 pairs (272 unsuffixed + suffixed items).
  - **Unsuffixed items**: all monosyllabic words
  - **Suffixed items**: 125 monosyllabic words (e.g. **[lin^{35}]+ɻ**) + 11 phonologically well-formed monosyllabic non-words (e.g. ***[ɕye^{214}]+ɻ**]) were tested.
- In the production task, items were displayed a pair at a time (unsuffixed and suffixed), in one of two alternative carrier sentences:
  - For **words/non-words**: 我 (不) 知道 ___ 的 意思 是 什么。**[wo^{214} (pu^{51}) ʈʂɻ^{55}tau __ tə i^{51}sɻ ʂɻ^{51} ʂən^{35}mɤ]** 'I (don't) know what the meaning of ___ is.'
  - These were elicited as answers to the question 你 知道 ___ 的 意思 是 什么 吗? **[ni^{214} ʈʂɻ^{55}tau __ tə i^{51}sɻ ʂɻ^{51} ʂən^{35}mɤ ma]** 'Do you know what is the meaning of ___?'

Analysis

- 2 992 tokens were segmented using Montreal Forced Aligner and manual correction.
- ***F*0, *F*1, *F*2, *F*3 frequencies** were extracted at 21 equidistant points.
- Formant frequencies and F0 were Lobanov-normalised; outliers (1.5 IQR) were removed.
- Generalised additive mixed models (**GAMMs**) were fit to model the dynamic formant trajectories and tone contours.
- For each model, the last 5 points from the time series were removed to reduce coarticulatory effect.
- The effectiveness of the full model was evaluated by comparing it to a nested model to arrive at the best fit.
- Predicted values were obtained and used for visualisation.
  - *unsuffixed vs suffixed F*1-*F*2 vowel space
  - merging suffixed *F*1, *F*2, *F*3 formant trajectories
  - *unsuffixed vs suffixed* tone contours

Results





Discussion

- Suffixation makes spectral changes across all rime types, with varying degrees of vowel raising, lowering, and retraction.
  - Low-nuclear vowels: significant spectral change after suffixation and complete merger.
  - High-nuclear rimes such as [i] and [y] also demonstrated substantial changes, with suffixed [ie] and [ye] remain distinguishable within their respective groups. [uəi] and [uən] merge completely.
  - Mid-nuclear vowel [ɤ] exhibited less quality change and were distinctive after suffixation.
- Tone contour shapes were preserved after suffixation; overall F0 values have been lowered.
- Challenges to the modular feed-forward phonology-phonetics interface: phonetics only has access to the discrete phonological output that does not contain any gradient phonetic information.

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