LARYNGEAL CONTRAST AND SOUND CHANGE: THE PRODUCTION AND PERCEPTION OF PLOSIVE VOICING AND CO-INTRINSIC PITCH

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P1.1 Experimental Phonetik

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12/11/2024

Question for Discussion

Can Beddor ‘s cue trading model for nasalization be applied to explaining tonogenesis?

Background

- **Co-intrinsic Pitch Perturbations and Sound Change**

Vowel F0 is raised, relative to the presumed intonational baseline, following phonologically voiceless obstruents (Kirby & Ladd 2016), but lowered F0 following phonologically voiced obstruents has also been observed (Coetzee et al. 2018).

- **2 Leading Models**

1) Ohala’ s Model (1989)

i) Coarticulation rarely leads to sound change, because adult listeners are sensitive to induced variation and compensate for it in speech perception.

ii) Sound change is fundamentally abrupt, the result of a perceptual parsing error on the part of the listener.

2) Beddors’ model (2009, 2023) – Coarticulatory Path Model (CoPath)

i) The source of change is parsing variability. The flexibility observed in cue may lead to individual differences in cue weights (Yu 2021).

ii) Listeners may treat covarying cues to a phonological contrast as **PERCEPTUALLY EQUIVALENT**.

Background

- **Articulatory Covariation & Perceptual Equivalence**

A robust trading relation— perceptual equivalence and articulatory covariation between coarticulatory source and effect-an inverse correlation between source and effect (i.e. when the source is weaker the effect is stronger, and vice versa).

- **The case of Vowel Nasalization**

/VN/ in American English (e.g. in *bent* vs. *bend*)

Background

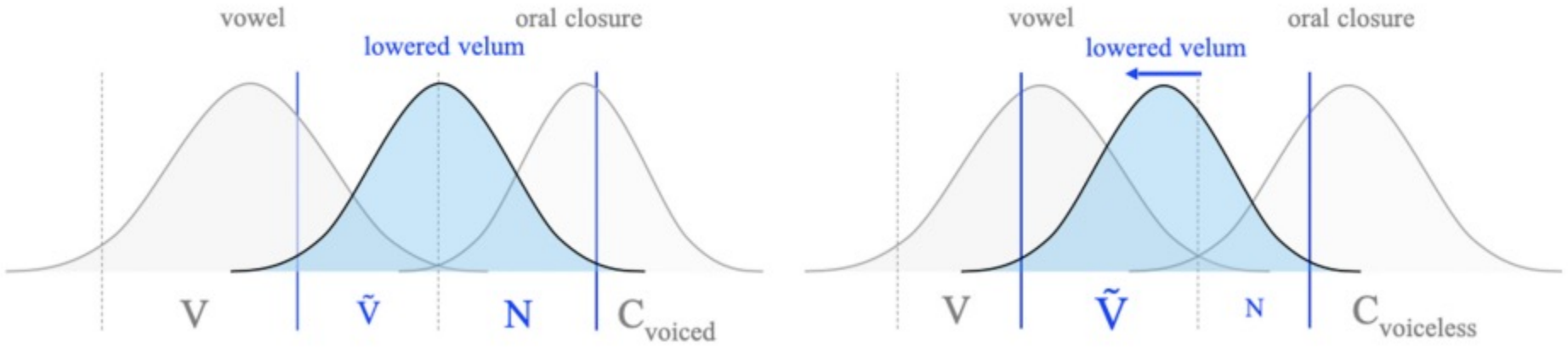


Figure 1. Oral –nasal gestural alignment in two consonantal contexts (Gao & Kirby,2024)

- Vowel nasality is longer and consonantal nasality is shorter in VNCvoiceless than in VNC voiced, and the (acoustic) durations of vowel nasality and consonantal nasality correlate negatively.
- On the perception side, listeners are sensitive to the total duration of nasality, but not to whether nasality is present in the consonant or the preceding vowel. (Listeners do not perceptually differentiate source from effect.)

Motivation

- Through a study of 2 cues to the laryngeal (voicing) contrast: closure voicing & pitch
- To assess whether, and to what extent, articulatory-acoustic covariation and/or perceptual equivalence obtain between voicing and CF0 in Metropolitan French, a true-voicing language

(i) whether voicing covaries with the magnitude of CF0 in production, both within and across categories

(ii) whether closure voicing and CF0 are treated as perceptually equivalent both within the voiced category and at the voiced-voiceless category boundary (i.e. whether they trade across a wide range of stimulus conditions, not just in configurations where the primary cue is ambiguous.)

Research Question

Production:

RQ1: Does VOT covary with onset F0 within the voiced and/or voiceless category?

RQ2: Does VOT covary with onset F0 across the voiced and voiceless categories?

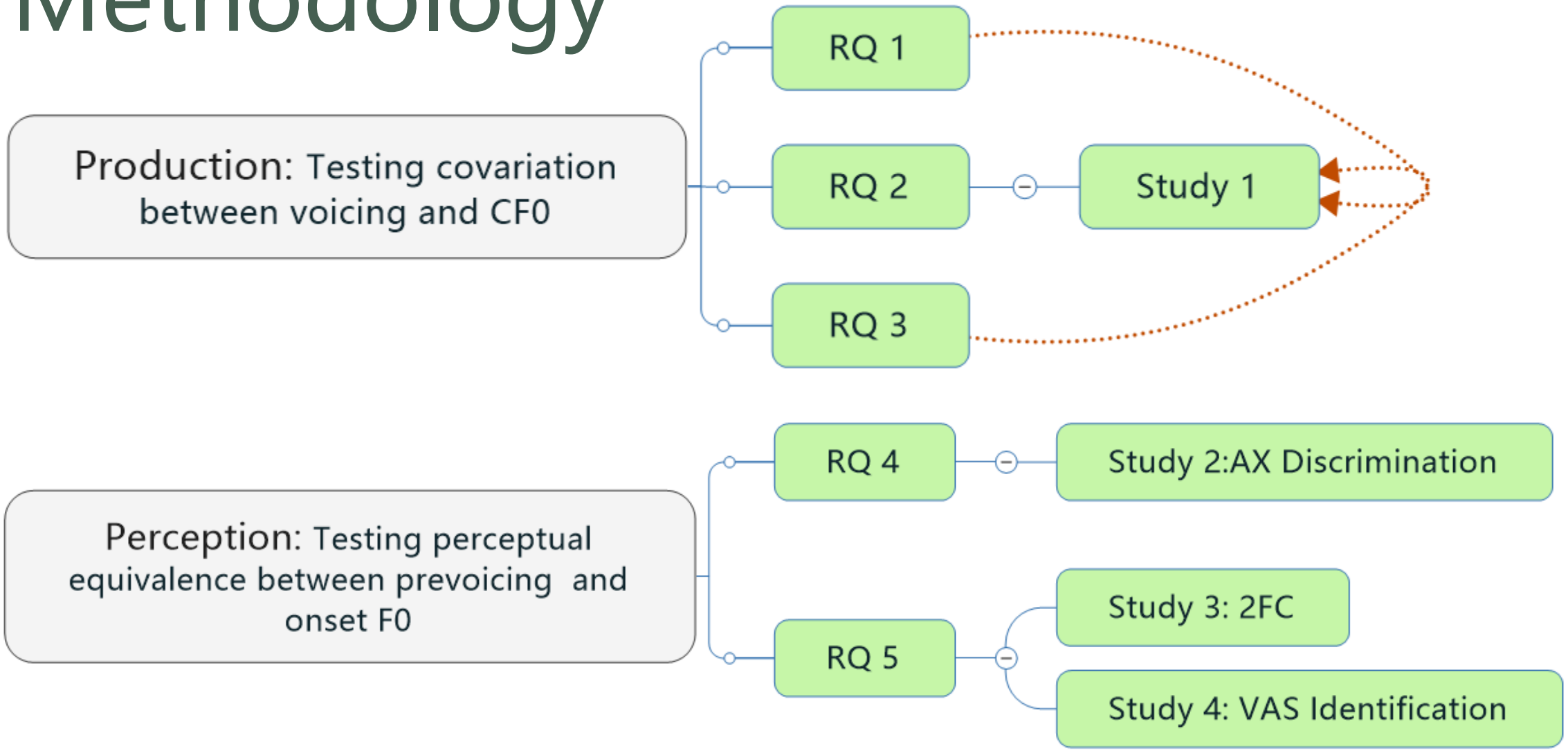
RQ3: Are voiced plosives that are devoiced followed by a lower onset F0 than those that are typically prevoiced?

Perception:

RQ4: Is longer prevoicing perceived as equivalent to a lower onset F0 across a wide range of stimulus conditions, whether VOT is ambiguous or not?

RQ5: Does onset F0 affect voicing categorization along the entire VOT continuum, and not only at the voiced-voiceless boundary?

Methodology



Study 1

- **Participants**

11 native speakers of French (9 women+2 men)

Age (median=21, mean=21, SD=1.5)

- **Materials & Procedures**

Read 72 mono-& disyllabic French lexical items with /p,b,m/onsets

Study 1- Analysis

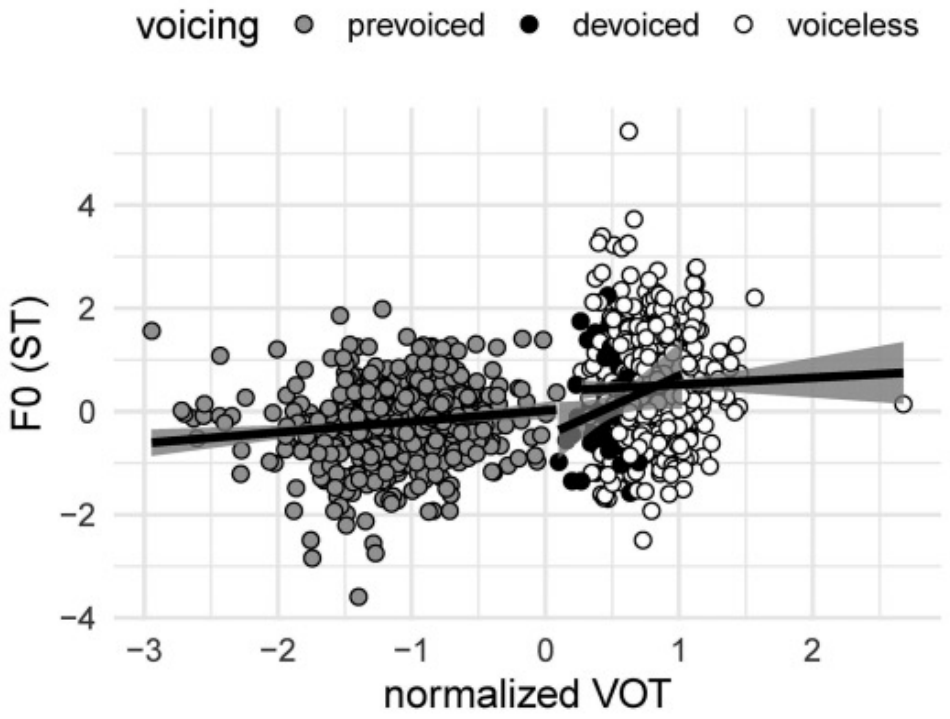


FIGURE 2. Scatterplot of onset F0 against speaker-normalized VOT across all speakers and tokens with linear smoothing. (Gao & Kirby, 2024)

Study 1- Results

- **RQ1:** Does VOT covary with onset F0 within the voiced and/or voiceless category?

VOT has at best a weakly positive correlation with onset F0 within both voiced and voiceless categories

- **RQ2:** Does VOT covary with onset F0 across the voiced and voiceless categories?

Same as across categories

- **RQ3:** Are voiced plosives that are devoiced followed by a lower onset F0 than those that are typically prevoiced?

Devoiced plosives are not produced with a lower onset F0 than prevoiced plosives

Study 2 – AX Discrimination

- **Participants**

115 native speakers of Metropolitan French
Age >=18

- **Materials**

All stimuli——Ca syllables (C – labial plosive)
Syllables were created with 2 crossed parameters:
1) 4 levels of VOT：-100，-60，-40，0ms
2) 2 levels of onset F0：90，130Hz
Stimuli pairs were organized according to **Condition** & **Ambiguity**

Study 2 – AX Discrimination

- **Condition**

	Characteristics	VOT	Onset F0	Example
(A0) Control	Sharing identical	same	same	VOT (−100, −60, −40, or 0 ms) onset F0 (90 or 130 Hz)
(A1) VOT-only	Differed only in VOT	by 60 ms	same	VOT (−100 vs. −40 ms, or −60 vs. 0 ms onset F0 (90 or 130 Hz).
(A2) Additive	The cues were expected to reinforce each other to increase the perceived difference	Longer prevoicing vs. Shorter or no prevoicing	Low vs. Flat	−100 ms VOT with 90 Hz onset F0 vs. −40 ms VOT with 130 Hz onset F0
(A3) Canceling	The cures were expected to trade with each other, canceling out the perceived difference	Longer prevoicing vs. Shorter prevoicing	Flat vs. Low	−100 ms VOT with 130 Hz onset F0 vs. −40 ms VOT with 90 Hz onset F0

Study 2 – AX Discrimination

- **Ambiguity of prevoicing**

Design to examine whether the weight of the F0 cue differed depending on the ambiguity of the primary cue, VOT.

In terms of VOT, 2/3 of the stimuli pairs were clearly within the voiced category (sharing a VOT of −100, −60, or −40 ms), while 1/3 were defined as ambiguous (sharing a VOT of 0 ms)

Study 2 – AX Discrimination

- **Ambiguity of prevoicing**

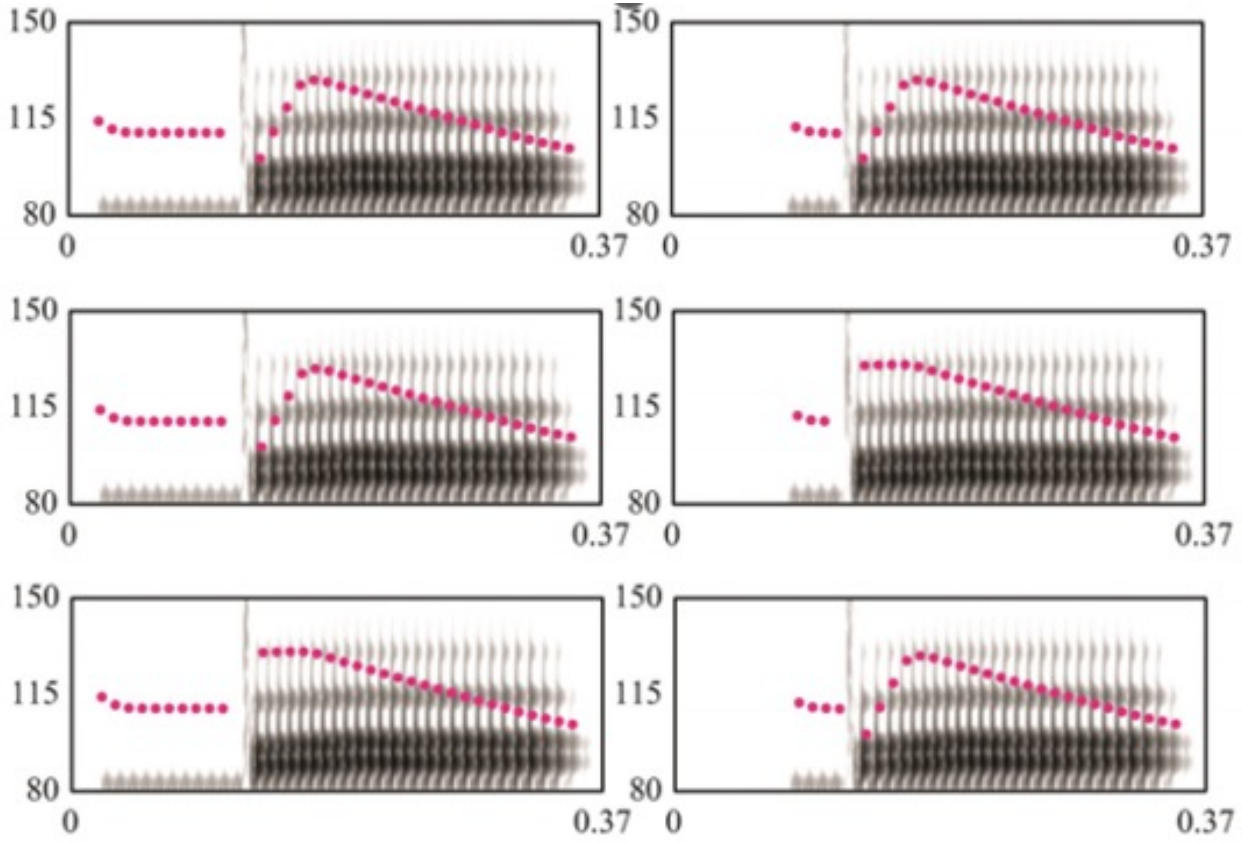


Figure 3. Illustrations of the 3 conditions for stimuli pairs where both are unambiguously /b/ in terms of VOT (Gao & Kirby, 2024)

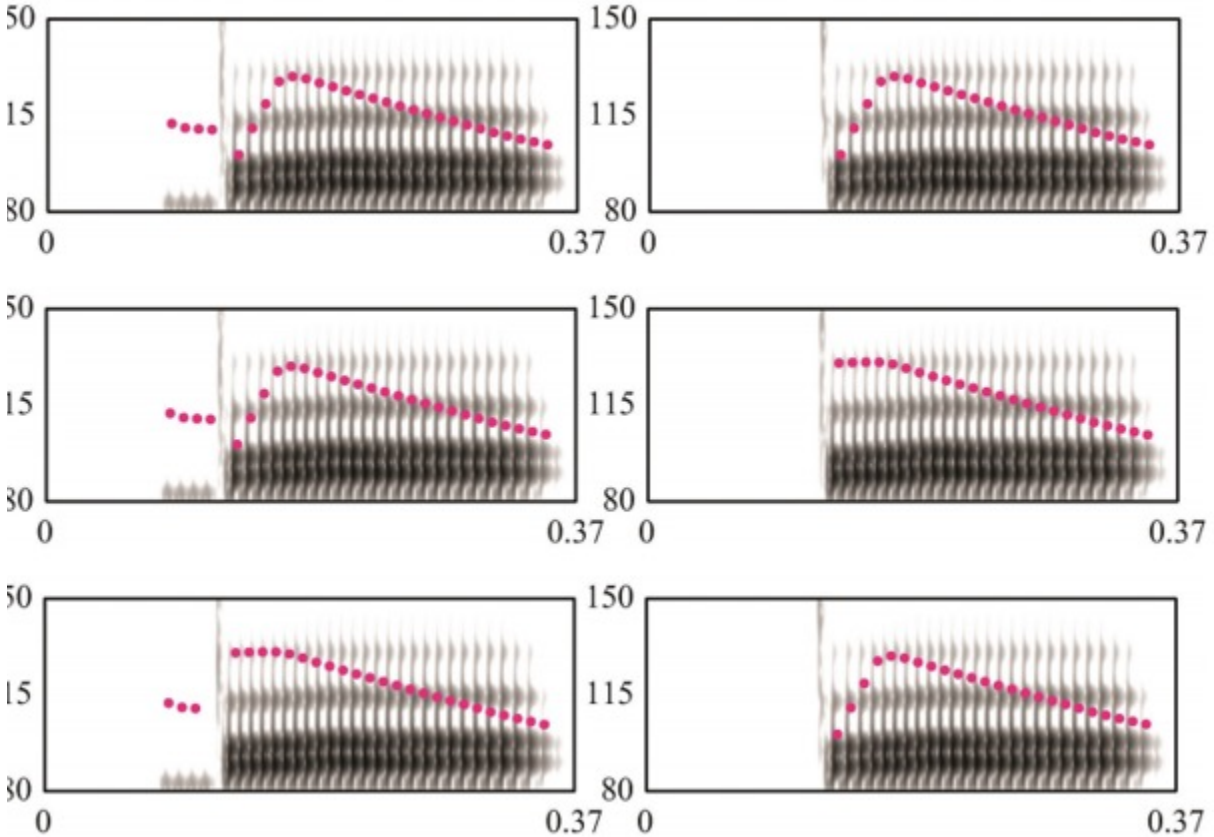


Figure 4. Illustrations of the 3 conditions for stimuli pairs where one stimulus is ambiguous between /p/ and /b/ in terms of VOT (Gao & Kirby, 2024)

Study 2 – AX Discrimination

- **Prediction**

If prevoicing and low onset F0 are perceived as equivalent across the stimulus space,

i) Discrimination accuracy in the additive condition should be greater than in the VOT-only condition, which should in turn be higher than in the canceling condition: **additive > VOT-only > canceling**

ii) This pattern should hold regardless of the ambiguity of prevoicing.

In contrast, if listeners discriminate the stimuli pair based on their acoustic (dis)similarity, we expect the discrimination accuracy to follow the order: **additive = canceling > VOT-only**

Study 2 – AX Discrimination

- **Procedure**

Presented with 2 stimuli on each trial to identify whether sounded identical or different

- Interstimulus interval (ISI) -330ms
- Intertrial interval -700ms
- Time-out - 2.5s
- Training phase –twice
- Entire session- 20~30min

After experiment – an exit survey about (i.e. language, education, music-related) background

Study 2 – Analysis

- **Data**

114 Listeners (83 women & 31 men)

Age: 18-61 (median=28, mean=32, SD=12)

- **Discrimination accuracy (d’ scores)**

d’ was calculated for each participant, based on hit vs. miss responses to different stimuli pairs, and false alarm vs. correct rejection responses to identical stimuli pairs.

Study 2 – Analysis

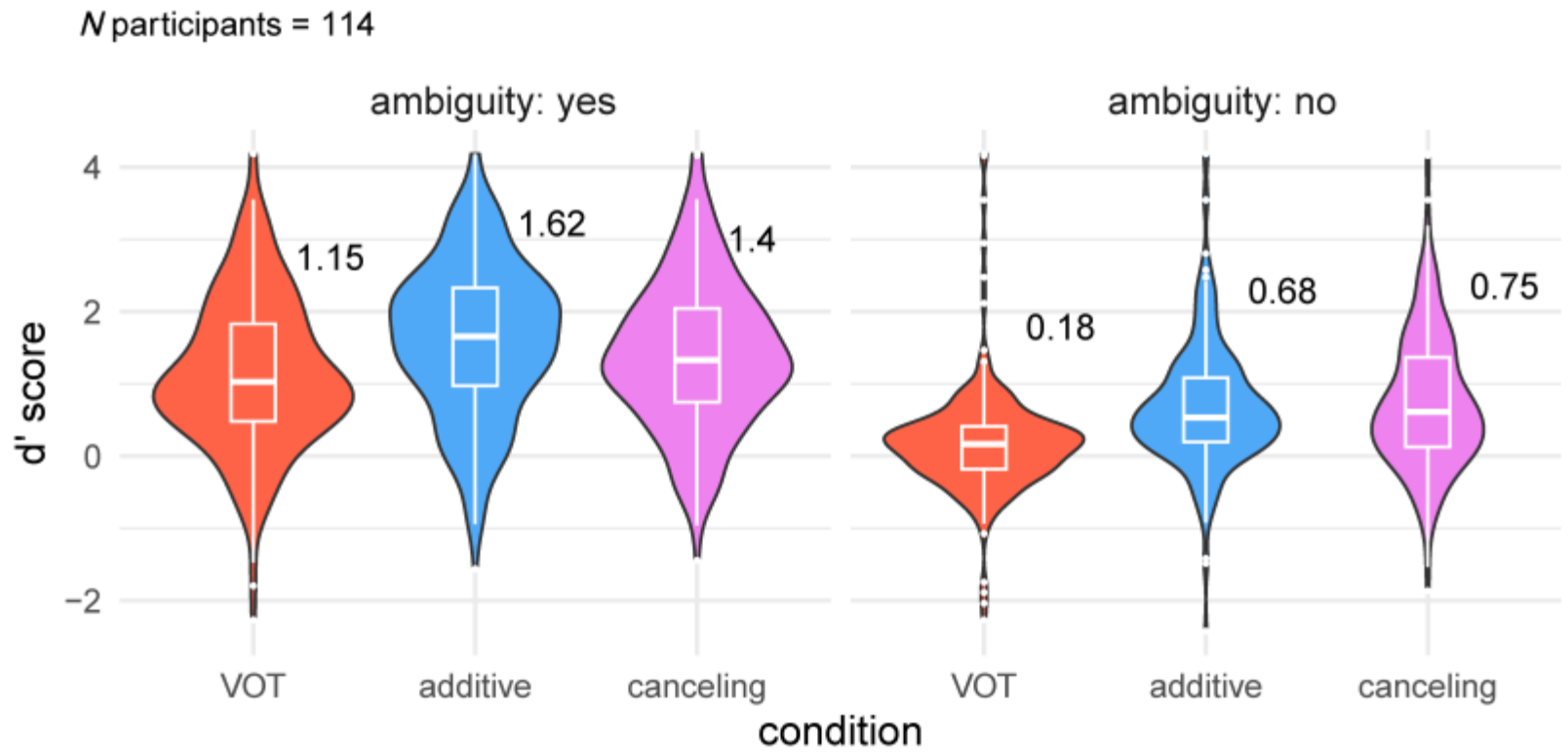


FIGURE 6. Density plots of d' for VOT-only, additive, and canceling conditions by ambiguity. Numbers indicate means. (Gao & Kirby, 2024)

Study 2 – Analysis

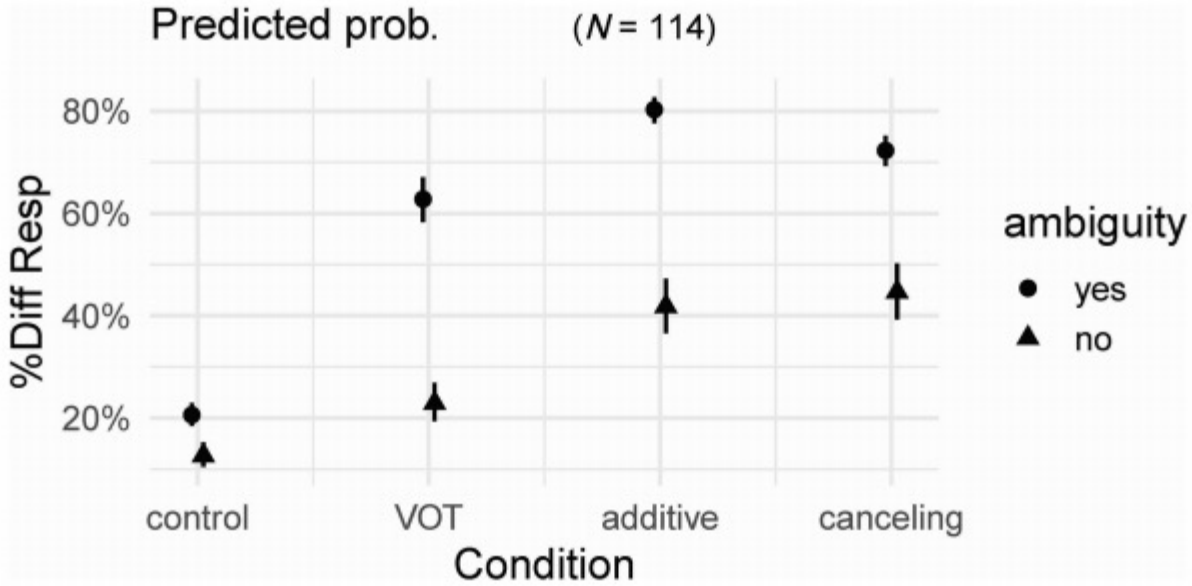


FIGURE 7. Prediction plot of the GLMM model showing the interaction between Condition and Ambiguity predicting the probabilities of 'different' responses (model: *glmer*(*response* ~ *ambiguity* * *condition* + (1 + *condition* + *ambiguity*)|*subject*)). Error bars indicate 95% confidence intervals.

(Gao & Kirby, 2024)

Study 2- Results

- For ambiguous stimuli pairs

additive > canceling >VOT-only

- For unambiguous stimuli pairs

Canceling = additive > VOT-only

- **RQ4：** Is longer prevoicing perceived as equivalent to a lower onset F0 across a wide range of stimulus conditions, whether VOT is ambiguous or not?

Prevoicing trades perceptually with low onset F0 only when VOT is ambiguous, but a strict perceptual equivalence relationship between the two cues is not established when prevoicing is robust.

Study 3 & 4: 2AFC & VAS IDENTIFICATION

	2 AFC (Two –Alternative Forced -Choice)	**VAS** (Visual Analog Scaling)
Purpose	To see where on the VOT continuum onset F0 exerted the most influence on voicing category judgments	
Participants	72 paricipants who completed the AX task	
Materials	**The same stimuli from the AX task, 4 VOT levels** (ranging from -60 ms to 0 ms, stepping in 20 ms intervals) and **2 onset F0 levels** (low, flat)	More extensive **6-level VOT continuum** (-60 ms to +20 ms) with **3 onset F0 levels** (low, flat, high), creating finer gradation along the VOT and F0 dimensions
Procedures	Each participant listened to a stimulus and then selected one of two response options	Participants used a slider on a continuous scale anchored by "pa" on one end and "ba" on the other

Study 3 & 4 – Analysis

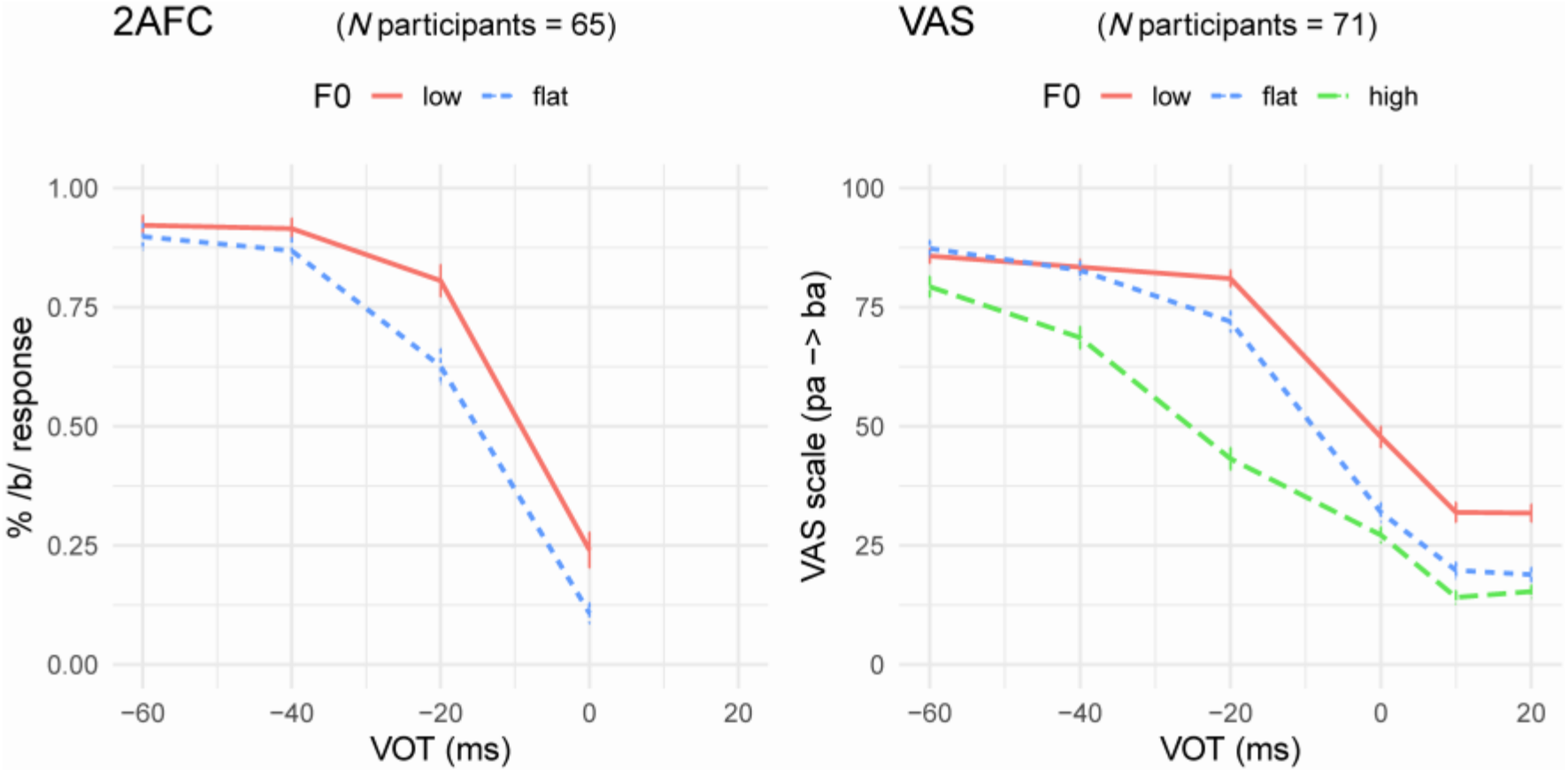


FIGURE 8. Observed identification rate for 2AFC and VAS by VOT and Onset F0. Error bars indicate 95% confidence intervals. (Gao & Kirby, 2024)

Study 3 & 4 – Analysis

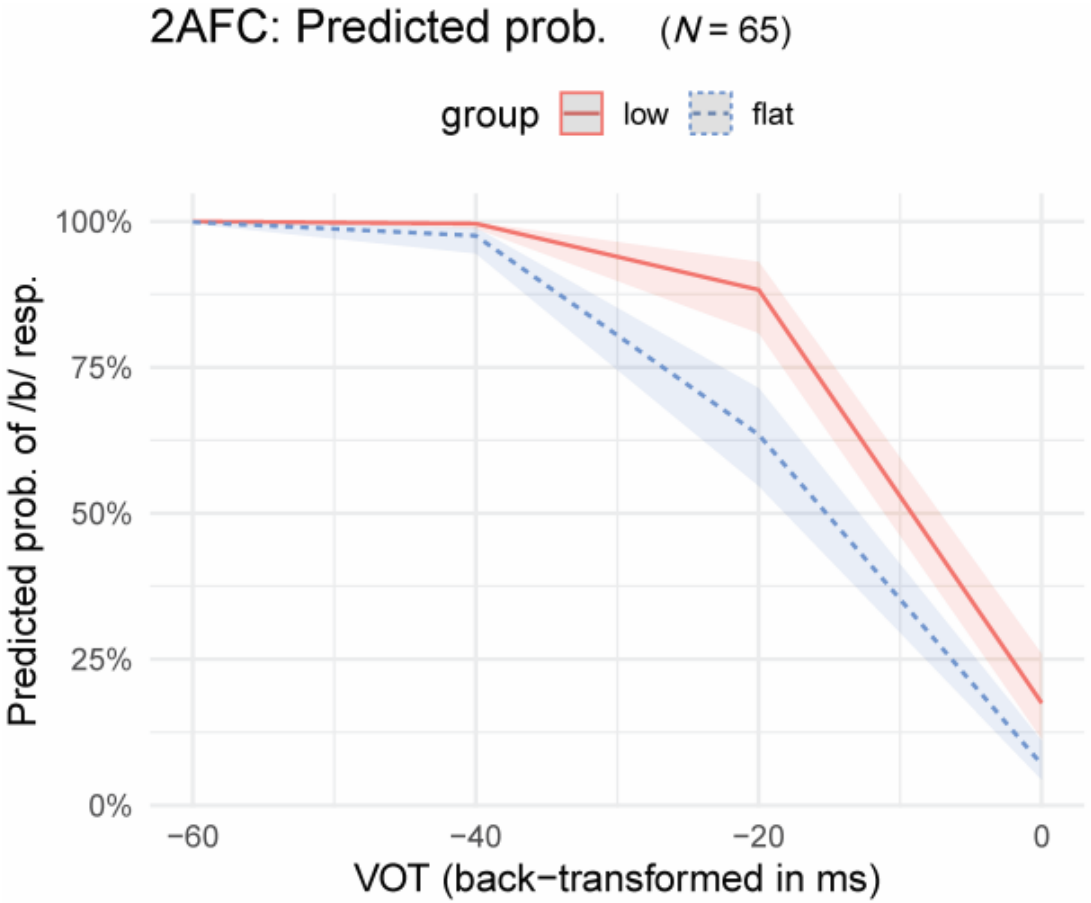


FIGURE 9. Prediction plot for /b/ response by VOT and F0 (model: *glmer*(*response* ~ *F0* * *VOT* + (1 + *F0* * *VOT*)|*subject*)). Shaded areas indicate 95% confidence intervals. (Gao & Kirby, 2024)

Study 3 & 4- Results

- **RQ5：** Does onset F0 affect voicing categorization along the entire VOT continuum, and not only at the voiced-voiceless boundary?

Onset F0 has the greatest influence around the category boundary, which is estimated to lie between −20 and 0 ms. In addition, onset F0 affects voicing categorization especially when VOT is ambiguous, or when VOT and F0 are conflicting. The effect of onset F0 is not evenly distributed along the entire VOT continuum.

Conclusion

- Rather than an inverse correlation in production, we found at best a weakly positive correlation between the extent of prevoicing and onset F0.
- Rather than perceptual equivalence across the stimulus space, we found that the cue trading between prevoicing and onset F0 operates especially at the voiced-voiceless boundary.
- The phonologization of CF0 seen in 'tonogenetic' sound changes is driven not by an articulatorily based perceptual equivalence relation, as in the coarticulation of VN sequences. Instead, spontaneous devoicing of onsets creates an ambiguity in voicing categorization that redirects listener attention to the secondary CF0 cue.
- Over time, listeners may gradually come to upweight CF0 for lexical disambiguation and subsequently such a perception pattern will lead to establish phonologization.

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Thank You !