

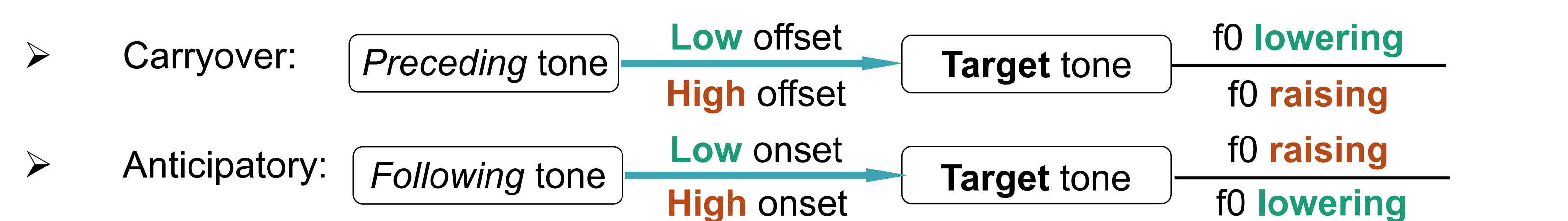
F0 and voice quality of coarticulated Mandarin tones

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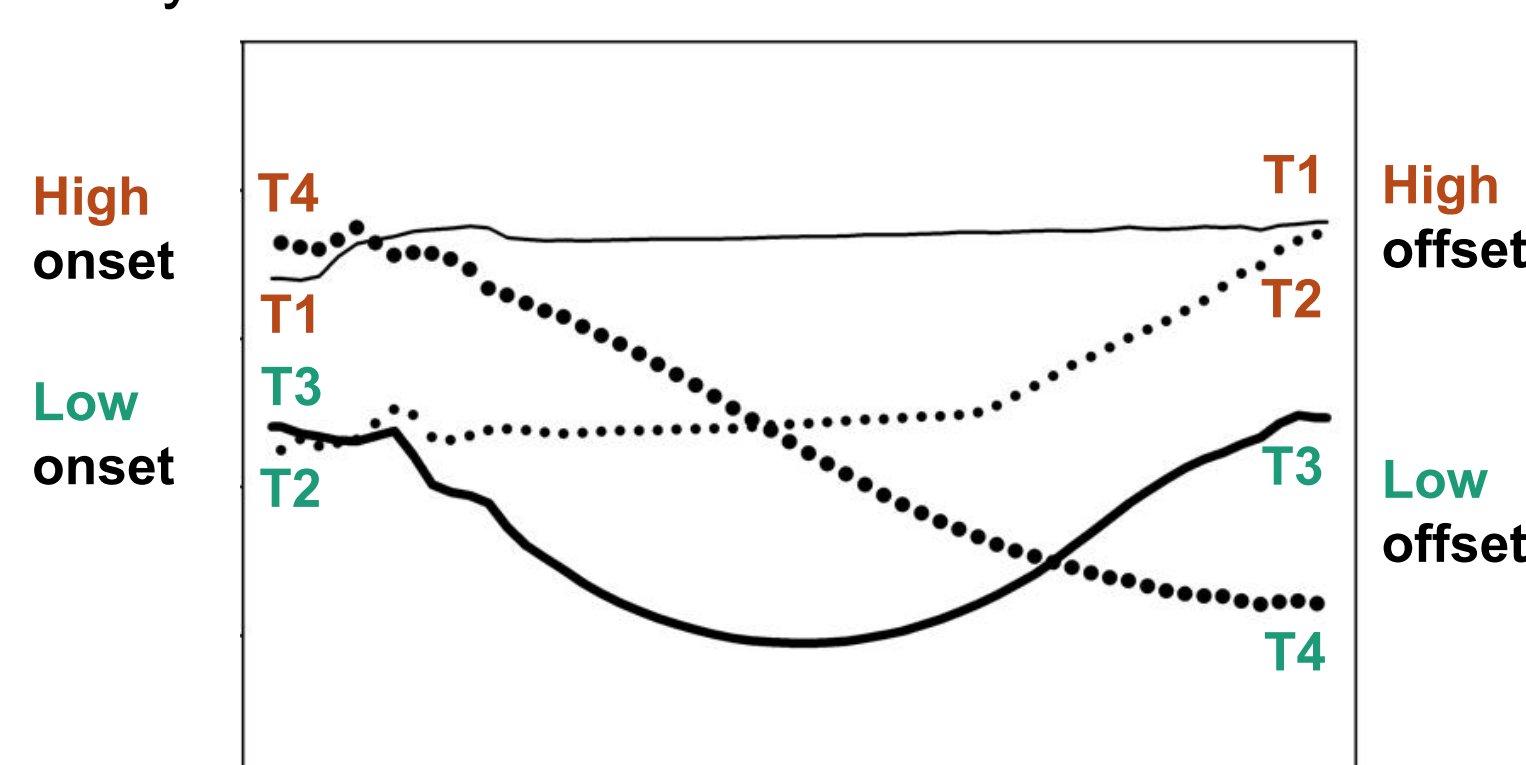
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INTRODUCTION

- Tonal coarticulation often induces changes in f0^{1,7} and voice quality³.
- In Mandarin, coarticulation has both carryover and anticipatory effects on f0^{6,7}:



Resynthesized f0 contour of Mandarin four tones⁴



f0 lowering environments		f0 raising environments	
T3-X-T1	T3-X-T4	T1-X-T2	T1-X-T3
T4-X-T1	T4-X-T4	T2-X-T2	T2-X-T3
Preceding: raising	Following: lowering	Preceding: lowering	Following: raising
T1-X-T1	T1-X-T4	T3-X-T2	T3-X-T3
T2-X-T1	T2-X-T4	T4-X-T2	T4-X-T3

- In Mandarin, voice quality covaries with f0:
 - Creaky voice is associated with low f0^{2,5};
 - Low f0 is used by listeners for citation tone identification⁴.
- Research question: How do f0 raising and lowering due to tonal coarticulation affect voice quality in Mandarin?**
- Hypotheses:**
 - Lowering of f0 → increase in creakiness (more constricted);
 - Raising of f0 → decrease in creakiness (more modal).

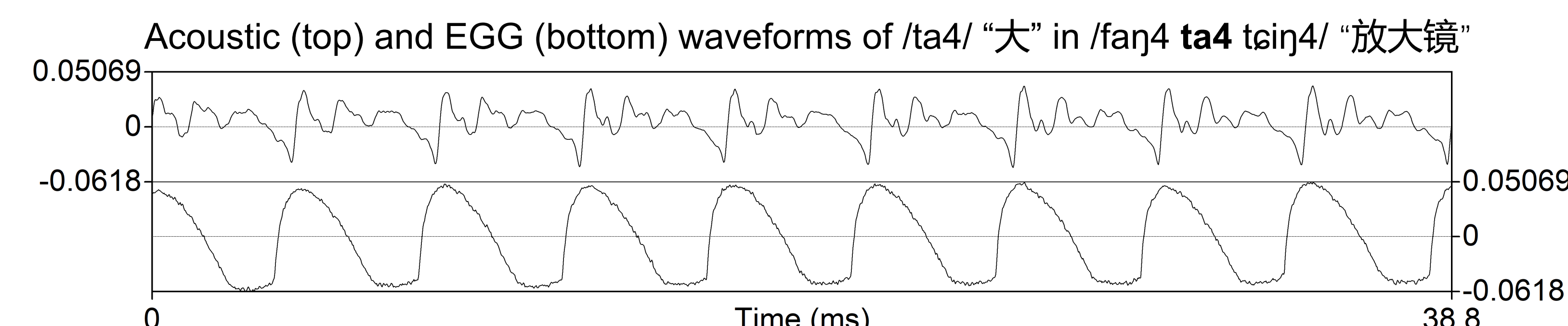
METHODS

- Audio & electroglottography (EGG) recordings of scripted sentences with varying tritone sequences
- Tritone sequences = Tones 1-4 (pre) – **Tones 1-4 (target)** – Tones 1-4 (post)
- Target tone syllables are embedded in trisyllabic Mandarin compounds, for example:

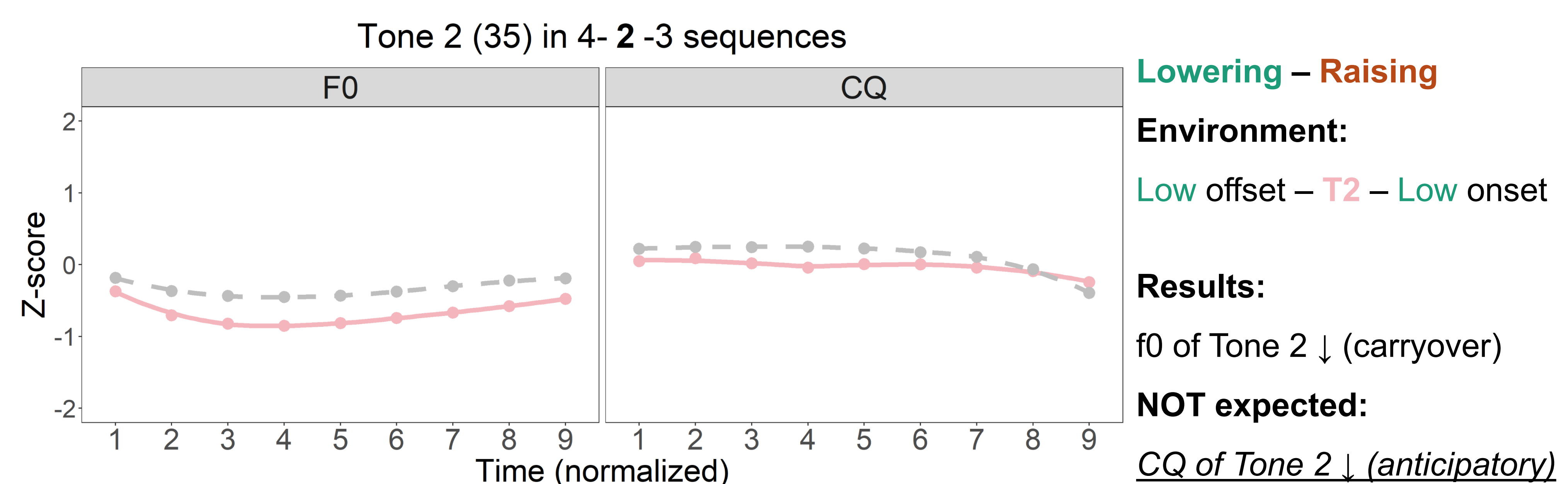
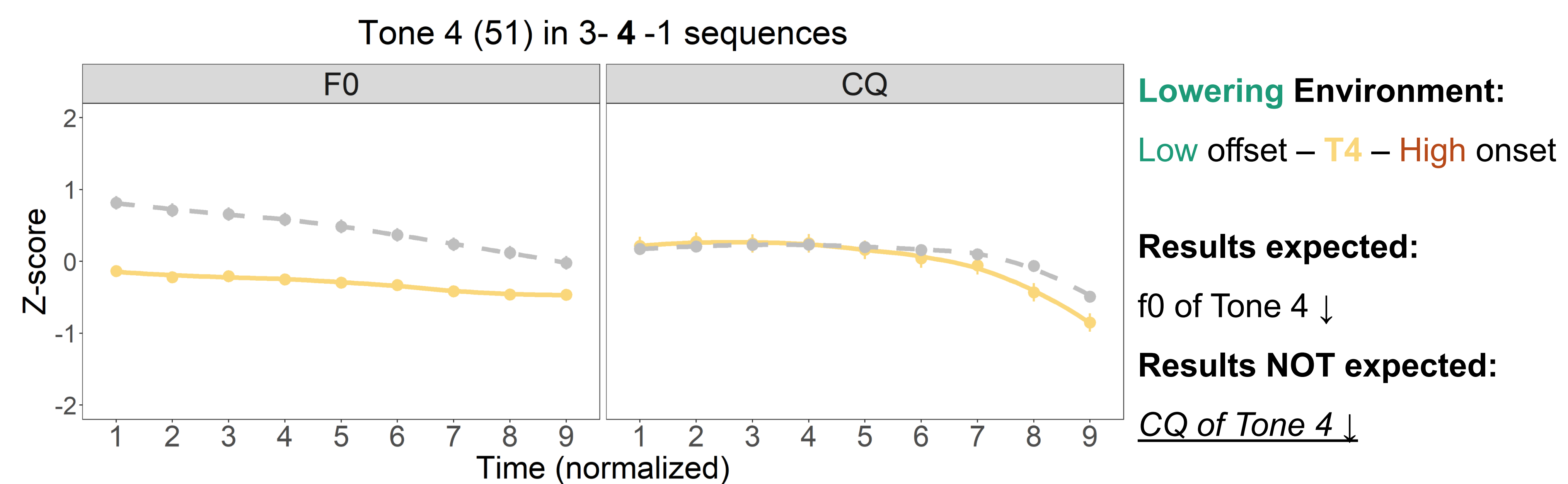
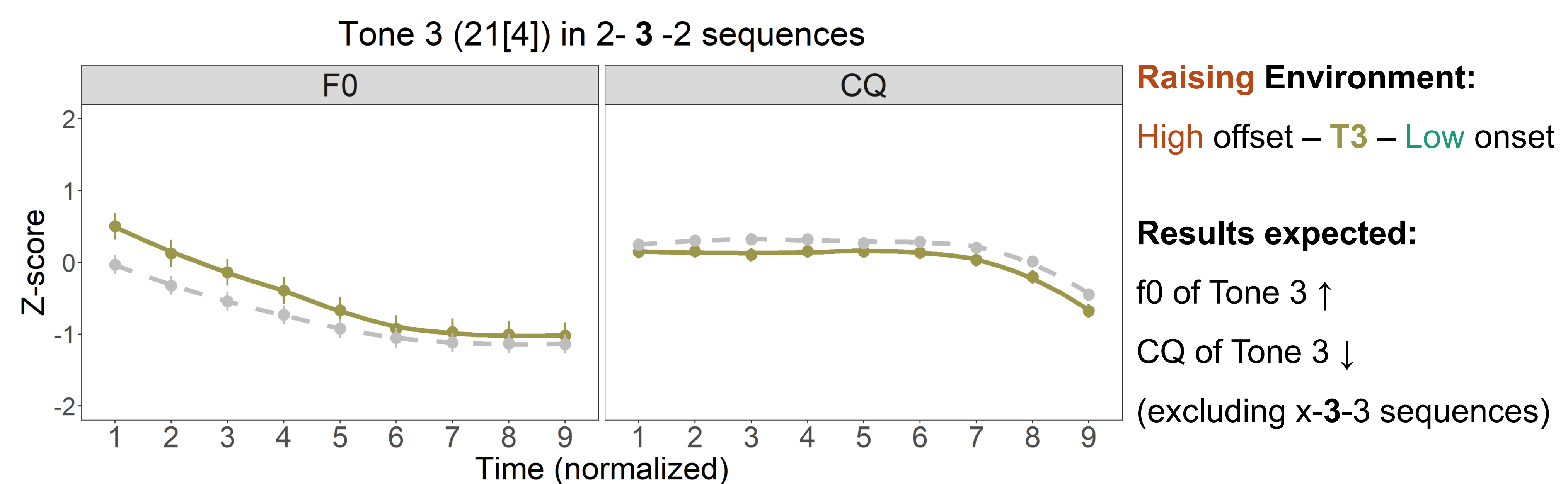
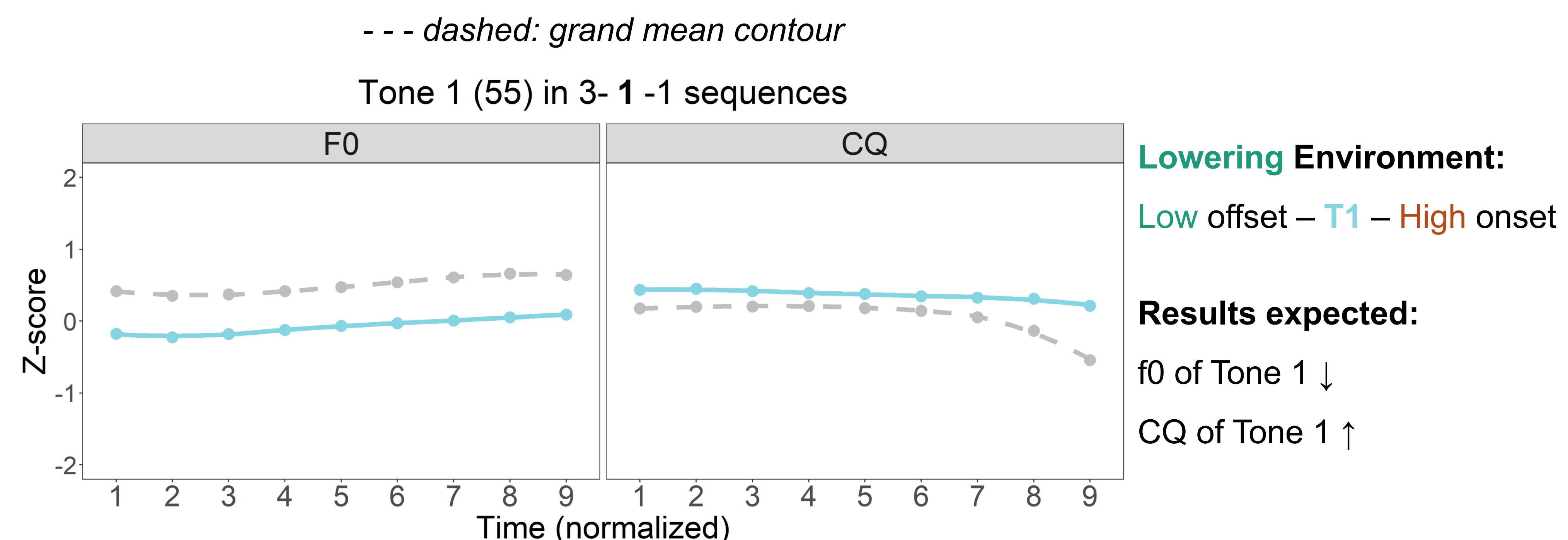
收割机	ʂəu1 kɤ1 tɕi1	'Harvester'
齐白石	tɕi2 pai2 ʂi2	'Baishi Qi'
老古董	lau3 kʷu3 ton3	'Old-fashioned'
放大镜	fan4 ta4 tɕən4	'Magnifier'
- Tritone sequences (underlined) with target tone (bolded) are embedded in a carrier sentence:

我教你收割机怎么说。Wo3 tɕəu1 ni3 ʂəu1 **kɤ1** tɕi1 tsən3 mɤ5 ʂʷo1.

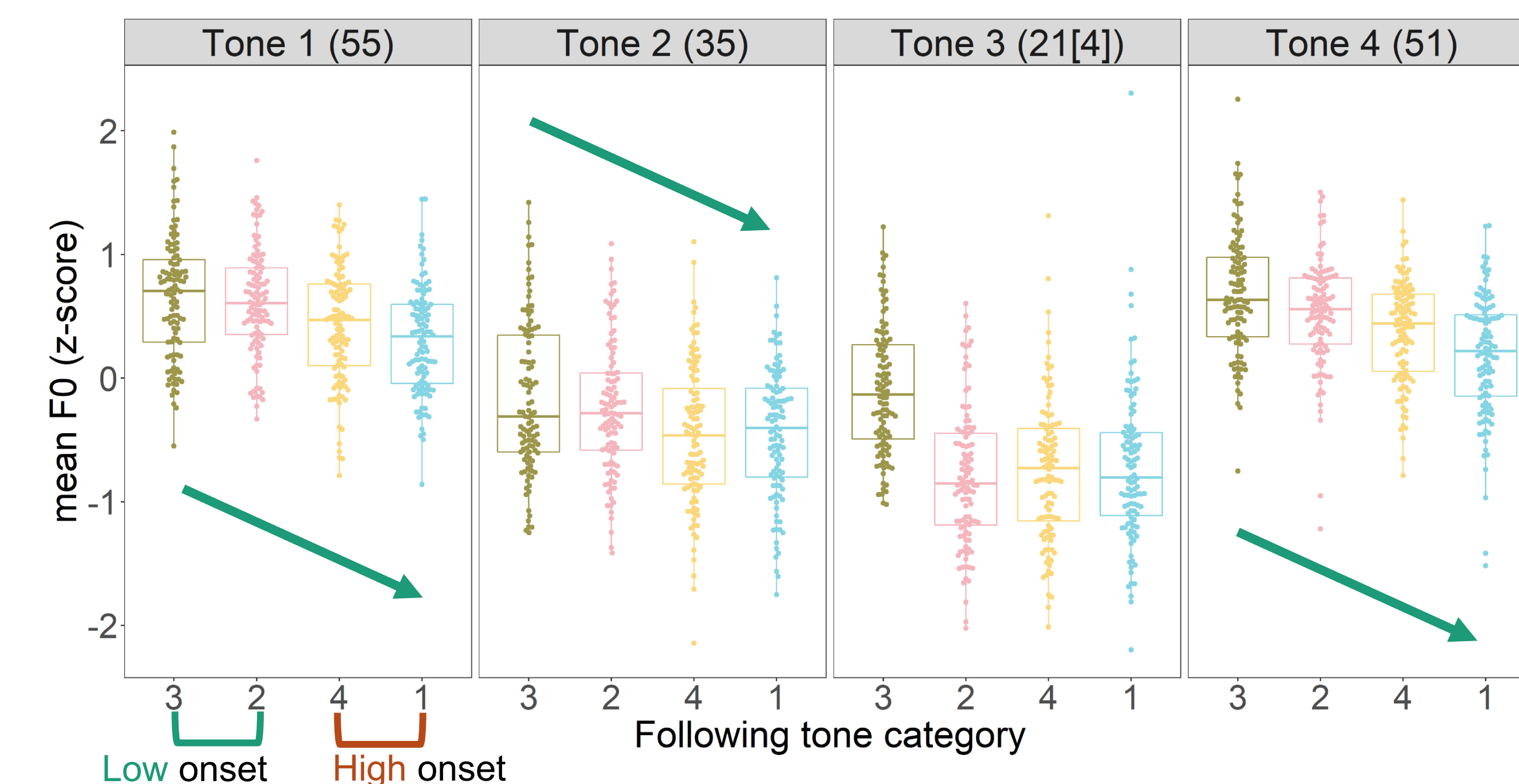
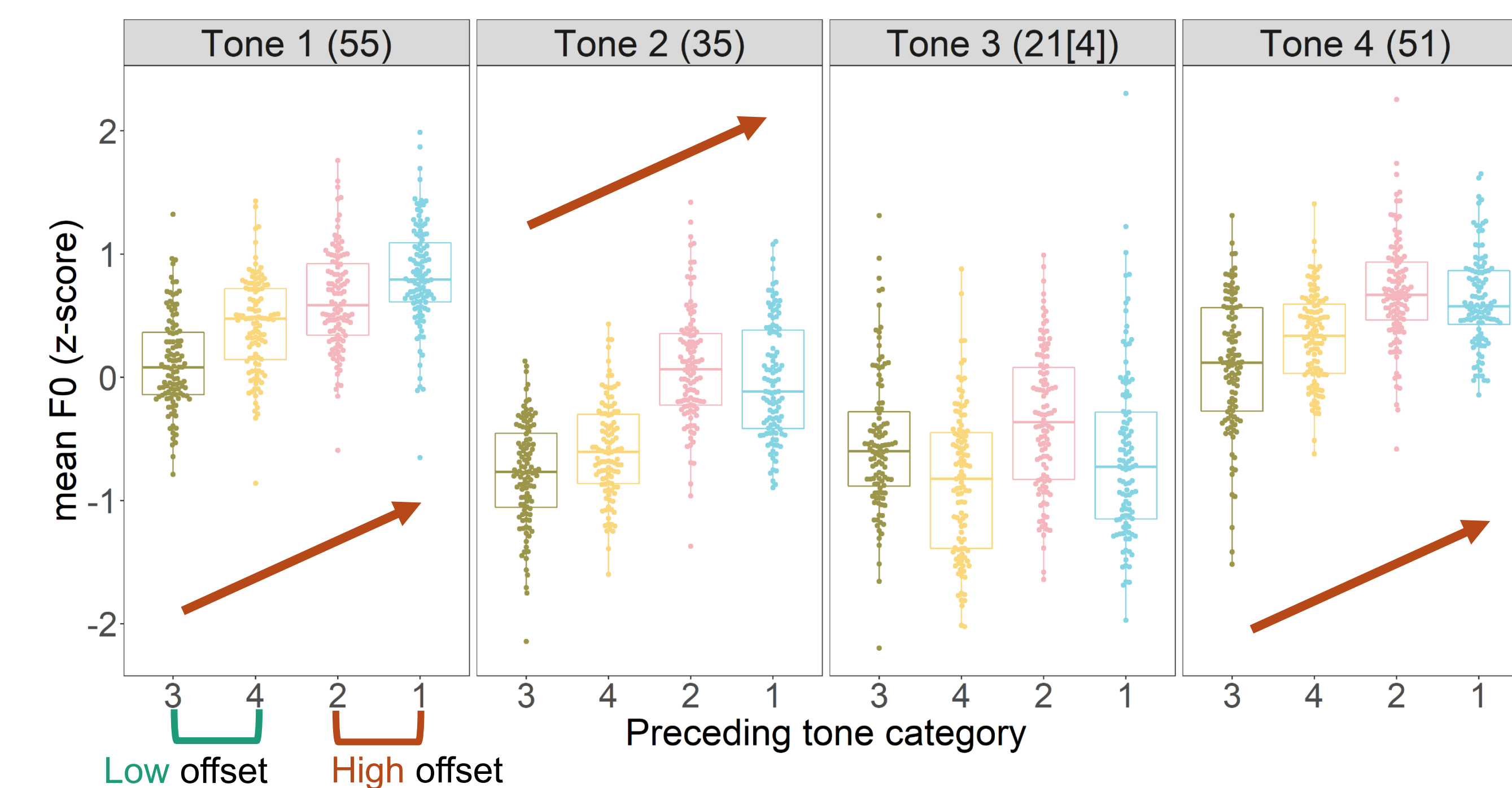
"I teach you 'harvester' how to say."
- 27 native Mandarin speakers (14F); 128 tokens per speaker (4 tones (pre) x 4 (target) x 4 (post) x 2 (repetition) = 128); 128 x 27 speakers = 3456 data points
- f0 and Contact Quotient (EGG) of the **target** syllable analyzed by VoiceSauce and EggWorks
 - z-scored and time-normalized each measure's values over nine equal intervals (9 points/syllable)
- Higher values of CQ = more constricted → creakier



SAMPLE RESULTS FOR COARTICULATED TONES



CARRYOVER & ANTICIPATORY EFFECTS



DISCUSSION & CONCLUSION

- Preceding tone and following tone have **carryover** and **anticipatory** effects on f0, which largely accords with Xu (1997).
- These effects often entail corresponding **changes in voice quality**, as Kuang (2017) found for f0 variation more broadly.
- But f0 and CQ **do not necessarily show a uniform** carryover or anticipatory effects. For example, for sequences where CQ have anticipatory effects, their f0 can have carryover effects.
- Overall, this shows that carryover and anticipatory f0 effects have **mixed influence** on voice quality, and that voice quality can be **INDEPENDENT** of f0.

REFERENCES

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[4] Huang, Y. (2019). The role of creaky voice attributes in Mandarin tonal perception. 19th ICPHS, Melbourne, Australia 2019 (pp. 1465-1469).

[5] Kuang, J. (2017). Covariation between voice quality and pitch: Revisiting the case of Mandarin creaky voice. *The Journal of the Acoustical Society of America*, 142(3), 1693-1706.

[6] Sun, Y. & Shih, Chinlin (2019). Anticipatory tonal coarticulation: How, when and why it occurs. 19th ICPHS, Melbourne, Australia 2019 (pp. 196-200).

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DISCUSSION CONTINUED

Expectation		f0 raising & CQ lowering (less creaky)	f0 lowering & CQ raising (more creaky)
Results	As expected	13 / 14 (sequences)	12 / 14 (sequences)
	<i>Contradicted</i>	<i>1 / 14</i>	<i>1 / 14</i>
	No change	0 / 14	1 / 14
f0	As expected	8 / 14	7 / 14
	<i>Contradicted</i>	<i>2 / 14</i>	<i>1 / 14</i>
	No change	4 / 14	6 / 14

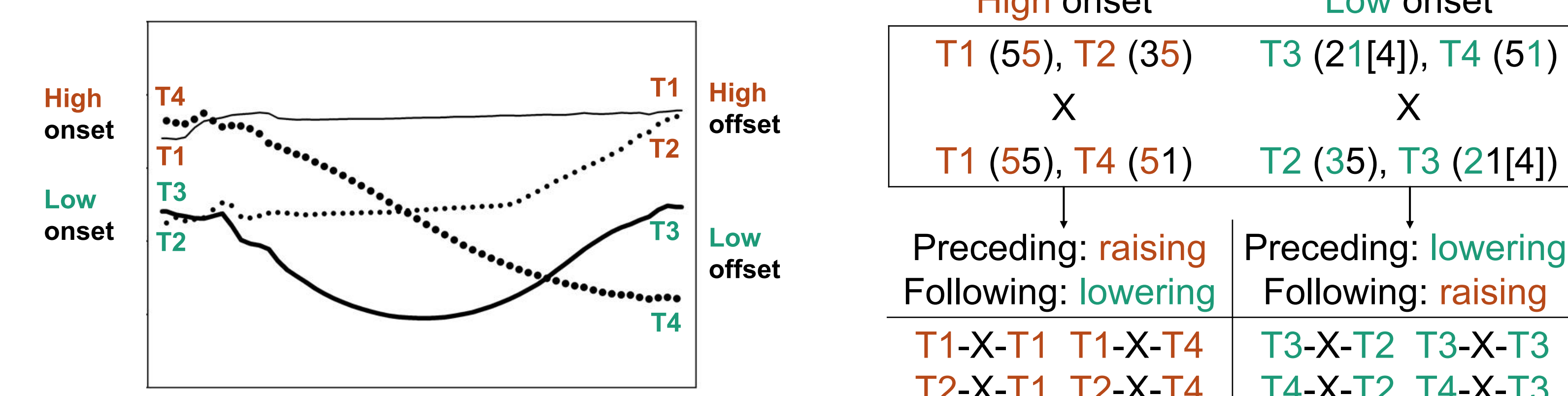
Environment		f0 raising & CQ lowering (less creaky)	f0 lowering & CQ raising (more creaky)
Expectation		f0 raising	f0 lowering
Results	As expected	1-1-2	3-1-1
	<i>Contradicted</i>	<i>1-1-3</i>	<i>3-1-4</i>
	No change	2-1-2	4-1-1
f0	As expected	2-1-2	3-2-1
	<i>Contradicted</i>	<i>1-2-2</i>	<i>3-2-4</i>
	No change	1-2-3	4-2-1
	As expected	2-2-2	4-2-4
	<i>Contradicted</i>	<i>2-2-3</i>	<i>4-3-1</i>
	No change	2-3-2	4-3-4
	As expected	1-4-2	3-4-1
	<i>Contradicted</i>	<i>1-4-3</i>	<i>3-4-4</i>
	No change	2-4-2	4-4-1
	As expected	2-4-2	4-4-1
	<i>Contradicted</i>	<i>1-3-2</i>	<i>4-1-4</i>
	No change	NA	4-4-4

Expectation		CQ lowering (less creaky)	CQ raising (more creaky)
Results	As expected	1-1-2	3-1-1
	<i>Contradicted</i>	<i>2-1-2</i>	<i>3-2-4</i>
	No change	2-1-3	4-2-1
CQ	As expected	1-2-3	4-2-4
	<i>Contradicted</i>	<i>2-2-2</i>	<i>4-3-1</i>
	No change	2-3-2	4-3-4
	As expected	1-4-2	4-4-1
	<i>Contradicted</i>	<i>1-4-3</i>	<i>3-4-1</i>
	No change	2-4-2	3-4-4
	As expected	1-1-3	3-1-4
	<i>Contradicted</i>	<i>1-2-2</i>	<i>4-1-1</i>
	No change	2-2-3	4-1-4
	As expected	1-3-2	3-2-1
	<i>Contradicted</i>	<i>2-4-3</i>	<i>3-4-4</i>
	No change	4-4-4	4-4-4

RESEARCH QUESTION II

- Xu (1997) suggests that the carryover effect has stronger influence on f0 than the anticipatory effect.
- In a tritone sequence, the first tone and the last tone may have opposite effects on the middle tone.

Resynthesized f0 contour of Mandarin four tones⁴



- Research question:** How do the f0 and CQ of the target tone change when the preceding tone and the following tone have opposite effects?
- Hypotheses:**
 - f0 is more likely to be influenced by the **preceding tone** than by the following tone.
 - When the preceding tone has **high offset**: **Raising of f0** → **decrease in creakiness (more modal)**;
 - When the preceding tone has **low offset**: **Lowering of f0** → **increase in creakiness (more constricted)**.

RESULTS AND DISCUSSION II

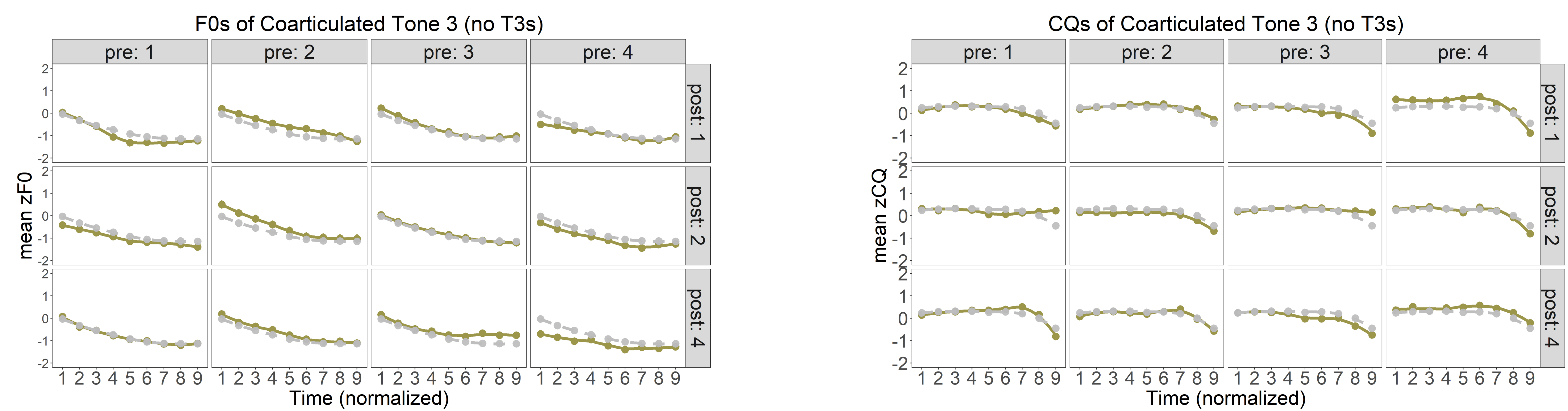
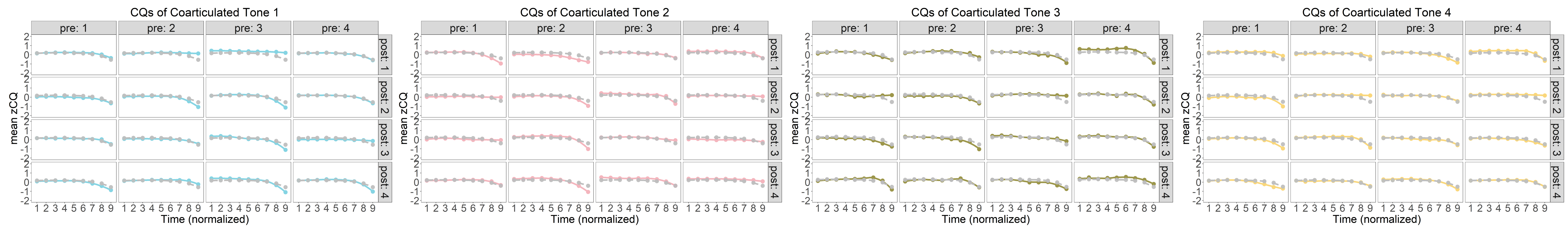
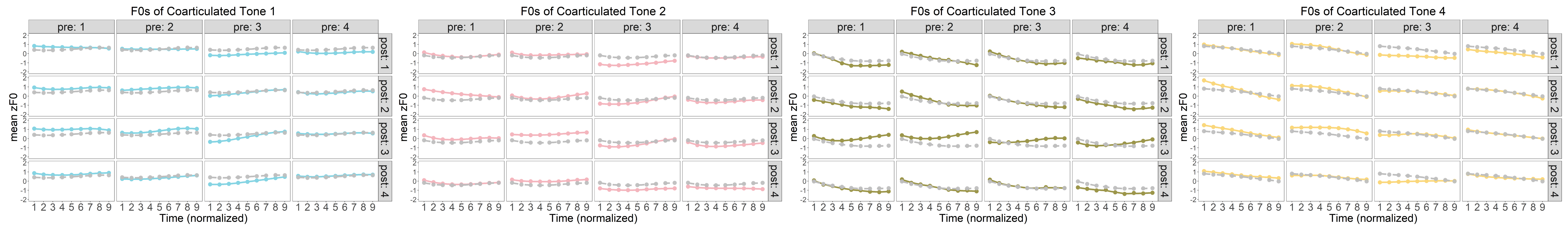
- Out of 29 sequences in total:

Environment		f0 raising-lowering CQ lowering-raising	f0 lowering-raising CQ raising-lowering
Expectation		Raising (carryover)	Lowering (carryover)
Results	As expected	10 / 16 (sequences)	9 / 13 (sequences)
	<i>Contradicted</i>	<i>2 / 16</i>	<i>1 / 13</i>
	No change	4 / 16	3 / 13
f0	As expected	10 / 16 (sequences)	9 / 13 (sequences)
	<i>Contradicted</i>	<i>2 / 16</i>	<i>1 / 13</i>
	No change	4 / 16	3 / 13
CQ	As expected	4 / 16	3 / 13
	<i>Contradicted</i>	<i>4 / 16</i>	<i>4 / 13</i>
	No change	8 / 16	6 / 13

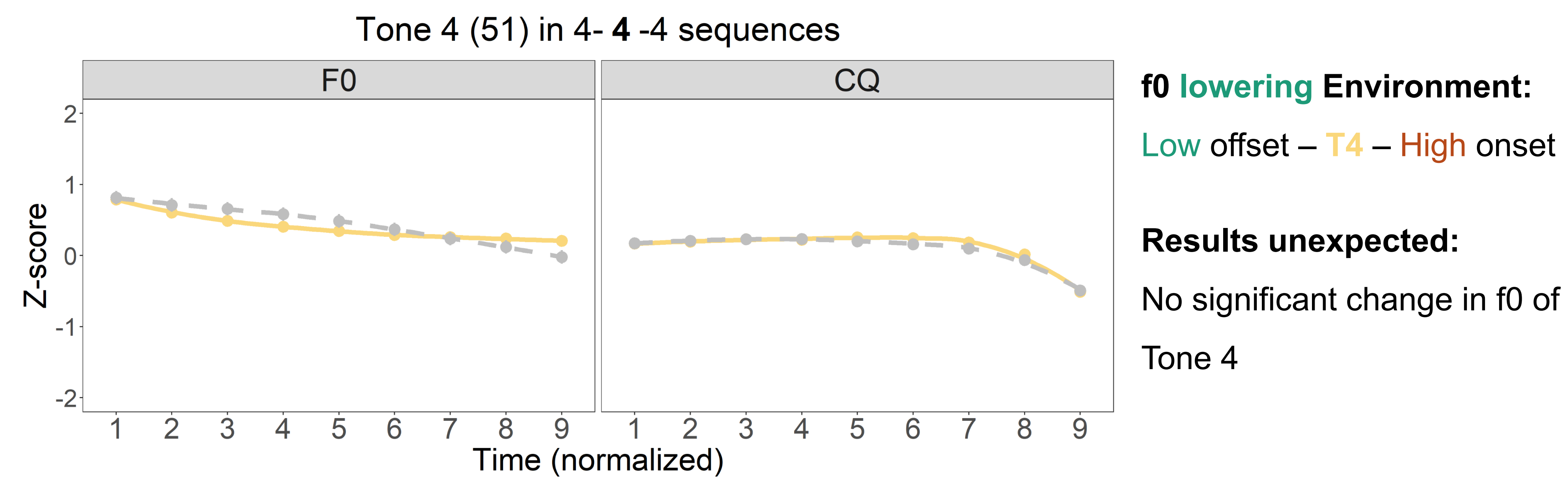
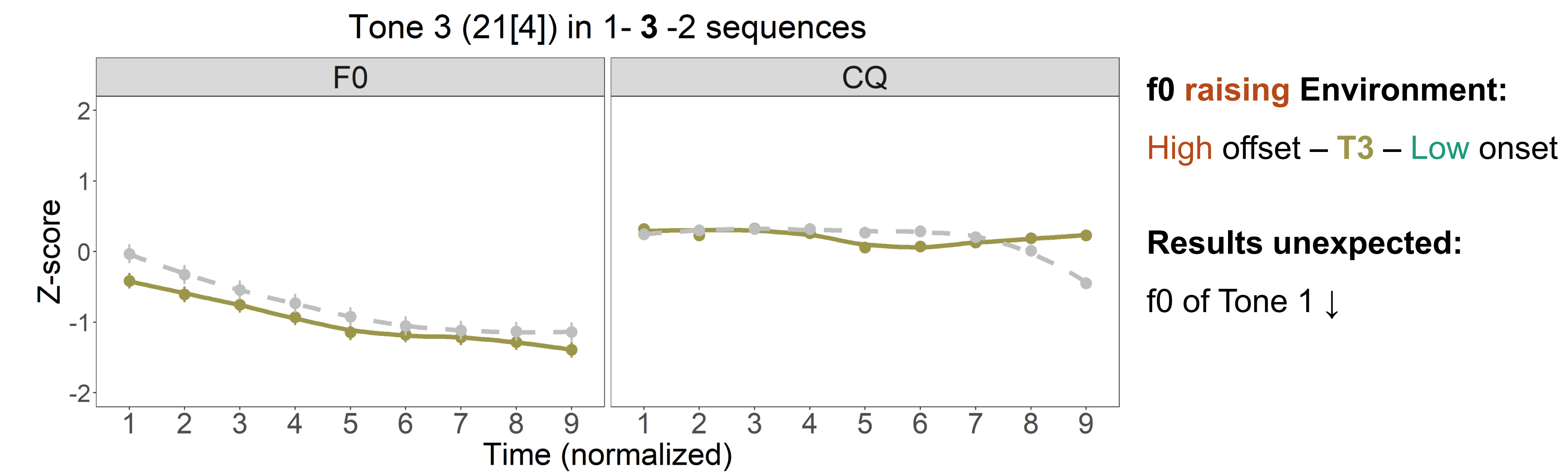
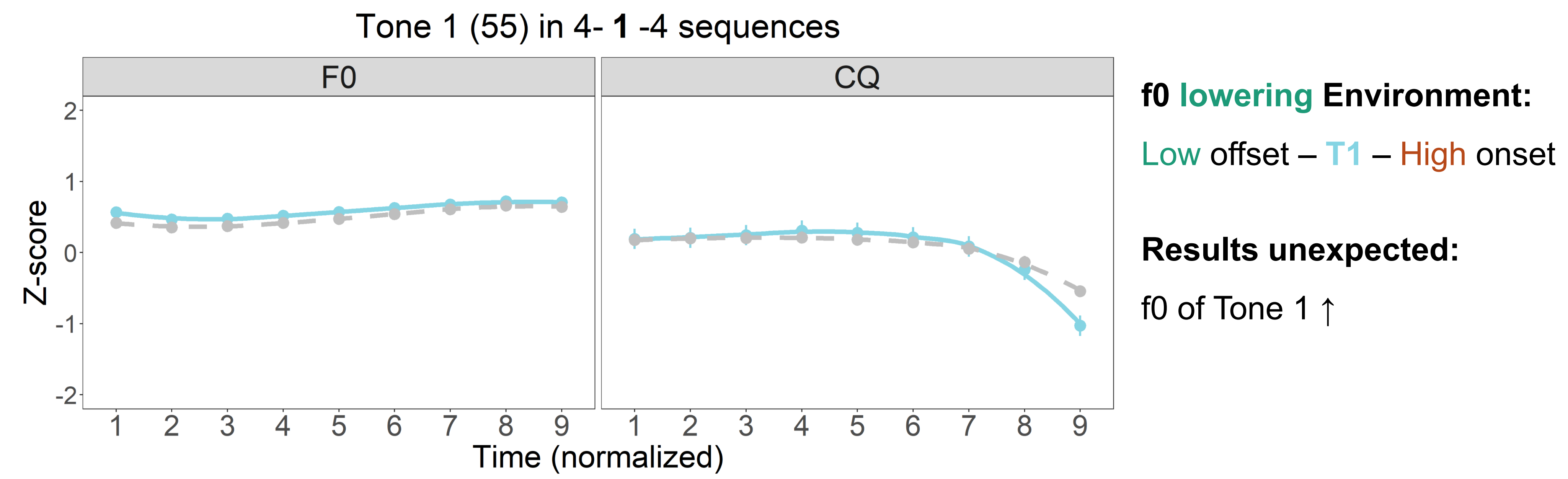
- When the preceding and the following tone has contradictory effect on the middle tone:
 - For **f0**, the carry-over effect of the preceding tone tends to override the anticipatory effect of the following tone, which largely accords with Xu (1997);
 - CQ** values tend not to change; if they change, the number of the different combinations where the direction is lowering or raising seems to be even.
 - f0 and CQ do not necessarily show a uniform carryover or anticipatory effects. For example, for sequences where CQ have anticipatory effects, their f0 can have carryover effects.
 - Overall, this shows that contradicting f0 effects have **mixed influence** on voice quality, and that voice quality does **NOT** entirely depend on f0.

DISCUSSION II CONTINUED

Environment		f0 raising-lowering CQ lowering-raising	f0 lowering-raising CQ raising-lowering
Expectation		Raising (carryover)	Lowering (carryover)
Results	As expected	1-1-1	3-1-2
	<i>Contradicted</i>	<i>1-1-4</i>	<i>3-1-3</i>
	No change	1-2-1	4-1-2
f0	As expected	1-2-4	3-2-2
	<i>Contradicted</i>	<i>2-2-1</i>	<i>3-2-3</i>
	No change	2-2-4	4-2-2
	As expected	2-3-1	4-2-3
	<i>Contradicted</i>	<i>2-3-4</i>	<i>4-3-2</i>
	No change	1-4-4	3-4-3
	As expected	2-4-1	3-4-3
	<i>Contradicted</i>	<i>2-4-4</i>	<i>4-1-3</i>
	No change	1-3-1	4-1-3
	As expected	2-1-4	4-1-3
	<i>Contradicted</i>	<i>1-3-1</i>	<i>4-1-3</i>
	No change	2-1-1	3-4-2
	As expected	1-3-4	4-4-2
<i>Contradicted</i>	<i>1-4-1</i>	<i>4-4-3</i>	
No change	2-4-4	4-4-4	
Expectation	As expected	Lowering (carryover)	Raising (carryover)
	<i>Contradicted</i>	<i>Lowering (carryover)</i>	<i>Raising (carryover)</i>
	No change	Lowering (carryover)	Raising (carryover)
Results	As expected	1-1-4	3-2-2
	<i>Contradicted</i>	<i>2-2-1</i>	<i>3-2-3</i>
	No change	1-3-1	4-4-2
CQ	As expected	1-4-4	4-4-2
	<i>Contradicted</i>	<i>1-1-1</i>	<i>4-1-3</i>
	No change	2-1-1	4-2-3
	As expected	2-1-4	3-4-3
	<i>Contradicted</i>	<i>1-4-1</i>	<i>4-4-3</i>
	No change	1-2-1	3-1-2
	As expected	1-2-4	3-1-3
	<i>Contradicted</i>	<i>2-2-4</i>	<i>4-1-2</i>
	No change	1-3-4	4-2-2
	As expected	2-3-1	4-3-2
	<i>Contradicted</i>	<i>2-3-4</i>	<i>3-4-2</i>
	No change	2-4-1	4-4-4
	As expected	2-4-4	4-4-4



F0 RESULTS NOT EXPECTED



CQ RESULTS NOT EXPECTED

