

# An indexed constraint account of incomplete neutralization in Huai'an Mandarin

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# Overview

- Incomplete neutralization: lexicon “bypasses” phonology and influences phonetics directly
- Difficult for most standard models of phonology
- Proposal: lexical indices (of indexed constraint fame) are very detailed and cannot be changed by phonology
- Consequence: indices reflect underlying forms and may whisper to the phonetics even if surface phonology has neutralized a contrast

# Incomplete neutralization

- Classic case: Dutch, German and other languages have final devoicing, but still fine-grained phonetic cue differences between final underlyingly voiced and voiceless sounds (e.g., Warner et al. 2004)

		UR	SR	phonetic realization
<i>Dutch</i>	<i>'wheel'</i>	/rad/	rat	[rat <sub>d</sub> ]
	<i>'rat'</i>	/rat/	rat	[rat <sub>t</sub> ]

- Surface representation has lost voicing contrast
- How does information about contrast reach phonetic realization?

# Further empirical case studies

- Japanese long vs. lengthened vowels (Braver & Kawahara 2016, Braver 2019)
  - Length contrast in vowels: ki ‘tree’ vs. kii ‘key’
  - Monosyllabic NPs are lengthened: ki-mo ‘tree also’ vs. ki: ‘tree’
  - However, lengthened short vowels are still systematically shorter than long vowels in same prosodic position:  $\text{duration}(ki:) < \text{duration}(kii)$
- Huai’an Mandarin underlying vs. derived Tone 3 (Du & Durvasula 2022)
  - Contrast between tones 1 and 3: pa<sup>1</sup> ‘play with’ vs. pa<sup>3</sup> ‘smash (to eat)’
  - Sandhi prohibits \*T1-T1, creates new T3: /u<sup>2</sup> pa<sup>1</sup> xa<sup>1</sup>/ → [u<sup>2</sup> **pa**<sup>3</sup> xa<sup>1</sup>]
  - Derived T3 = underlying T3 in phonology, but not in phonetic realization

# Theoretical proposals

- Van Oostendorp (2008): Containment theory of faithfulness leaves traces of UR in surface phonology, may be exploited by phonetics (*Containment*)
- Braver (2019): Paradigm uniformity is active in phonetic realization and biases realizations towards un-neutralized paradigm members (*Paradigm pressures*)
- Nelson & Heinz (2022, 2025), Du & Durvasula (2022): Direct route from the lexical intention to the phonetics (in the architecture or in processing) (*Enriched architecture*)

# Proposals vs. Case studies

- Braver (2019) argues Japanese case is incompatible with the Containment solution, since it is neutralization to a structurally marked situation (bimoraic rather than monomoraic)
- Mandarin appears to be incompatible with paradigm pressures, as tone adjustments appear to operate on the phrase level
- Enriched architectures should be sufficient to account for all three, but are enrichments also necessary for these phenomena?

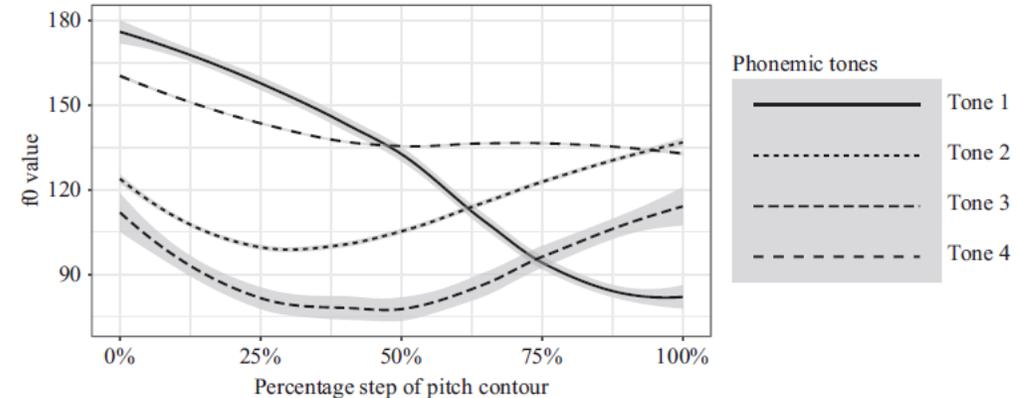
	Containment	Paradigm pressures	Enriched architecture
Dutch devoicing	✓	✓	✓
Japanese lengthening	✗	✓	✓
Mandarin tone sandhi	?	✗	✓

# My contribution

- Goal: account for Mandarin case study with standard architecture (i.e., lexicon → phonology → phonetics)
- Means: apply insights of Containment idea (hidden parts of surface representation pass on UR information to phonetics) to prosodic cases, adding explicit phonetic constraints (Flemming 2001, Braver 2019)
- Implementation: a special version of indexed constraints (Round 2017), used earlier to account for opacity in Parallel OT (Nazarov 2019)

# Data: Huai'an Mandarin

- Case study that is prosodic and non-paradigm-based
- Based on between-word tonal adjustments
- Tone inventory (Du & Durvasula):
  - Tone 1: high falling
  - Tone 2: high rising
  - Tone 3: low rising
  - Tone 4: high level



*Figure 1. Tonal contour of phonemic tones in Huai'an.*

Figure taken from Du & Durvasula

# Phonological side: Neutralizing tone sandhi

- \*T1-T1: first syllable changes to T3 (optional process)

/u<sup>2</sup> pa<sup>1</sup> xa<sup>1</sup>/ → [u<sup>2</sup> pa<sup>3</sup> xa<sup>1</sup>] ‘Mr. Wu<sup>2</sup> plays with shrimp’  
MH HL HL            MH LM HL

- \*T3-T3: first syllable changes to T2 (obligatory)

/u<sup>3</sup> pa<sup>3</sup> xa<sup>1</sup>/ → [u<sup>2</sup> pa<sup>3</sup> xa<sup>1</sup>] ‘Mr. Wu<sup>3</sup> smashes shrimp (to eat)’  
LM LM HL            MH LM HL

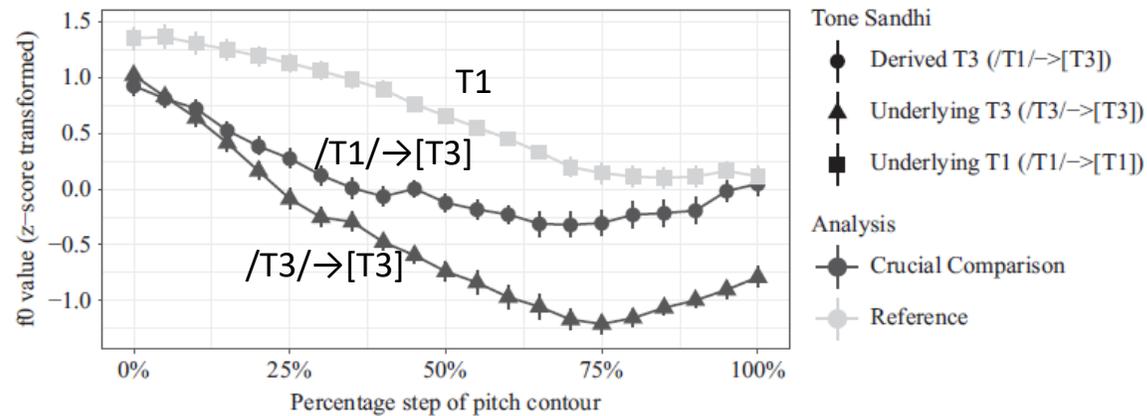
- T1 sandhi feeds T3 sandhi: derived T3 counts as true T3 (neutralization)

/u<sup>3</sup> pa<sup>1</sup> xa<sup>1</sup>/ → (u<sup>3</sup> pa<sup>3</sup> xa<sup>1</sup> →) [u<sup>2</sup> pa<sup>3</sup> xa<sup>1</sup>] ‘Mr. Wu<sup>3</sup> plays with shrimp’  
LM HL HL            LM LM HL            MH LM HL

Examples from Du & Durvasula

# Phonetic side: T1/T3 contrast remains expressed

- T3 derived from /T1/ is realized differently from underlying T3 (closer to the high tone of T1)



*Figure 3. Comparison of second-syllable contours in Experiment 1 (Tone 1; error bars indicate standard error).*

Figure taken from Du & Durvasula

# Analytic framework

- Indexed constraints: constraints have variants that have violations only in certain lexically determined circumstances

e.g.  $*CC_i$  where  $i$  corresponds to certain lexical items only:  
 $/mamta_i/ \rightarrow [mata_i]$  but  $/mamto/ \rightarrow [mamto]$  if  $*CC_i \gg \text{Max} \gg *CC$

- Local indexation (e.g., Round 2017): constraints have violations only for certain lexically determined segments

e.g.,  $*CC_j$  where  $j$  refers to certain consonants in the lexicon only:  
 $/mam_j\text{-tam-tan}/ \rightarrow [matamtan]$  if  $*CC_j \gg \text{Max} \gg *CC$

- Useful for local exceptions, (Temkin-Martinez 2010), opacity (Nazarov 2019)

# Lexical persistence via indices

- Indices necessary in surface candidates for evaluating indexed Markedness constraints (e.g., \*CC<sub>j</sub> is violated by mam<sub>j</sub>ta, not mamto) cf. Pater 2010)
- Indices have no direct phonological or phonetic interpretation
- Assumption here: GEN cannot manipulate indices – indices are the same in UR and SR
  - Cf. Chomsky & Halle (1968) on how phonological rules should not manipulate “alphabet features”, which are similar to indices
- If this is true, indices can “sneak” UR information past the SR to the phonetics!

# General setup of analysis

- Syllables (nuclei) that normally surface with Tone 1 have index  $j$

$/pa^3/$        $/pa_j^1/$        $/xa_j^1/$

- High-ranked \*T1-T1 forces certain  $j$  syllables to be realized with T3

$/u^3 pa_j^1 xa_j^1/$  ( $\rightarrow u^3 pa_j^3 xa_j^1$ )  $\rightarrow u^2 pa_j^3 xa_j^1$

- Constraints on the realization of T3 and tones over  $j$ -indexed syllables compete to create blended T1/T3 melody (inspired by Braver 2019) – this requires weighted constraints (Harmonic Grammar)

$/pa_j^1 xa^1/ \rightarrow [pá\grave{a}\bar{a}_j^3 xa^1]$        $/pa^3 xa^1/ \rightarrow [pá\grave{a}\grave{a}^3 xa^1]$

# Details: data

- 3 actual data points based on Du and Durvasula (F0 realization quantized to 3 time points and 5 height points):

$/(u^2) pa^3 xa_j^1/ \rightarrow [(u^2) pá\grave{a}\grave{a}^3 xa_j^1]$  Mr. Wu<sup>2</sup> plays with shrimp

$/(u^2) pa_j^1 xa_j^1/ \rightarrow [(u^2) pá\grave{a}\bar{a}_j^3 xa_j^1]$  Mr. Wu<sup>2</sup> smashes shrimp (to eat)

$/u^3 pa_j^1 xa_j^1/ \rightarrow [u^2 pá\grave{a}\bar{a}_j^3 xa_j^1]$  Mr. Wu<sup>3</sup> smashes shrimp (to eat)

- 4 Richness-of-the-Base inputs:

$/pa_j^3 xa_j^1/ /pa_j^3/$  (T3<sub>j</sub> should behave like T1)

$/pa^1 xa_j^1/ /pa^1/$  (unindexed T1 should behave like T3)

- Surface values considered:  $\{u^2, u^3\}$ ,  $\{pa^1, pa^3\}$  x all quantized F0 values between T3 ( $\acute{v}$   $\grave{v}$   $\grave{v}$ ) and T1 ( $\acute{v}$   $\bar{v}$   $\bar{v}$ )

# Details: constraints

- Tonal constraints:

\*T1 Ident(T)    \*T3<sub>j</sub>    \*T1-T1    \*T3-T3    weight = 20  
 weight = 1

- F0 realization constraints link Tone value (Tx<sub>j</sub>: any tone on index *j*) to desired quantized F0 value (0 and 5) at start, middle, or end of the syllable
- Violations: distance between true and desired value is squared, then negative summed as per Braver (2019)

T1=ǀ(5)v	T1=vǀ(3)v	T1=vvǀ(3)	T3=ǀ(4)vv	weight = 5
Tx <sub>j</sub> =ǀ(5)v	Tx <sub>j</sub> =vǀ(3)v	Tx <sub>j</sub> =vvǀ(3)		weight = 3
T3=vvǀ(0)v	T3=vvǀ(1)			weight = 1



# Derived T3: incomplete neutralization

$/u^2 pa_j^1 xa_j^1/$	w = 20	20	20	5	5	3	1	1	Harmony
	*T1-T1	*T1	*T3 <sub>j</sub>	T3=úvv	T1=úvv	Tx <sub>j</sub> =úvv	T3=vùv	ID(T)	
	*T3-T3				T1=v̄v	Tx <sub>j</sub> =v̄v	T3=vv̄		
					T1=vv̄	Tx <sub>j</sub> =vv̄			
$u^2 p\acute{a}_5 \bar{a}_3 \bar{a}_{3j}^1 xa_j^1$	-1	-2							-60
$u^2 p\acute{a}_4 \grave{a}_2 \bar{a}_{3j}^1 xa_j^1$	-1	-2			-1-1-0=-2	-1-1-0=-2			-76
$u^2 p\acute{a}_5 \bar{a}_3 \bar{a}_{3j}^3 xa_j^1$		-1	-1	<b>-1</b>			<b>-(3<sup>2</sup>)-(2<sup>2</sup>)=-13</b>	-1	-59
$\text{☞ } u^2 p\acute{a}_4 \grave{a}_2 \bar{a}_{3j}^3 xa_j^1$		-1	-1			<b>-1-1-0=-2</b>	<b>-(2<sup>2</sup>)-(2<sup>2</sup>)=-8</b>	-1	-55
$u^2 p\acute{a}_4 \grave{a}_0 \grave{a}_{1j}^3 xa_j^1$		-1	-1			<b>-1-(3<sup>2</sup>)-(2<sup>2</sup>)=-14</b>		-1	-83

# Derived T3 triggers T3 sandhi

$/u^3 pa_j^1 xa_j^1/$	w = 20	20	20	5	5	3	1	1	Harmony
	*T1-T1	*T1	*T3 <sub>j</sub>	T3=úvv	T1=úvv	Tx <sub>j</sub> =úvv	T3=vùv	ID(T)	
	*T3-T3				T1=v̄v	Tx <sub>j</sub> =v̄v	T3=vv̄		
					T1=vv̄	Tx <sub>j</sub> =vv̄			
$u^3 p\acute{a}_5 \bar{a}_3 \bar{a}_{3j}^1 xa_j^1$	-1	-2							-60
$u^3 p\acute{a}_4 \grave{a}_2 \bar{a}_{3j}^3 xa_j^1$	<b>-1</b>	-1	-1			-1-1-0=-2	-(2 <sup>2</sup> )-(2 <sup>2</sup> )=-8	-1	-75
$\text{☞ } u^2 p\acute{a}_4 \grave{a}_2 \bar{a}_{3j}^3 xa_j^1$		-1	-1			-1-1-0=-2	-(2 <sup>2</sup> )-(2 <sup>2</sup> )=-8	-2	<b>-56</b>
$u^2 p\acute{a}_4 \grave{a}_0 \grave{a}_{1j}^3 xa_j^1$		-1	-1			-1-(3 <sup>2</sup> )-(2 <sup>2</sup> )=-14		-2	-84

# Generalizability

- /T3/ vs. /T1<sub>j</sub>/ undergo **both** phonological neutralization (derived T3 triggers T3 sandhi) **and** phonetic differentiation (derived T3 is realized as a compromise between T1/T3 melodies)
- Behaviour of ROTB inputs shows that no fully neutralizing alternations are expected even in novel words:
  - Unindexed /T1/ behaves like /T3/: /pa<sup>1</sup>/ → [pa<sup>3</sup>], /pa<sup>1</sup> xa<sub>j</sub><sup>1</sup>/ → [páàà<sup>3</sup> xa<sub>j</sub><sup>1</sup>]
  - Indexed /T3<sub>j</sub>/ behaves like /T1<sub>j</sub>/: /pa<sub>j</sub><sup>3</sup>/ → [pa<sub>j</sub><sup>1</sup>], /pa<sub>j</sub><sup>3</sup> xa<sub>j</sub><sup>1</sup>/ → [páàā<sub>j</sub><sup>3</sup> xa<sub>j</sub><sup>1</sup>]
  - This means: not underlying tone, but indexation determines both tone and F0 behaviour – and it is indexation that carries information from lexicon to phonetics

# Discussion

- Indexation successfully revives Van Oostendorp's (2008) idea that neutralized contrasts can be “smuggled” through phonetically inert aspects of surface structure
- Braver's (2019) phonetic constraints, based on Flemming (2001), allow an explicit account of the F0 contours
- Thus, if this account holds, enriched architectures do not appear to be strictly necessary for incomplete neutralization
- However, a cost-benefit evaluation of the mechanisms necessary for the various proposals is yet to be done

# Conclusion

- Indexed constraints can provide a mechanism to account for incomplete neutralization with a standard grammar architecture
- Also provide an account of opacity (Nazarov 2019; also present in Van Oostendorp 2008)
- Crucial idea: indexation remains constant throughout phonological derivation
- More detailed analysis of F0 trajectories needed
- Next stop: Japanese lengthening, other cases of incomplete neutralization

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