Asymmetries in V-to-V coarticulation among harmonic and non-harmonic sequences in Khalkha Mongolian

Auromita Mitra [1,2] Indranil Dutta [3]

[1]The English and Foreign Languages University

[2]New York University

[3]Jadavpur University

Coarticulation and Vowel Harmony

Relationship between coarticulation and vowel harmony

- Acoustic variation due to overlapping gestures in V-to-V coarticulation (Öhman, 1966)
- Coarticulatory propensity and directionality varies cross-linguistically depending on size, shape & density of segmental inventories (Manuel, 1990)

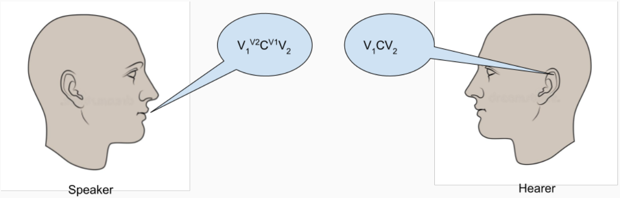


Figure 1: Listener's perceptual compensation of speaker's acoustic variation due to coarticulation

Relationship between coarticulation and Vowel Harmony

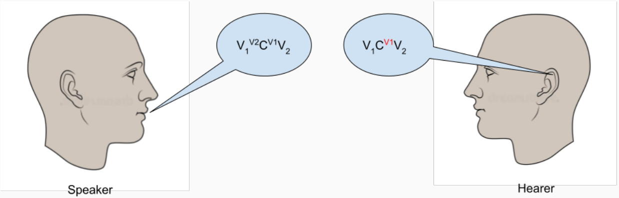


Figure 2: Development of vowel harmony when acoustic variation is not perceptually compensated

- Lack of perceptual compensation →phonologization of acoustic variation and emergence of vowel harmony (Ohala, 1994; Przezdziecki, 2000; Beddor, Harnsberger, and Lindemann, 2002)
- Directionality in VH patterns should follow the direction of coarticulatory propensity

Vowel Harmony in Khalkha Mongolian

Khalkha Mongolian vowel system

Seven phonological vowel categories, classified as non-pharyngeal (+ATR) and pharyngeal (-ATR) (Svantesson et al., 2005):

	[+ATR]	[-ATR]	neutral
high	u	ʊ	i
non-high	e, o	a, ɔ	

Table 1: Monopthongs in Khalkha Mongolian, classified by harmony class

- Non-high vowels have rounded (right) and non-rounded (left) counterparts
- i : 2 allophones: [i] in ATR words, [ɪ] in non-ATR words

Khalkha Mongolian vowel system

- **Vowel harmony:** vowels in non-compound words must share the feature [ATR]. A subset of vowels (non-high: e, o, a, ɔ) show rounding harmony.
- Focus of present study: ATR harmony
- **Directionality:** left-to-right
- [i] is 'transparent' $\rightarrow$non-harmonic sequences

Research Questions

Research questions

- How does coarticulation function within an established vowel harmony system?
- What explains the development of non-harmonic sequences in such a system?
- Broadly: abstract grammar vs physiological processes in speech
- Present study: compare patterns of coarticulatory propensity in harmonic vs non-harmonic sequences within the same language – Khalkha Mongolian

Materials, methods

Measuring coarticulation

- Data: read speech items from Svantesson et al., 2005, 14 female native speakers
- (C) V C V (C)
- (C) V_1 C V_2 (C)
- groups: harmonic vs non-harmonic

Acoustic analyses

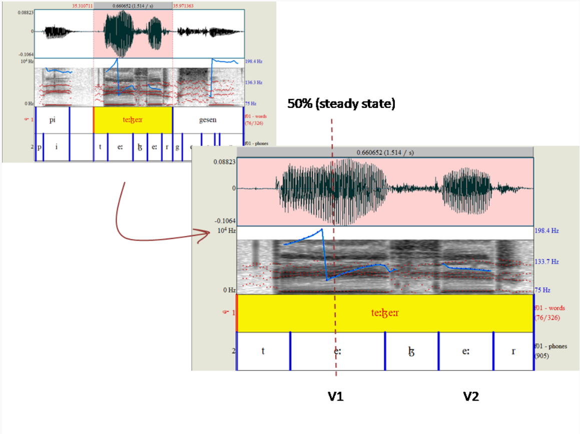
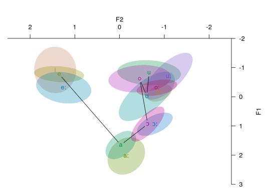


Figure 3: Acoustic measurements

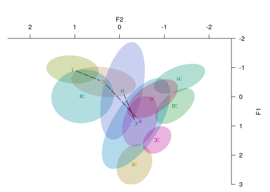
- Alignment and annotation using the MFA (McAuliffe et al., 2017)
- Lobanov normalization

Results and analyses

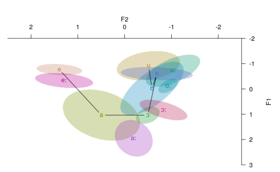
Vowel space diffusion: harmonic vs non-harmonic



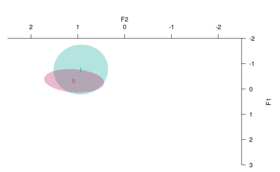
(a) harmonic subset: V_1



(b) harmonic subset: V_2



(c) non-harmonic subset: V_1



(d) non-harmonic subset: V_2

Figure 4: Steady-state formants for harmonic and non-harmonic vowel sequences

Statistical analyses: F1

Q: How well is formant frequency predicted by the identity of the contiguous vowel in the word?

Harmony type	Direction	Model fixed effects	ChiSq	Df	p	effect size (η^2) [1]
harmonic	anticipatory	F1V1t5 ~ V1+**V2**	17.174	9	0.04606 *	0.322
	carryover	F1V2t5 ~ V2+**V1**	34.131	11	0.003443 ***	0.536
non-harmonic	anticipatory	F1V1t5 ~ V1+**V2**	100.87	1	< 2.2e-16 ***	0.133
	carryover	F1V2t5 ~ V2+**V1**	133.41	10	< 2.2e-16 ***	0.174

Table 2: Model outputs for coarticulation in F1, compared to a null model lacking the explanatory variable (bold)

- Robust coarticulation in both directions, with greater propensity in the carryover (left-to-right) direction.

[1] using the effectsize package in R Ben-Shachar, Lüdecke, and Makowski, 2020

Statistical analyses: F2

Harmony type	Direction	Model fixed effects	ChiSq	Df	p	effect size (η^2)
harmonic	anticipatory	F1V1t5 $\sim$ V1+**V2**	9.3863	9	0.4024	0.191
	carryover	F1V2t5 $\sim$ V2+**V1**	22.79	11	0.01892 *	0.404
non-harmonic	anticipatory	F1V1t5 $\sim$ V1+**V2**	110.57	1	< 2.2e-16 ***	0.146
	carryover	F1V2t5 $\sim$ V2+**V1**	74.809	10	5.182e-12 ***	0.101

Table 3: Model outputs for coarticulation in F2, compared to a null model lacking the explanatory variable (bold)

- Harmonic subset: coarticulation is left-to-right
- Non-harmonic subset: greater anticipatory coarticulation (right-to-left)

Coarticulatory resistance and preservation of contrast

Findings and discussion

- Patterns of coarticulation differ: V2 is enhanced in non-harmonic sequences
- Coarticulatory resistance in high front vowel
- Coarticulation as a contrast-preserving force

Future directions

- Explicit measurement of coarticulatory resistance using the Locus Equation framework
- Typology of vowel harmony systems

Data and materials

Materials, data files, and analysis code are available at https://github.com/auromitamitra/mongolian_vowel_harmony

Acoustic model for Khalkha Mongolian trained on study corpus: https://github.com/auromitamitra/Mongolian_Acoustic_Model

References

Beddor, Patrice Speeter, James D Harnsberger, and Stephanie Lindemann (2002). "Language-specific patterns of vowel-to-vowel coarticulation: Acoustic structures and their perceptual correlates". In: *Journal of Phonetics* 30.4, pp. 591–627.

Ben-Shachar, Mattan S, Daniel Lüdecke, and Dominique Makowski (2020). "effectsize: Estimation of effect size indices and standardized parameters". In: *Journal of Open Source Software* 5.56, p. 2815.

Manuel, S. (1990). "The role of contrast in limiting vowel-to-vowel coarticulation indifferent languages". In: *Journal of the Acoustical Society of America* 88, pp. 1286–1298.

References ii

- McAuliffe, Michael et al. (2017). "Montreal Forced Aligner: Trainable Text-Speech Alignment Using Kaldi.". In: *Interspeech*. Vol. 2017, pp. 498–502.
- Ohala, John J (1994). "Towards a universal, phonetically-based, theory of vowel harmony". In: *Third International Conference on Spoken Language Processing*.
- Öhman, Sven E. G. (1966). "Coarticulation in VCV Utterances: Spectrographic Measurements". In: *Journal of the Acoustical Society of America* 39, pp. 151–168.
- Przezdziecki, Marek (2000). "Vowel harmony and vowel-to-vowel coarticulation in three dialects of Yoruba". In: *Working Papers of the Cornell Phonetics Laboratory* 13, pp. 105–124.
- Svantesson, Jan-Olof et al. (2005). *The phonology of Mongolian*. OUP Oxford.