

Articulatory correlates of morphologically conditioned assimilation: Evidence from ultrasound imaging

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Introduction

- **Impact of morphology on phonology:**
- casual speech processes (Shockey 2003)
- allophonic variation of /l/ (Sproat & Fujimura 1993)
- palatalization (Zsiga 2000)
- **Articulatory studies**
- intergestural timing (Cho 2001, Gafos et al. 2010)
- coarticulation in coda clusters (Song et al. 2013)
- l-darkening (Strycharczuk & Scobbie 2016)

- **Articulatory correlates of palatalization:**
- raising and/or fronting of tongue front towards the hard palate (Ladefoged & Maddieson 1996)
- Tongue root and dorsum advancement (Bennett et al. 2018, Cavar & Lulich 2021)

- **Impact of lexical frequency on articulation**
- more frequent words have more coarticulation/ gestural overlap than less frequent words (Bybee 2000, Bush 2001)

- This study presents articulatory data on regressive place assimilation in two-member consonant clusters C1C2 in Polish.
- The main objectives are to investigate
- 1. articulatory correlates of assimilation
- 2. effects of morphological boundaries with differing strength
- 3. The role of lexical frequency and tempo

Instrumental Study: Method

- Tongue articulatory data was collected via real-time 3D ultrasonography, using the Philips EpiQ-7G machine and a Philips xMatrix x6-1 digital 3D/4D transducer. The ultrasound probe was stabilized under the jaw with an Articulate Instruments Ltd headset (Scobbie et al. 2008).
- Audio signals—recorded at a sampling rate of 48 kHz with a SHURE KSM32 directional dynamic microphone—were captured simultaneously with the ultrasound recordings.
- 8 native speakers of Polish, aged 23–60;
- Ultrasound files were analyzed using custom MATLAB toolbox, called “WASL”.

Assimilation in clusters

fricative + fricative/affricate

dental /s z/ + pre-palatal /ç ʒ ʦ ʣ ʤ ʥ/

- Assimilation possibilities:
- > two gestures = no assimilation /sç ʒʒ stʃ ʒdʒ/
- > one gesture = assimilation /çç ʒʒ çʦ ʣʣ ʤʥ/
- > or possibly an intermediate category

References

Bennett, R., Ni Chiosáin, M., Padgett, J., & McGuire, G. (2018). An ultrasound study of Connemara Irish palatalization and velarization. *JIPA*, 48(3), 261–304.

Cavar, M. E. & Lulich, S. M. (2021). Variation in the articulation of Russian stressed vowels and the mechanics of palatalization in consonants. *Phonological Data and Analysis* 3, 1–44.

Cho, T. (2001). Effects of morpheme boundaries on intergestural timing: Evidence from Korean. *Phonetica*, 58, 129–162.

Gafos, A. I., Hoole, P., Roon, K., & Zeroual, C. (2010). Variation in overlap and phonological grammar in Moroccan Arabic clusters. *Laboratory Phonology X*, 657–698. Berlin, Germany: Mouton de Gruyter.

Song, J. Y., Demuth, K., Shattuck-Hufnagel, S., & Ménard, L. (2013). The effects of coarticulation and morphological complexity on the production of English coda clusters: Acoustic and articulatory evidence from 2-year-olds and adults using ultrasound. *Journal of Phonetics*, 41, 281–295.

Strycharczuk, P., & Scobbie, J. (2016). Gradual or abrupt? The phonetic path to morphologisation. *Journal of Phonetics*, 59, 76–91.

Design of the study

Predictions:

- Assimilation depends on the **morphological composition** of the clusters and the **strength/transparency** of the boundary:
- the stronger the boundary, the more assimilated the C1.
- the faster the **tempo**, the more assimilated the C1.
- more **frequent** words – more assimilation than less frequent words

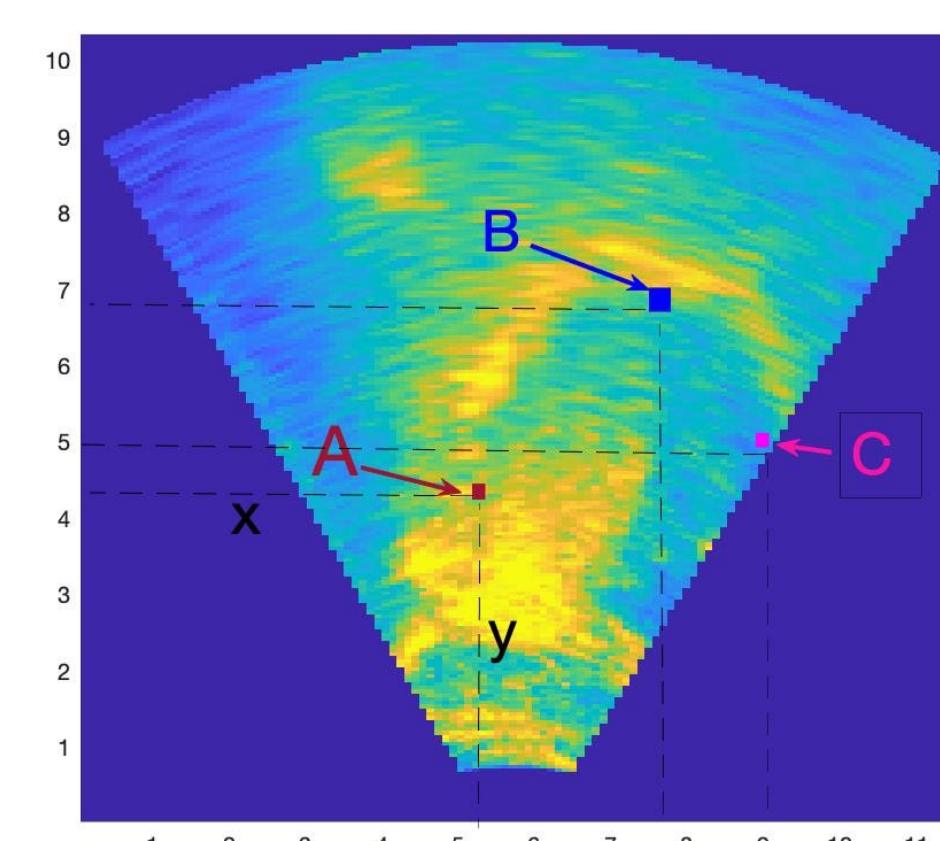
Question:

- What is the best **articulatory correlate** of palatalization for ultrasound studies?
tongue front, tongue body, tongue root

Stimuli: 75 phrases

Procedure (1) memorize, (2) say it slowly, (3), say it fast

Carrier sentence (They said ...)



Measured points:

- the point opposite of the **tendon of the genioglossus (A)**
- the position of the **tongue body (B)**
- the frontmost position of the **tongue front (C)**.

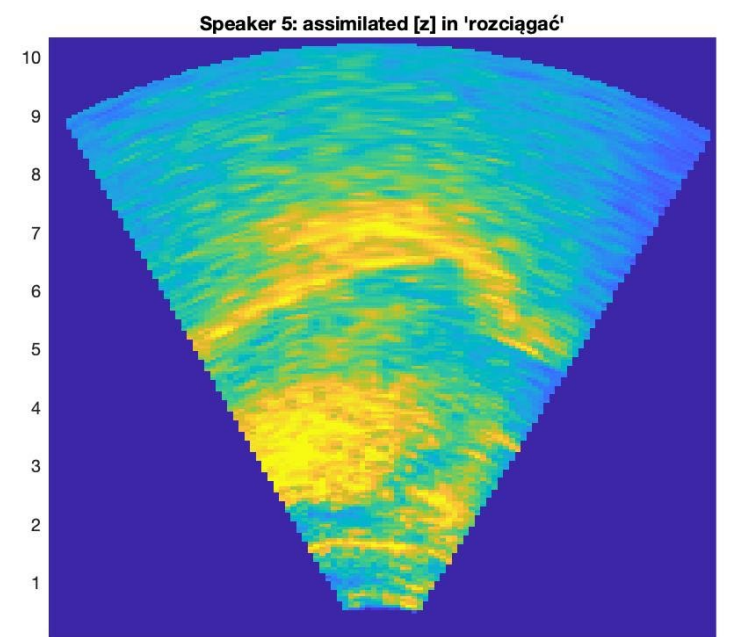
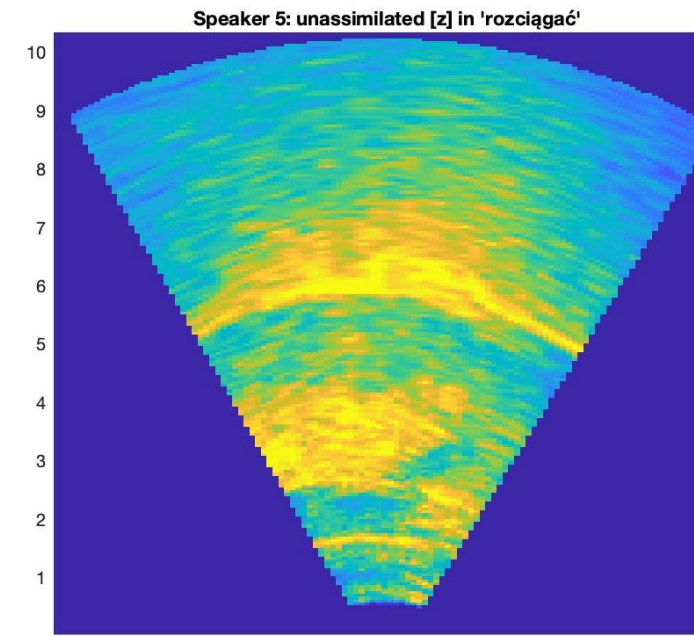
morphology: Strength of morphological boundaries:

1. intra-morphemic:
w Odessie mieszkać /sç/ 'to live in Odesa'
2. weak morpheme boundary:
roz+ciągliwa guma /s+ʦ/ 'stretchy rubber'
3. strong morpheme boundary:
roz++siadać się wygodnie /s+ç/ 'sit comfortably'
4. clitic boundary:
chleb bez ziaren /s#ʒ/ 'seedless bread'
5. word boundary:
włos siwy /s#ç/ 'a gray hair'

word frequency

tempo of speech

unassimilated vs. assimilated C1



Statistics

Measurements:

Tongue Root (TR) x axis, y axis

Tongue Body (TB) x axis, y axis

Tongue Front (TF), x axis, y axis

Deltas (difference between the reference palatal and C1):

Reference palatals: /ç ʒ/ in the V_V context: TR_ref, TB_ref, TF_ref

DeltaTRx = TRx_ref – TRx

DeltaTRY = TRY_ref – TRY

DeltaTBx = TBx_ref – Tbx

Values close to zero indicate full assimilation.

Linear mixed-effect regression models

Dependent variables:

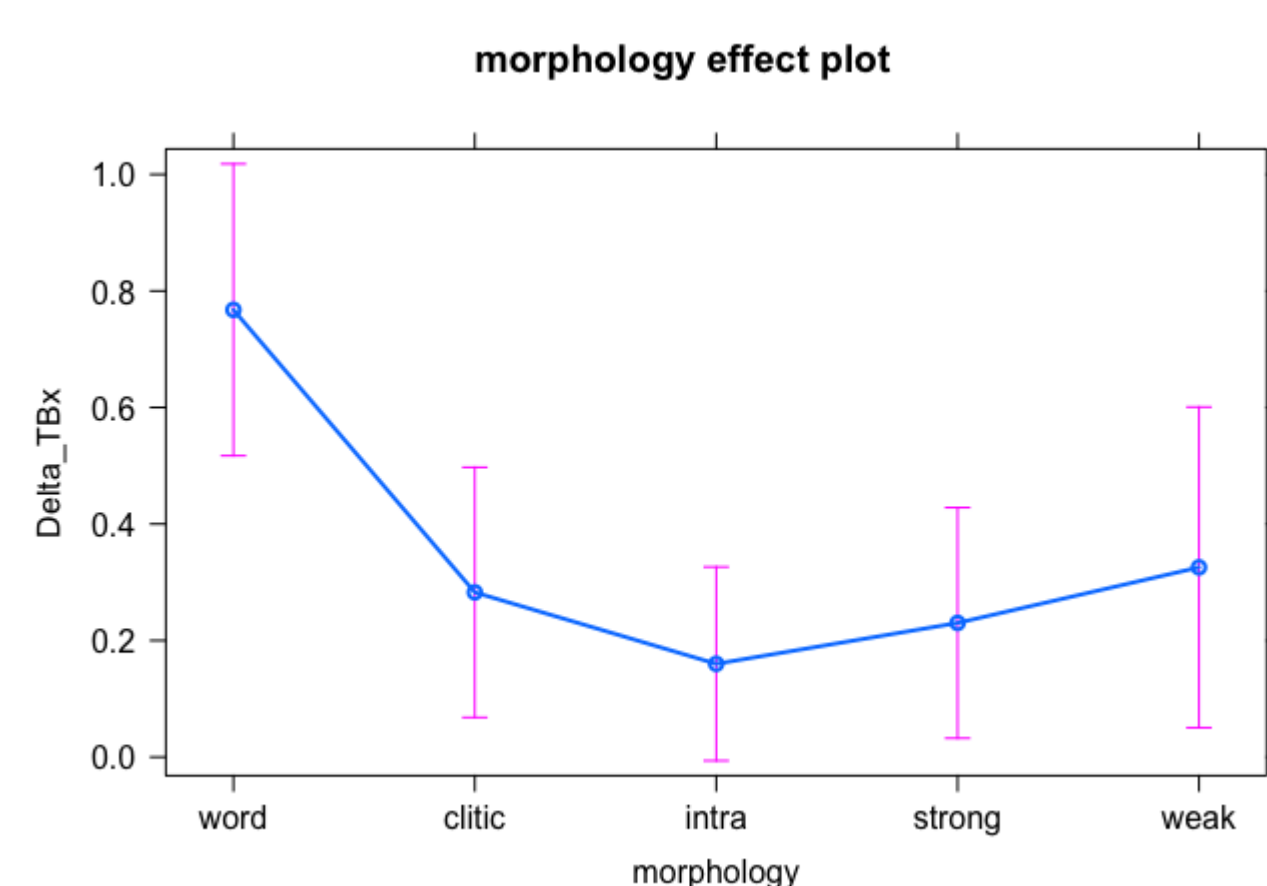
DeltaTF, DeltaTB, DeltaTR (x and y)

Predictors:

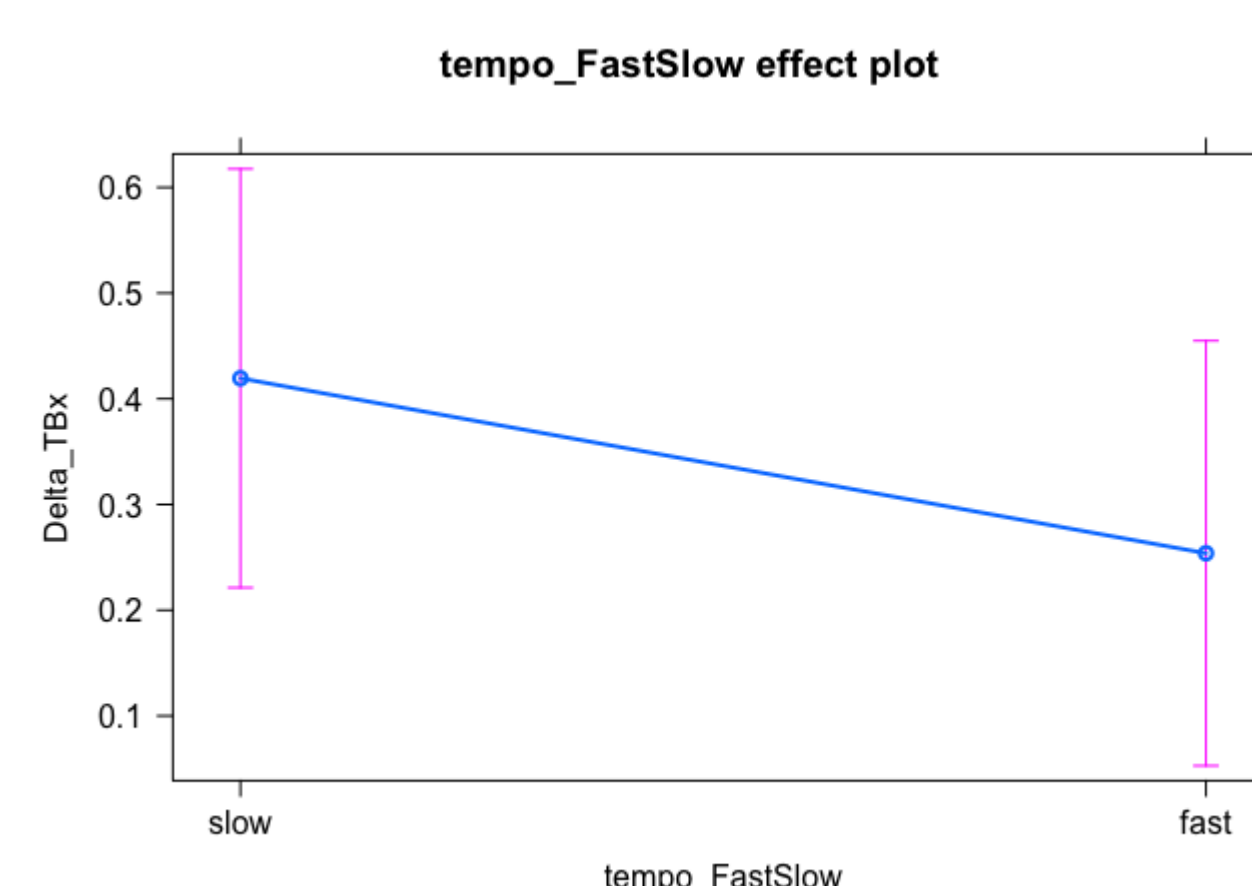
- **Morphology: word, clitic, weak, strong, intra**
- **Tempo (subjective): fast/slow**
- **Tempo (measured): syllables per second (target phrase)**
- **Frequency (categorical): low, medium, high (corpus data)**
- **Frequency (continuous): log-scaled (corpus data)**
- Manner of C2
- Voicing of C2

Results

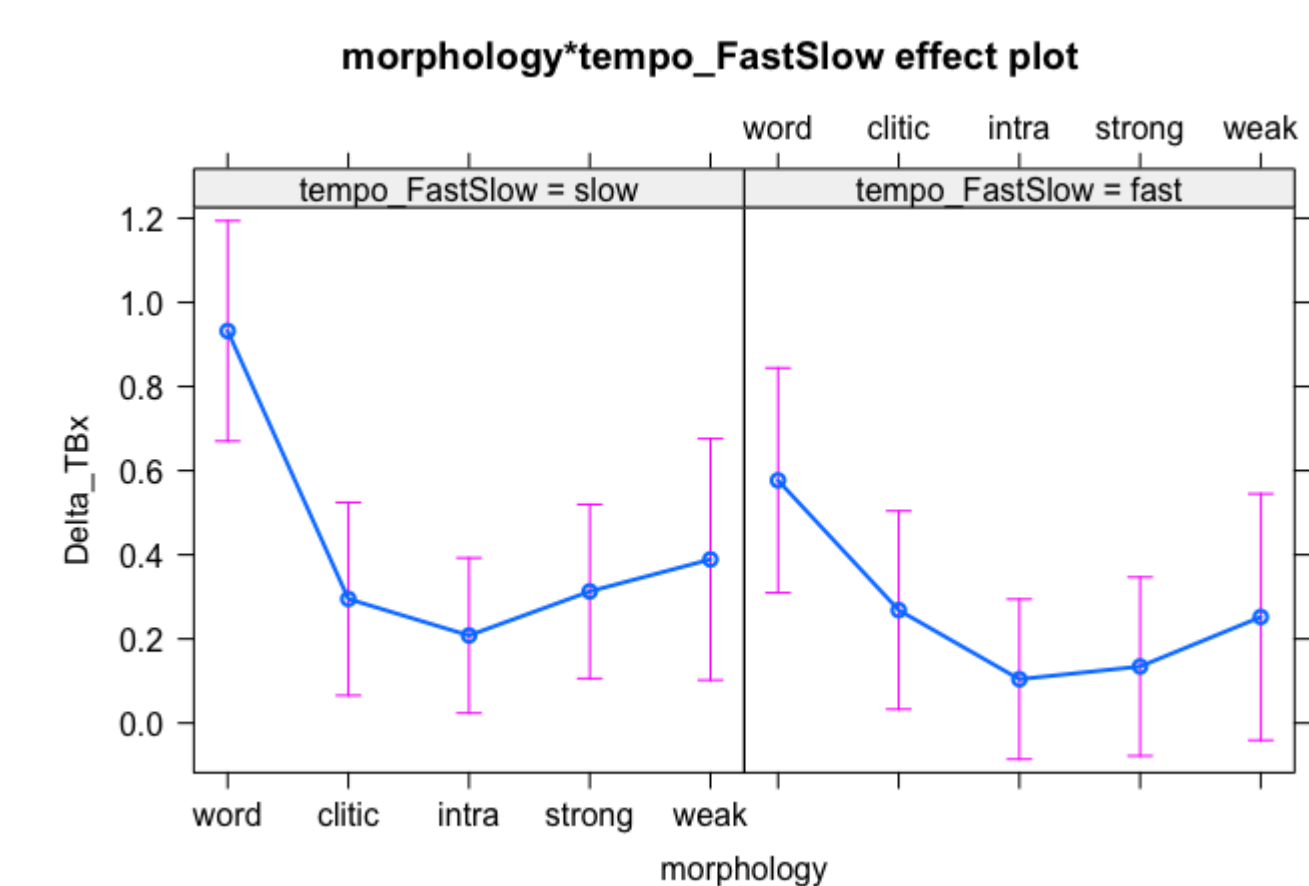
Tongue Body fronting (Delta TBx)



word is different from all the other categories (p < .001 ***)

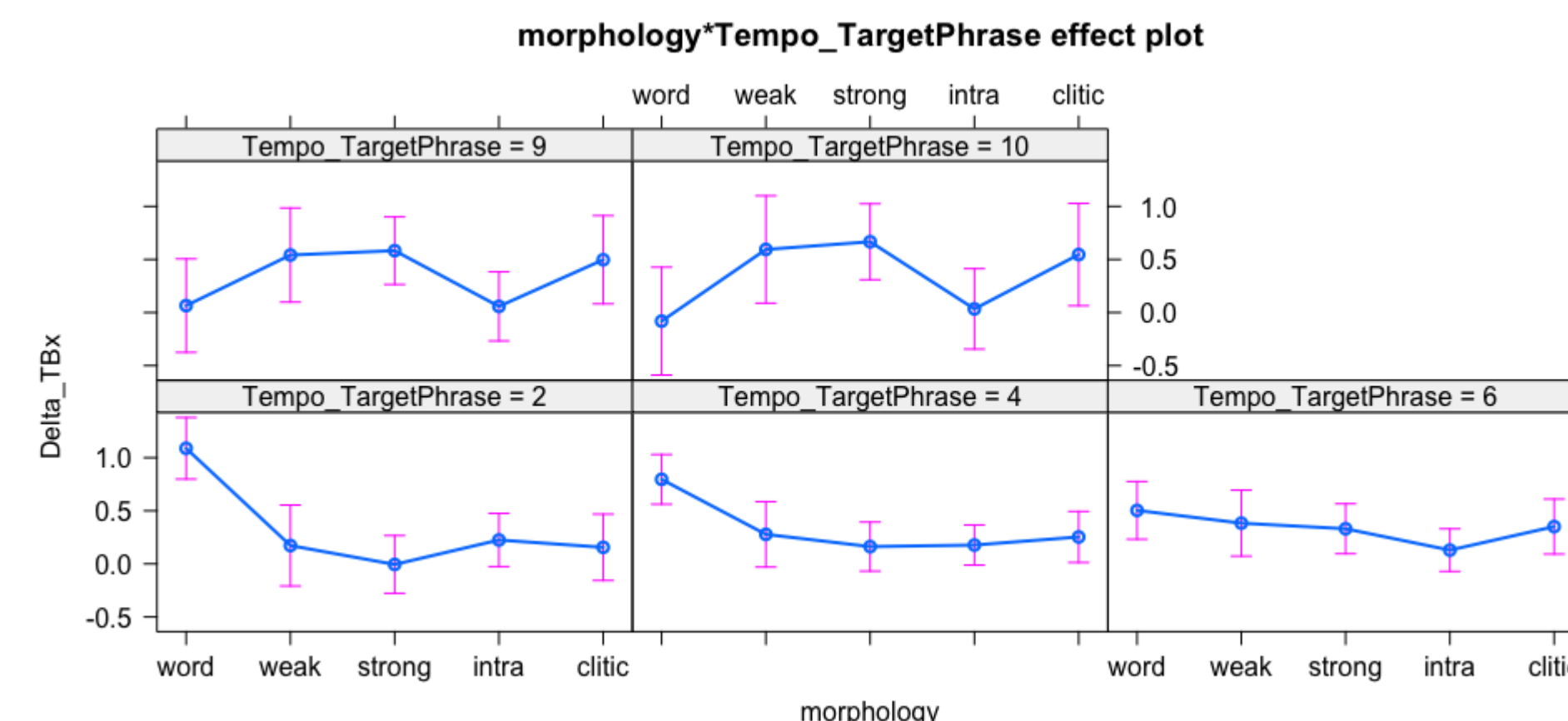


fast is different from slow (p = .003***)

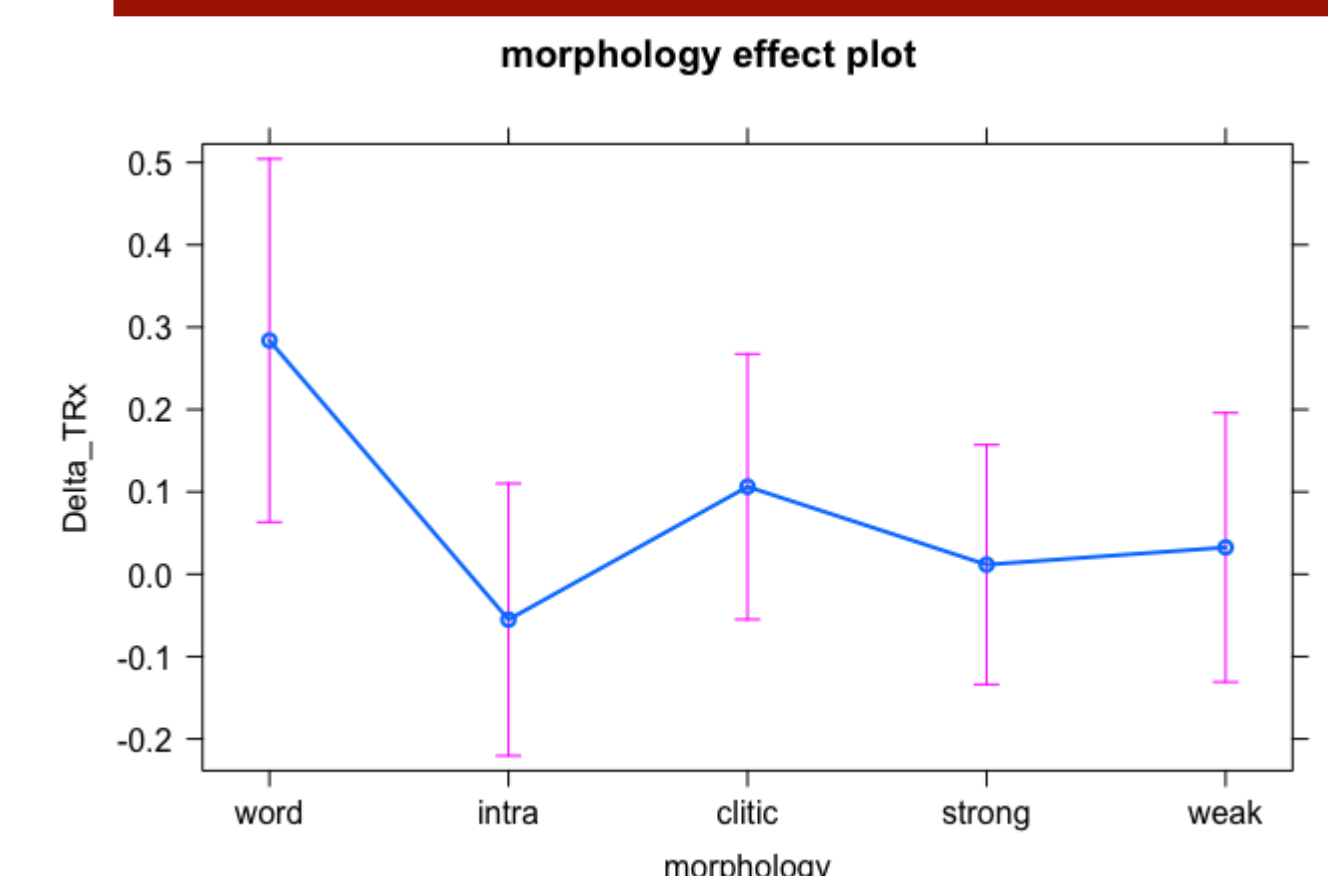


word is different from clitic, intra and weak.

Tongue Root fronting (Delta TRx)



word is different from clitic, strong and weak; the faster the tempo, the more assimilation across word boundaries.



word is different from intra, weak and strong.
intra is different from word, clitic and strong.

Articulatory correlates of palatal assimilation:

- Tongue body fronting
- Tongue root fronting

stronger and more consistent effects

Morphology:

- Word boundaries are consistently different from all the other categories.
- Intramorphemic is different from the other categories (for tongue root fronting)

The most assimilation

The least assimilation

Tempo:

- Effects of subjective tempo (slow vs. fast)
- Effects of measured tempo (syll. per sec.) for clusters across word boundaries.

Lexical frequency:

no significant effects