Stiffness and articulatory overlap in Moroccan Arabic consonant clusters

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INTRODUCTION

- Jun (2004) has claimed that patterns of regressive place assimilation in consonant clusters are attributable to the amount of overlap in the cluster. This claim has 2 components:

1) A relatively fast articulator followed by a relatively slow articulator (Fig. 1A and D) will have more overlap than a relatively slow articulator followed by a relatively fast articulator (Fig. 1 B and C).

2) The rapidity of a consonantal gesture depends on the "inherent velocity" of the primary oral articulator. Tongue tip gestures are assumed to be fastest, followed by lower lip gestures, then tongue back gestures. Thus, typologically:

- Faster articulators are more likely to be targets of assimilation.

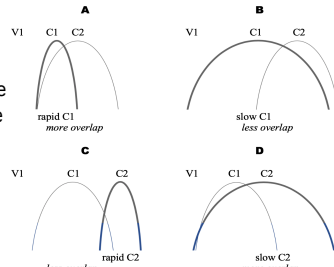- Slower articulators are more likely to be triggers.

Fig 1. Predictions of Jun (2004) for effects of relative rapidity on consonantal overlap in VC1C2 clusters

The proposal by Jun (2004) makes testable—yet untested—predictions, which we test in this study.

HYPOTHESES

H-J1: Articulations of tongue tip (TT) consonants should be faster than articulations of lower lip (LL) and tongue back (TB) consonants, and articulations of LL consonants should be faster than those of TB consonants, all things being equal.

H-J2: The amount of overlap in a heterorganic cluster is predicted by cluster type in the following way:

TT-TB > {LL-TB, TT-LL} > {TB-LL, LL-TT} > TB-TT

no prediction is made between pairs within curly brackets.

H-3: The amount of overlap in a cluster increases as the rapidity of C1 increases compared to C2.

- H-J1 is a direct test of the claim of Jun (2004).
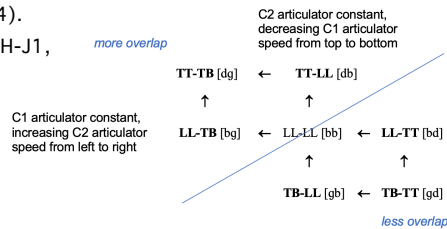
- H-J2 follows from H-J1, per Fig. 2.

Fig 2. Derivation of H-J2 based on the inherent rapidity of articulators tested in H-J1.

- H-3 is an alternative to H-J1 and H-J2 which proposes that overlap may be related to gestural rapidity, but independently from the specific articulators involved.

METHODS

- **6 native speakers** of Oujda dialect of Moroccan Arabic (25-38 y.o., one female).

- **Stimuli**
  - 3 corpora from data collected for other studies/purposes.
  - Word-medial, stop-stop clusters with /a/ on both sides, in real words: [bd], [bt], [bg], [bk], [dg], [dk], [tg], [tk], [db], [gb], [gd], [gt], [kb], [kd], [kt], [tb].
  - Presented in Arabic orthography with vowel diacritics.
  - 5 repetitions each (pseudo-randomized within other stimuli).

- Articulatory data collected using 3D EMA at 200 Hz sampling rate at LMU, Munich.

- EMA sensors attached to lower lip, tongue tip, and tongue body, plus fiduciary sensors for head-correction.

- "Landmarks" (Fig. 3) calculated using MVIEW (Tiede, Haskins Labs) for each gesture based on 20% velocity thresholds (Chitoran et al., 2002, and others).
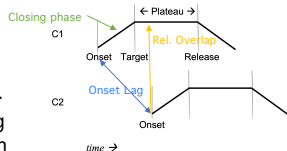

Fig 3. Landmarks calculated for each consonantal gesture.

Articulator rapidity

It is unclear in general and unstated by Jun (2004) specifically how to quantify articulator "rapidity". We therefore evaluated H-J1 and H-3 with two different quantifications (both based on the closing phase of each gesture). The first was peak velocity ($v^\wedge$, cm/sec).

Velocity covaries with movement amplitude (A), and is influenced by context (e.g., Kent & Moll, 1976; Kuberski & Gafos, 2019).

Stiffness is an *abstract control parameter* used in the Task Dynamics Model (Munhall et al., 1985) that modulates the time-space behavior of an articulator in various ways.

Per Munhall et al. (1985) and others, we measured stiffness (k') as: $v^\wedge/A$, thereby relativizing by amplitude.

Gestural overlap

It is also unclear what the most appropriate quantification of articulatory overlap is, so we used two different measures, both defined with reference to the landmarks in Fig. 3. Following Chitoran et al. (2002) and Gafos et al. (2010), we defined a relative overlap measure:

Rel. Overlap $= 1 - (time_{OnsetC2} - time_{TargetC1})/(time_{ReleaseC1} - time_{TargetC1})$

as well as a non-relative measure: **Onset Lag** $= time_{OnsetC1} - time_{OnsetC2}$

RESULTS

Fig. 4. $v^\wedge$ (A) and k' (B) values by articulator within cluster position.
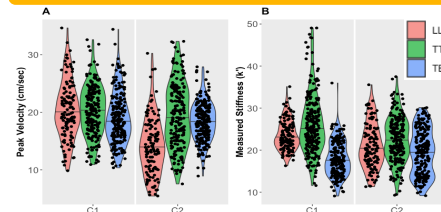
- **Little to no support for H-J1** (Fig. 4).
- LL had lowest $v^\wedge$ and k' in C2 position only, *contra* H-J1.
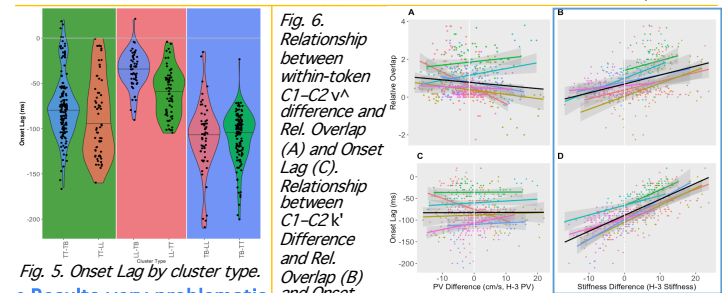- TB had lower than LL & TB but only as C1.

Fig. 5. Onset Lag by cluster type.

- **Results very problematic for H-J2** (Fig. 5).
- TT-initial clusters significantly less overlapped than others, *contra* H-J2.
- Not surprising given H-J1 not supported.
- Qualitative results the same if overlap indexed with Rel. Overlap.

Fig. 6. Relationship between within-token C1-C2 $v^\wedge$ difference and Rel. Overlap (A) and Onset Lag (C). Relationship between C1-C2 k' Difference and Rel. Overlap (B) and Onset Lag (D).

- Difference in $v^\wedge$ and k' (C1–C2) calculated within-token.
- Both difference values regressed onto overlap measures (Fig. 6).

- **Strong support for H-3.**
- Within-token k' difference significantly predicts overlap, for both overlap indexes.
- Holds across *and within* cluster types.
- $v^\wedge$ difference *not* a sig. predictor of overlap.

CONCLUSIONS

- One key insight of Jun (2004) is that the amount of overlap in a consonant cluster is a function of the relative rapidity of the articulations of the closing phase of the two consonants. Our results provide strong support for this aspect of his proposal, but only when rapidity was indexed by the abstract dynamical parameter of stiffness of the closing gestures of the two articulations in the cluster.

- However, attributing differences in stiffness (or peak velocity) in a cluster based on the articulators involved seems implausible given the present results.

- Jun's hypothesis crucially appeals to language universals, so testing the hypothesis with Moroccan Arabic is valid.

- Differences in overlap may ultimately be part of an explanation for observed typological patterns of assimilation. Our results strongly suggest that further research toward such an explanation should include the role of stiffness on overlap, which stands at the right level of abstraction from highly context-dependent, surface kinematics.

References: Chitoran et al. (2002) ISBN: 3110197103; Gafos et al. (2010) ISBN: 3110197103; Jun (2004) ISBN: 0521825784; Kent & Moll (1976) DOI: 10.1044/jshr.1503.453; Kuberski & Gafos (2019) DOI: 10.1371/journal.pone.0213851; Munhall et al. (1985) DOI: 10.1037/0096-1523.11.4.457