

PERTURBATION OF STABILITY PATTERNS IN SYLLABLE PRODUCTION

Anne Hermes*, Doris Mücke*, Bastian Auris*

*I/L-Phonetik, University of Cologne
{anne.hermes; doris.muecke; bastian.auris}@uni-koeln.de

ABSTRACT

The aim of the present study is to capture the variation of continuous phonetic parameters associated with distinct phonological syllable organisations in Tashlhiyt Berber and Polish. In a first step, we investigate stability patterns for simple and complex onset coordination based on EMA data. In a second step, we test the degree of perturbation of the stability patterns under variation of phonetic parameters in a simulation task. While Tashlhiyt shows a clear simple onset parse across all tested conditions, the dominance of the preferred complex onset parse for Polish is perturbed when anchor variability is increased. We conclude that the degree of perturbation on a stability pattern differs within and across languages, a fact that has to be taken into account when capturing quantitative consequences of phonological syllable parses.

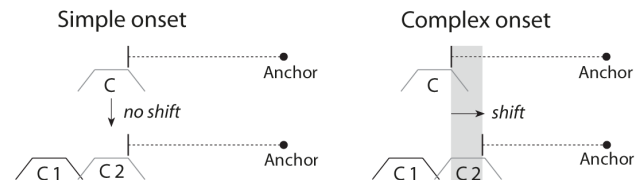
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1. INTRODUCTION

It has been shown in the Articulatory Phonology framework [2] that syllable structure is reflected in the coordination of articulatory gestures [5,6,7,8,9]. In CV syllables, the consonant and the vowel are initiated at the same time. However, when a consonant is added to a word initial CV sequence, two different patterns are described: While languages such as Tashlhiyt Berber [6] or Moroccan Arabic [13,14] have simple onsets only, other languages such as American English [8], Polish [11] or Georgian [5] allow for complex onsets. Fig. 1 provides schematised coordination patterns for (i) simple and (ii) complex onset coordination:

- (i) *Simple onset coordination* (Fig. 1; left): Adding a C to a singleton does not involve an adjustment of the prevocalic C. There is no shift towards the anchor (referred to as right-edge stability)
- (ii) *Complex onset coordination* (Fig. 1; right): Adding a C to a singleton leads to an adjustment of both Cs. There is a shift of the prevocalic C towards the anchor, leading to C-center stability (C-center is defined as the midpoint of consonantal targets relative to a following anchor, [2]).

Figure 1: Simple and complex onset coordination.



In this study, we use a computational model to evaluate syllabification patterns of word initial clusters in Tashlhiyt Berber and Polish. Recent studies provide evidence for a simple onset parse in Tashlhiyt [5,6] and a complex onset parse in Polish [11]. Clusters such as /kt/ in a word like <ktid> ('remember') in Tashlhiyt are syllabified as heterosyllabic: /k.tid/. In contrast, clusters in Polish such as /kr/ in a word like <krasić> ('to flavour') are syllabified as homosyllabic.

The aim of the present study is to capture the variation of continuous phonetic parameters associated with distinct phonological syllable organisations, a method suggested by [4,13,14]. Empirical EMA data and a simulation task on Tashlhiyt and Polish clusters are used for this. In a first step, we compute stability indices from kinematic data to quantify the temporal behaviour of consonants and vowels in a given syllable. In a second step, we run a corresponding computational model, based on the *ParseEval* script [14]. In the model, noise is added systematically to the system by increasing variability of the temporal intervals within the syllabic constituents. It has been shown for Moroccan Arabic, a language with a simple onset parse, that stability patterns are not always robust against prosodic variation and segmental context [4,13,14]. We seek to investigate the dynamic behaviour of stability patterns in two languages with different phonological syllable parses, Tashlhiyt Berber and Polish.

2. METHOD

2.1. Kinematic Data

We used articulographic data from three native speakers of Tashlhiyt Berber [6] (3 male) and three native speakers of Polish [11] (2 female, 1 male).

The data was recorded with a 2D electromagnetic midsagittal articulograph (AG 200). For each language, 6 target words (starting with singleton vs. consonant clusters: /f-kf/, /t-kt/, /k-lk/ for Tashlhiyt; /r-pr/, /r-kr/, /l-kl/ for Polish), randomly ordered, went into the analysis. Target words were embedded in a carrier phase (6 target words x 7 repetitions x 3 speakers x 2 languages):

- (1) Tashlhiyt: Inna ____ bahra.
(*'He says ____ a lot.'*)
- (2) Polish: Ona mówi ____ aktualnie.
(*'She says ____ a lot.'*)

Table 1: Target pairs for Tashlhiyt and Polish.

	Single	Cluster
(1) Tashlhiyt	<u>f</u> ik 'give yourself'	<u>k</u> fik 'give yourself'
	<u>k</u> if 'same'	<u>l</u> kif 'hashish'
	<u>t</u> id 'those'	<u>k</u> tid 'remember'
(2) Polish	<u>l</u> abrys 'ax'	<u>k</u> lawisz 'key'
	<u>r</u> abin 'rabbi'	<u>k</u> raśić 'to flavour'
		<u>p</u> ranie 'laundry'

For the empirical kinematic data, the Relative Standard Deviation (RSD) is computed for the two language datasets. This stability measurement (standard deviation divided by the mean) is calculated for the following indices:

- a) left-edge index (LE): leftmost C in a cluster/singleton relative to a following anchor (e.g. target of /l/ in <lkif> to target /f/)
- b) center index (CC): midpoint of C targets relative to a following anchor (e.g. midpoint between target /l/ and target /k/ in <lkif> to target /f/)
- c) right-edge index (RE): rightmost C in a cluster/singleton relative to a following anchor (e.g. target of /k/ in <lkif> to target /f/)

The RSD values provide preliminary insight into the temporal stability pattern for a language. The lower the RSD value the more stable the landmark is.

2.2. Computational Model

For the computational model we took the *ParseEval* script provided by [14], and programed it as a *ParseEval* function in R [1,12]. Generally, the computational model gives an evaluation of how good the empirical input data fits the idealised simulated patterns, when the variability of a certain parameter increases.

The RSD values described in section 2.1 for Tashlhiyt Berber and Polish served as the *input* for the model. Furthermore, we used two different pre-sets of phonetic parameters provided within the original *ParseEval* script¹: the Moroccan Arabic preset for simple onset parses, i.e. Tashlhiyt Berber,

and the American English preset for complex onset parses, i.e. Polish.

To add noise to the data the anchor variability is gradually increased, in 15 steps of 5ms. This anchor variability is chosen as the parameter to test the stability of a certain measured temporal coordination pattern. 1000 simulations of the model were run for each coordination type (simple and complex onset coordination) for each language in order to evaluate the simulation results.

3. RESULTS

3.1. Tashlhiyt

The analysis of the kinematic data for the Tashlhiyt clusters supports the claim that these show a simple onset coordination pattern.

Figure 2: Averaged trajectories for <kif> and <lkif>; one Tashlhiyt speaker.

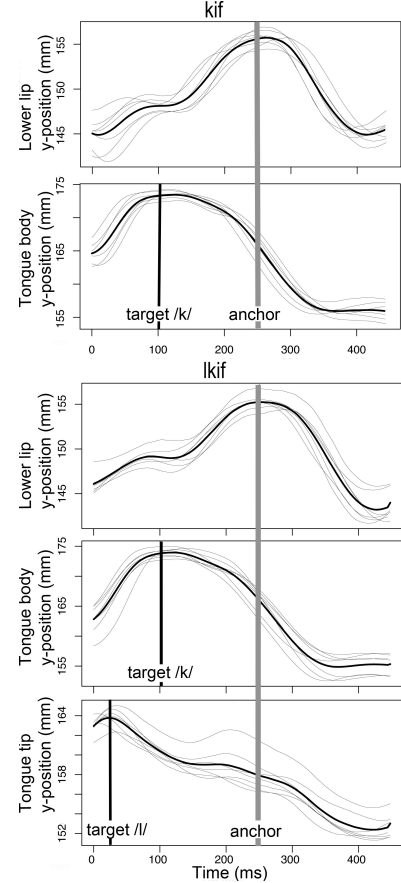


Figure 2 displays the averaged trajectories for one Tashlhiyt speaker for singleton <kif> (top: vertical position for lower lip and tongue body movement) compared to cluster <lkif> (bottom: vertical position for lower lip, tongue body and tongue tip movement). The anchor point (marked by a vertical solid grey line) within the syllable was chosen as the gestural target of the coda consonant, i.e. /f/. The

vertical black lines mark the target of the initial C(s). It can be seen from Fig. 2 that the cluster condition in <lkif> does not involve a shift of the rightmost consonant towards the anchor. Target /k/ in <kif> (Fig. 2, top) remains at the same distance from the anchor as target /k/ in <lkif> (Fig. 2, bottom).

We computed RSD values for the empirical EMA data. They indicate a right-edge stability pattern (see Table 2). In line with [5,6], the right-edge represents the most stable index in Tashlhiyt clusters as compared to the center and the left-edge index (overall mean: RE=13.73<CC=16.71<LE=22.66).

Table 2: RSD values (given as percentage) for Tashlhiyt clusters for left-edge (LE), center (CC) and right-edge (RE). Lowest values marked in italics.

	LE	CC	RE
fik-kfik	19.94	11.86	<i>8.40</i>
kif-lkif	22.70	15.20	<i>11.70</i>
tid-ktid	18.75	13.99	<i>12.91</i>
overall mean	22.66	16.71	13.73

In a second step, the respective stability patterns (based on the RSD values reported above) were tested in the simulation. During the simulation, this model computes statistical significant hits for how good the empirical data fits the simulated one.

Figure 3: Simulation results for Tashlhiyt clusters; testing (1) simple and (2) complex onset coordination. The number of hits with increasing anchor variability is presented in (3).

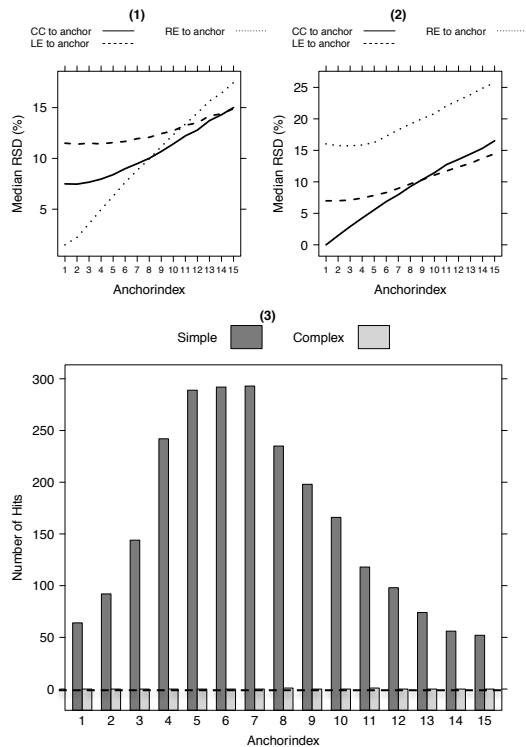
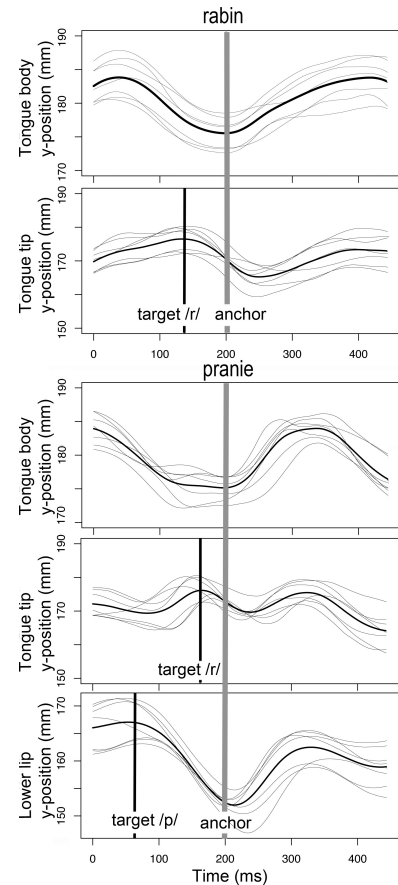


Figure 3 presents the simulation results graphically for Tashlhiyt, pooled for speakers and clusters. In Fig. 3(1) the simulation results for a simple coordination condition is shown and in Fig. 3(2) those for a complex coordination condition. There were only hits for simple onset coordination Fig. 3(3); there were no hits for complex coordination across all anchors (number of hits for simple=1274 vs. complex=0). The simple coordination pattern persists throughout the increase in perturbation, i.e. in anchor variability (see Fig. 3(3)).

3.2. Polish

The kinematic data for Polish provides evidence that the pattern is different from the one presented for Tashlhiyt. Fig. 4 shows the averaged trajectories for one Polish speaker for singleton <rabin> (top: vertical position for tongue body and tongue tip movement) compared to cluster <pranie> (bottom: vertical position for tongue body, tongue tip and tip movement). The anchor point (marked by a vertical grey line) within the syllable was chosen as the gestural target of the vocalic gesture of /a/. The vertical black lines mark the target of the initial C(s).

Figure 4: Averaged trajectories for <rabin> and <pranie>; one Polish speaker.



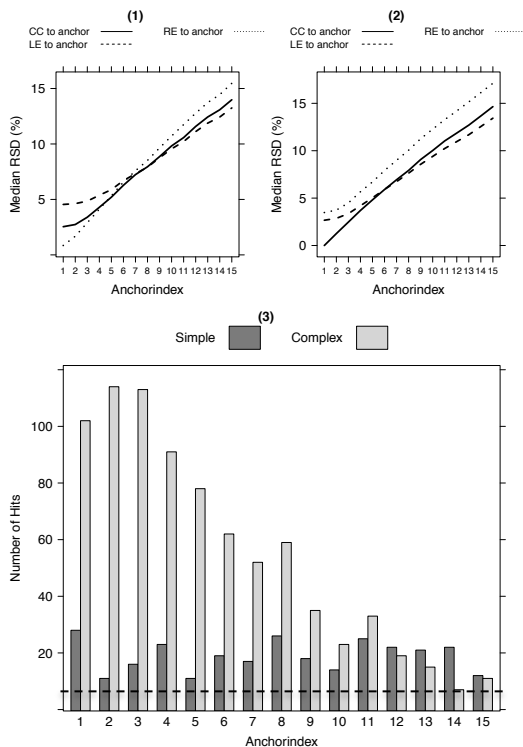
In Fig. 4, when comparing singleton <rabin> with cluster condition <pranie> for one Polish speaker, the coordination of the rightmost C in the cluster is adjusted: /r/ is shifted towards the anchor.

Table 3: RSD values (given as percentage) for Polish clusters for left-edge (LE), center (CC) and right-edge (RE). Lowest value marked in italics.

	LE	CC	RE
labrys-klawisz	31.12	23.67	26.83
rabin-kraśi	44.22	29.98	44.20
rabin-pranie	40.09	28.69	38.32
overall mean	39.99	32.86	43.52

Again, we computed RSD values for the empirical kinematic data. They confirm a center stability, which is expected for clusters that form complex onsets (overall mean: $CC=32.86 < LE=39.99 < RE=43.52$). In line with [11], the pattern for the Polish clusters points towards a complex onset coordination involving a shift of the rightmost C in a cluster towards the anchor.

Figure 5: Simulation results for Polish clusters; testing (1) simple and (2) complex onset coordination. The number of hits with increasing anchor variability is presented in (3).



The computational model for the Polish data, pooled for all speakers and all clusters, was run to test for simple (Fig. 5(1)) and complex onset coordination (Fig. 5(2)). There were dominant hits for the complex coordination pattern with a total of 627 hits (cf. 268 hits for simple onset coordination).

However, as the anchor variability increases the pattern changes at a certain crossover point. After adding 55 ms of anchor variability to the system (between steps 11 and 12 see bar chart in Fig. 5(3)), the pattern is reversed, and the number of hits for simple onset coordination becomes higher for complex onset coordination.

4. CONCLUSION

The stability patterns computed from the Tashlhiyt and Polish EMA data support previous findings that the coordination patterns for word initial clusters differ in these languages. Tashlhiyt word initial clusters /kt, lk, kf/ show a simple onset parse (lower RSD values for simple onset coordination) and Polish word initial clusters /kl, kr, pr/ a complex onset parse (lower RSD values for complex onset coordination). However, the simulation task reveals that the respective stability patterns respond differently when noise is added to the system.

For Tashlhiyt, the simple onset parse persists throughout the increase in perturbation. There were only hits for simple onset coordination, with no hits for complex coordination, even when anchor variability was increased.

A different pattern arises for the Polish clusters. When adding noise to the system, the computed stability pattern was less robust than for Tashlhiyt. Adding anchor variability leads to a critical switch from complex onset to simple onset parse.

So far, it is unclear whether the different segmental context (/kt, lk, kf/ and /kl, kr, pr/) also contributed to the variation found here, as has been reported elsewhere [3,4,13,14]. Factors such as prosody or segmental context can systematically affect the quantitative consequences of phonological syllable parses.

This computational model has been shown to capture possible quantitative and therefore continuous consequences of different categorical syllable parses, which provides insight into the perturbation of a stability pattern that may differ within and across languages.

In the datasets investigated here, perturbation had a much stronger impact on the complex onset parse in Polish than on the simple onset parse Tashlhiyt. This could be due to the nature of the attractors required for the different patterns. The simple onset parse is based on a single and strong in-phase attractor that is innate [10]. In contrast, the complex onset parse results from the competition of two incompatible attractors, the in-phase and the anti-phase mode. This complex pattern has to be learned and hence is more likely to be interfered with than a pattern based on a single, non-competitive attractor.

5. REFERENCES

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¹ Further information on the specific gestural parameters used in *ParseEval* can be found in [13].