GESTURAL COORDINATION IN TASHLHIYT SYLLABLES

Anne Hermes[a], *Rachid Ridouane*[b], *Doris Mücke*[a] *& Martine Grice*[a]

[a]I*f*L Phonetik, University of Cologne, Germany;
[b]Laboratoire de Phonétique et Phonologie (CNRS/Sorbonne Nouvelle), France
anne.hermes@uni-koeln.de; doris.muecke @uni-koeln.de;
martine.grice@uni-koeln.de; rachid.ridouane@univ-paris3.fr

ABSTRACT

In this study we investigated the coordination of consonantal and vocalic gestures in Tashlhiyt Berber as a function of their subsyllabic constituency. The aim was to determine whether the syllabification proposed of word initial clusters is reflected in the coordination of articulatory gestures. Two main results were obtained: (1) The timing of consonants in word initial clusters in relation to a gestural target in the syllable coda provided evidence for non-branching onsets only. (2) This was true both for target words containing a vocoid and for those with a non-vocoid nucleus.

Keywords: subsyllabic constituency, gestural coordination, non-vocoid nuclei

1. INTRODUCTION

In Tashlhiyt Berber, it has been shown that any consonant can occupy the nucleus position in the syllable [3, 9]. A specific aspect of this proposed syllable structure is that it does not allow complex onsets. Based on various arguments drawn from phonology, morphology and versification, it has been argued that initial clusters of the shape C_1C_2V are parsed as disyllabic (e.g. [k.ti] 'remember', where C = nucleus and '.' = syllable boundary). In this study, we seek to determine whether there is any phonetic evidence for such a claim. Specifically, we investigate whether the syllabic organisation of word-initial clusters can be ascertained on the basis of temporal stability patterns in the articulatory domain.

In an articulatory study on syllable timing and subsyllabic constituency in Tashlhiyt and Georgian, Goldstein, et al. [4] investigated word initial consonant clusters, focusing on the position of the rightmost consonant relative to an anchor later in the syllable. The aim was to test whether the kinematic coordination patterns are modified when a consonant is added to the beginning of the word. For Tashlhiyt, they investigated triads with target words containing a *vocoid* in nucleus position such as /mun/, /s.mun/, and /ts.mun/ and confirmed the 'simple onset hypothesis' for Tashlhiyt. This study was based on recordings of one speaker. The present study aims to follow up this study with three further speakers and more lexical items. In addition, we explore whether this pattern of stability also obtains in syllables with non-vocoid nuclei.

2. COUPLING

The syllable as a unit of speech planning can be described within the framework of Articulatory Phonology [1] in terms of coupled oscillators [7], where gestures are associated with oscillators, and coupled with each other in-phase (synchronously) or anti-phase (sequentially). Thus, in a CVC syllable the onset C and the nucleus (V) are coupled in-phase, whereas the V and the coda C are coupled in anti-phase mode.

In languages allowing for complex onsets all onset consonants are coupled in-phase with the nucleus (see (1), solid lines=in-phase, dotted lines=anti-phase). At the same time, they are coupled sequentially in relation to each other. These two coupling modes result in the center of these consonants being synchronised with the vowel rather than each individual C. This is referred to as *center stability* and was obtained for languages like American English [2, 6], Georgian [4] and Italian [5].

(1) C_1····C_2—V······C (e.g. English: /plan/)

In languages allowing for simple onsets only, the rightmost C in a cluster is timed in-phase with the nucleus (*right-edge stability*, [4, 10], see (2)). This has been shown for Moroccan Arabic [10].

(2) C_1 . C_2—V······C (e.g. Tashlhiyt: /s.mun/)

These specific timing relations hold for syllables with a vocoid nucleus. In the present study we test whether non-vocoid nuclei can be accounted for in the same way.

A recent study on Slovak [8] indicated that timing patterns for syllables with a vocoid nucleus (e.g. /rak/) were significantly different from those obtained for syllables with a non-vocoid one (e.g. /mrk/). Note, however, that this language is structurally very different from Tashlhiyt in terms of the complexity of the onsets it permits.

3. METHOD

3.1. Recordings

Articulatory and acoustic recordings were made with EMMA (Electromagnetic Articulograph, Carstens AG 100). Sensors were placed on upper and lower lip, tongue tip, tongue blade and tongue body. Two additional ones were placed on the bridge of the nose and on the upper gums to correct for head movements. A bite plate was used to rotate the data in relation to the occlusal plane.

Articulatory data was recorded at 400Hz, downsampled to 200Hz and smoothed with 40Hz low-pass filters. The acoustic data was digitised at 44.1kHz/16bit. In total 1134 items were recorded.

3.2. Subjects and speech material

Three native Tashlhiyt speakers, aged between 37 and 39, were recorded. All speakers spent their first 25-30 years in the area of Agadir (Morocco).

Target words contain one, two or three consonants initially and a vocoid or non-vocoid nucleus in the target position (see Table 1). They were produced in the carrier sentence: Inna __ bahra. (*He said __ a lot*). 252 tokens were included in the statistical analysis (6 items with a vocoid nucleus + 6 items with a non-vocoid nucleus x 7 repetitions x 3 speakers).

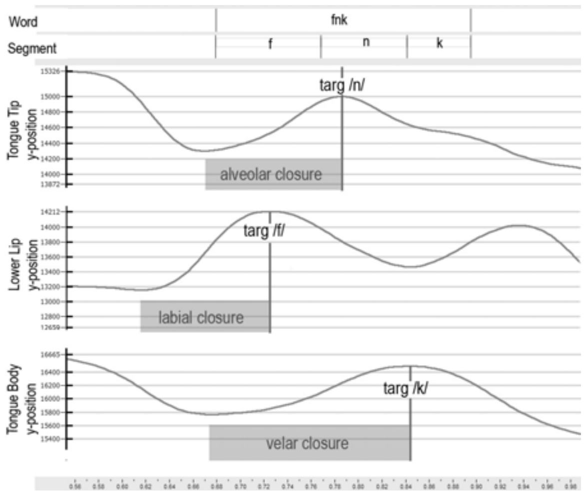
Table 1: Target words varying from one to three Cs initially, with vocoid or non-vocoid nucleus in '_'. The word for 'give' is [f] or [kf] in free variation.

	C_C	C.C_C	CC.C_C
Vocoid	fik *give yourself*	kfik *give yourself*	tkfik *she gave you*
	kif *same*	lkif *hashish*	flkif *for hashish*
Non-vocoid	fnk *they gave you*	kfnk *they gave you*	tkfnk *she buried you*
	klf *to appoint*	lklf *skin patches*	flklf *on skin patches*

3.3. Data annotation

Acoustic and articulatory records were labelled manually in the EMU Speech Database System: In the acoustic domain the target word and its acoustically defined segments; in the articulatory domain onsets and targets related to the gestural activation interval in the consonant and vowel production. An example for a labelling scheme is provided in Fig. 1.

Figure 1: Labelling scheme in target word /fnk/; articulatory data. Top to bottom: tongue tip vertical position for nucleus /n/, lower lip vertical position for onset /f/ and tongue body vertical position for coda /k/.



3.4. Measurements

The following four variables were calculated to test for gestural coordination patterns in Tashlhiyt:

Rightmost C Measure: The temporal interval from the target of the rightmost C (in word initial cluster) relative to the gestural target of the coda C. If a consonant is added to the syllable onset (i.e. forming a complex onset), the latencies for the rightmost C target relative to the anchor point (gestural target of coda C) is assumed to decrease, making room for the added C.

C-center Measure: The temporal interval from the C-center (mean of consonantal targets in word initial position) relative to the gestural target of the coda consonant. If a C is added to the syllable onset, the timing of the C-center relative to the anchor point is assumed to remain stable.

Rightmost C Stability Index and *C-center Stability Index:* For the measures described above, the respective stability index was calculated and compared. Therefore, the coefficient of variance is computed (see (3), also referred to as Relative Standard Deviation - %RSD).

(3) $$Cv = \frac{\sigma}{\mu}$$

The lower the percentage for a measure, the better the stability. In complex syllable onsets, a center-stability is predicted. If, instead, there is a simple syllable onset, a right-edge stability is expected [10].

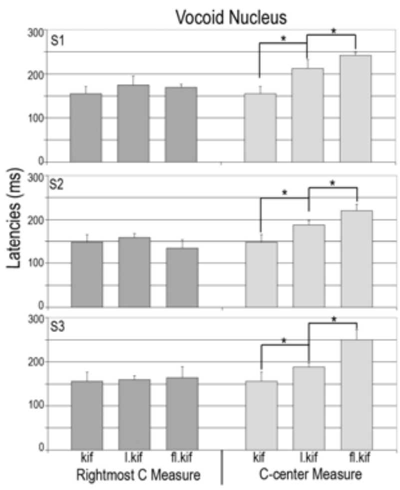
4. RESULTS

4.1. Rightmost C and C-center measure

For the vocoid nuclei, the temporal interval from the C-center to the target in the coda increases as each C is added to the beginning of the word.

Fig. 2 displays the results for the *vocoid* nucleus condition in the triad /kif/-/l.kif/-/fl.kif/ with mean latencies for the Rightmost C and C-center Measure. All measures were tested by a series of one-way ANOVAs conducted for each speaker separately and performed Tukey post-hoc tests. We included NUMBER OF INITIAL C (one/two/three) as independent variable. For multiple comparisons, we did a Bonferroni correction (α'=0.0043).

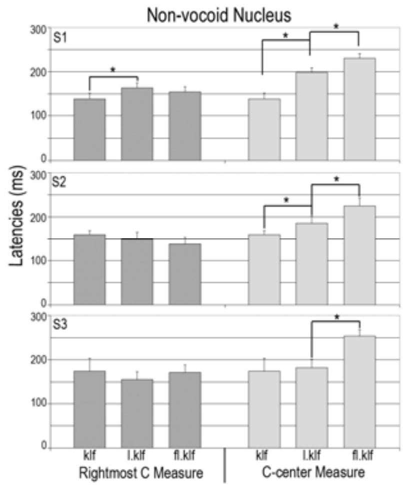
Figure 2: Rightmost C (dark grey bars) and C-center Measure (light grey bars) for items with vocoid nucleus: /kif/-/l.kif/-/fl.kif/; each speaker separately.



From /kif/ to /l.kif/, we measured an increase of 57ms for S1, 40ms for S2 and 32ms for S3, and from /l.kif/ to /fl.kif/ 30ms for S1, 32ms for S2 and 62ms for S3. The effect on the C-center Measure was significant for all speakers (post hoc test for NUMBER OF INITIAL C: one>two>three, S1: $F(2,21)=59.856$, $p<0.001$, S2: $F(2,21)=41.040$, $p<0.001$, S3: $F(2,21)=39.727$, $p<0.001$), whereas latencies for the rightmost C relative to the anchor point remain stable. There was no effect of the NUMBER OF INITIAL C for each of the three speakers in the individually conducted ANOVAs.

For the non-vocoid nuclei, the gestural timing pattern is similar to the one with a vocoid nucleus. Fig. 3 shows the mean latencies for the Rightmost C the C-center Measure in triads containing a *non-vocoid* nucleus: /klf/, /l.klf/ and /fl.klf/. The C-center to target latencies increase, as Cs are added to the word (post-hoc for NUMBER OF INITIAL C: one>two>three, S1: $F(2,21)=37.888$, $p<0.001$, S2: $F(2,21)=35.073$, $p<0.001$, S3: $F(2,21)=37.873$, $p<0.001$), e.g. in /klf/-/l.klf/: increase of 60ms for S1, 26ms for S2 and in /l.klf/-/fl.kf/: increase of 32ms for S1, 40ms for S2 and 71ms for S3. A Tukey post-hoc test reveals an exception for S3, showing no difference for the C-center Measure in /klf/-/l.klf/.

Figure 3: Rightmost C (dark grey bars) and C-center Measure (light grey bars) for items with non-vocoid nucleus: /klf/-/l.klf/-/fl.klf/; each speaker separately.



As in the vocoid nucleus condition, the latencies for the Rightmost C Measure do not decrease. With one exception (increase for S1: /klf/ vs. /l.klf/, but in the opposite direction), the Rightmost C Measure was not significantly affected by NUMBER OF INITIAL C.

The results for both measurements for all triads with vocoid and non-vocoid nuclei are provided in Table 2.

Table 2: Results for Rightmost C and C-center Measure in items with vocoid and non-vocoid nucleus; each speaker separately.

		Rightmost C Measure			C-center Measure		
		S1	S2	S3	S1	S2	S3
Vocoid	fik	124 (9)	138 (11)	140 (8)	124 (9)	138 (11)	140 (8)
	k.fik	123 (9)	126 (8)	131 (8)	139 (8)	153 (8)	171 (11)
	tk.fik	123 (9)	117 (10)	128 (7)	198 (3)	196 (15)	226 (9)
	kif	155 (16)	148 (18)	156 (20)	155 (16)	148 (18)	156 (20)
	l.kif	175 (20)	159 (9)	159 (9)	212 (20)	188 (10)	188 (10)
	fl.kif	169 (7)	134 (20)	164 (25)	242 (7)	220 (15)	250 (23)
Non-vocoid	fnk	126 (7)	136 (8)	164 (22)	126 (7)	136 (8)	162 (22)
	k.fnk	119 (4)	129 (8)	132 (12)	145 (3)	156 (7)	172 (14)
	tk.fnk	123 (4)	129 (9)	140 (8)	198 (3)	212 (10)	240 (13)
	klf	138 (13)	159 (9)	174 (29)	138 (13)	159 (9)	174 (29)
	l.klf	163 (12)	149 (16)	155 (18)	198 (11)	185 (17)	182 (19)
	fl.klf	154 (12)	138 (15)	171 (17)	230 (11)	225 (18)	253 (15)

For the across-speaker comparison, an overall ANOVA (repeated measures based on cell means) with a Tukey post-hoc test was conducted: independent variables of NUMBER OF INITIAL C (one/two/three) and NUCLEUS TYPE (vocoid/non-vocoid), dependent variables of the Rightmost C and C-center Measure. There was a main effect of NUMBER OF INITIAL C on the C-center Measure, ($F(2,36)=42.398$, $p<0.001$, one<two<three, strong effect size of $d=0.75$ for one<two and $d=0.76$ for two<three), but no significant results for the Rightmost C Measure ($F(2,36) =0.153$, $p>0.05$). Furthermore, there was no effect of NUCLEUS TYPE either on the Rightmost C Measure or the C-center Measure. No interaction was found for NUCLEUS TYPE x NUMBER OF INITIAL C.

4.2. Stability index measure

Following [10], the Relative Standard Deviation was applied to the Rightmost C Measure as well as the C-center Measure (see 3.4). In Table 3 the results are presented for each speaker separately. Lower values indicate a higher stability for this measurement.

Table 3: %RSD for Rightmost C and C-center Measure in items with vocoid and non-vocoid nucleus; each speaker separately.

			Right-most C	C-center	Stability
Vocoid	fi̲k	S1	7%	23%	Right-edge
	k.fi̲k	S2	10%	18%	Right-edge
	tk.fi̲k	S3	7%	21%	Right-edge
	ki̲f	S1	10%	20%	Right-edge
	l.ki̲f	S2	12%	18%	Right-edge
	fl.ki̲f	S3	13%	23%	Right-edge
Non-vocoid	fn̲k	S1	4%	21%	Right-edge
	k.fn̲k	S2	7%	20%	Right-edge
	tk.fn̲k	S3	14%	20%	Right-edge
	kl̲f	S1	11%	21%	Right-edge
	l.kl̲f	S2	10%	16%	Right-edge
	fl.kl̲f	S3	9%	18%	Right-edge

For all three speakers the %RSD values clearly supports the hypothesis that there is a right-edge stability present for word initial clusters in Tashlhiyt and no center-stability, as found for languages allowing for complex onsets. Again, this right-edge stability is present in items containing either a vocoid or non-vocoid as the nucleus.

5. CONCLUSION

We evaluated the proposed syllable structure of word initial clusters in Tashlhiyt as reflected in the patterns of interval stability of the consonants relative to a gestural target in the coda. We showed that when a C is added to the word, latencies for the C-center Measure constantly increase, whereas the Rightmost C Measure remains unaffected. Interestingly, items containing a non-vocoid nucleus showed the same intergestural timing pattern as those with a vocoid. Thus, coupling graphs developed for onset-nucleus relations (see (1)), where the nucleus is a vocoid, can most probably be generalised to this further, typologically rare, non-vocoid nucleus type.

This study supports the simple onset hypothesis for Tashlhiyt and – more importantly – shows for the first time that non-vocoids in nuclear position have the same intergestural timing pattern as vocoids. This indicates that it is the structural position (i.e. nucleus) which is crucial for timing and not the identity of the sound itself (vocoid or non-vocoid).

6. REFERENCES

[1] Browman, C.P., Goldstein, L. 1988. Some notes on syllable structure in articulatory phonology. *Phonetica* 45, 140-155.

[2] Browman, C.P., Goldstein, L. 2000. Competing constraints on intergestural coordination and self-organization of phonological structures. *Bulletin de la Communication Parlée* 5, 25-34.

[3] Dell, F., Elmedlaoui, M. 2002. *Syllables in Tashlhiyt Berber and in Moroccan Arabic*. Dordrecht: Kluwer.

[4] Goldstein, L., Chitoran, I., Selkirk, E. 2007. Syllable structure as coupled oscillator modes: Evidence from Georgian vs. Tashlhiyt Berber. *Proc. 16th ICPhS*, Saarbrücken, 241-244.

[5] Hermes, A., Grice, M., Mücke, D., Niemann, H. 2008. Articulatory indicators of syllable affiliation in word initial consonant clusters in Italian. *Proc. 8th ISSP* Strasbourg, 433-436.

[6] Marin, S., Pouplier, M. 2010. Temporal organization of complex onsets and codas in American English: Testing the predictions of a gestural coupling model. *Motor Control* 14(3), 380-407.

[7] Nam, H., Goldstein, L., Saltzman, E. 2009. Self-organization of syllable structure: a coupled oscillator model. *Approaches to Phonological Complexity*. New York: Mouton de Gruyter, 299-328.

[8] Pouplier, M., Benus, S. 2010. On the phonetic status of syllabic consonants: Evidence from Slovak. *Talk at LabPhon 12*. New Mexico: Albuquerque.

[9] Ridouane, R. 2008. Syllables without vowels: Phonetic and phonological evidence from Tashlhiyt Berber. *Phonology* 25(2), 321-359.

[10] Shaw, J., Gafos, A., Hoole, P., Zeroual, C. 2009. Syllabification in Moroccan Arabic: Evidence from patterns of temporal stability in articulation. *Phonology* 26, 187-215.