International Journal of Language and Linguistics
2024, Vol. 12, No. 6, pp. 231-237
https://doi.org/10.11648/j.ijll.20241206.14

Research Article

Syllable Position Effects on the Coordination of Two Lingual Stop Clusters in Tripolitanian Libyan Arabic: Testing the C-centre Hypothesis

Abdurraouf Shitaw*

Department of English Language, Faculty of Languages, University of Tripoli, Tripoli, Libya

Abstract

This study aims to test the validity of the C-centre hypothesis by investigating the pattern of temporal organisation of the articulatory gestures of two lingual stop clusters in Tripolitanian Libyan Arabic. Five speakers of Tripolitanian Libyan Arabic produced four singleton stops /t/, /d/, /tˤ/ and /g/, and three back-to-front clusters /gt/, /gd/ and /gtˤ/ in syllable onset and coda positions. The C-center lag for these singletons and the two-stop clusters was measured. The results show that word-initial two-stop consonants in Tripolitanian Libyan Arabic exhibit more inter-consonantal cohesion and overlap than the same clusters in word-final position. While word-initial clusters sometimes allow intrusive vowels, the same clusters in word-final positions have epenthetic vowels. This study proposes that Tripolitanian Libyan Arabic has two coordination patterns governing articulatory gestures of two-stop consonant clusters. First, there is the onset pattern in which the articulatory gestures of the two lingual stops are aligned in close transition, such that the release of the first stop is sometimes masked. In coda position, the articulatory gestures of the two lingual stops are loosely aligned. They exhibit a more open transition and no overlap. The pattern here is characterised by allowing the separation of the two articulatory gestures, leading to the insertion of an epenthetic vowel.

Keywords

Articulatory Phonology, C-center, Tripolitanian Libyan Arabic

1. Introduction

The terms gestures, phasing rules and timing are the cornerstones of articulatory phonology. Languages apply different gestural coordination patterns to allow for certain degrees of overlap or delays between articulatory gestures. Many factors influence these patterns. One of these factors is the position of the cluster within the word. It has been demonstrated that in onset position, the consonantal gestures are in an in-phase relation with the following vowel, and in an anti-phase relation with each other [3]. On the other hand, in coda position the consonantal gestures are in anti-phase relation with the preceding vowel [3]. In addition, onset clusters exhibit a more stable timing pattern when compared to coda clusters [9]. In this respect, the two stop lingual gestures are organised globally in relation with the succeeding vowel and they exhibit the C-centre organisation [5].

The C-center organisation is defined as "the mean of all the midpoints of the gestures in [a] sequence" [3], or "the arithmetic mean of the temporal midpoint of each plateau of peak

*Corresponding author: a.shitaw@uot.edu.ly (Abdurraouf Shitaw)

Received: 31 October 2024; **Accepted:** 2 December 2024; **Published:** 23 December 2024

articulatory displacement for each consonant gesture in [a] sequence" [8]. This means that in onset position, whether there are two or three consonants, the consonantal gestures are organised with the succeeding vowel so that the duration between the centre of the consonantal gestures and the offset of the vowel remains stable. However, this hypothesis has yet to be confirmed in all languages.

The current study aims to investigate how the gestural organisation of two lingual stops in Tripolitanian Libyan Arabic (TLA) is influenced by syllable position. It also aims to test the validity of the C-center hypothesis on TLA. Since the duration of singletons in coda position after short vowels is doubled in Arabic [42], the hypothesis to be tested is that two lingual stop clusters in TLA will exhibit the C-center organisation.

2. Literature Review

In his famous book "Language", Bloomfield [2] distinguished between open and close transition. While in the former, the two consonantal gestures are separated by an acoustic release, in the latter, there is an overlap between the two consonantal gestures. Open and close transitions have since been tested on many languages that allow consonant clusters. For example, Byrd [9] investigated the gestural coordination patterns of consonantal clusters across word boundaries in American English. She noticed that the way articulatory gestures are aligned may result in a gestural reduction or gestural overlap. While having no acoustic release can be taken as evidence of gestural overlap, a shorter hold phase duration and a missing release burst are signs of gestural reduction, too [43].

The coordination of articulatory gestures can be influenced by many factors such as the place of articulation of the consonants, whether the cluster in an onset or coda position, perceptual recoverability, gender and speech rate. Regarding the influence of place of articulation, whether the places of articulation front-to-back or back-to-front can determine how the two gestures are aligned. This has been proven by Kochetov and Goldstein [27] who conducted an experiment to investigate how the order of places of articulation affects gestural coordination in Russian. Their results confirmed previous findings that back-to-front articulation clusters exhibit less gestural overlap. This may be motivated by the need to enhance perception in these clusters [11].

In addition, the manner of articulation can also affect gestural coordination. Using electropalatogray (EPG) Byrd [7] conducted a study to investigate the gestural coordination of American English consonant clusters. She examined the overlap within clusters consisting of two stops, a stop + /s/, and /s/ + a stop. Her results revealed an evidence that clusters consisting of two sops exhibit more gestural ovelap that clusters consisting of a stop and a fricative.

Whether the cluster is an onset or coda position is another factor that can determine gestural coordination. In this respect, there are two main positions: word-initial and word-final. Browman and Goldstein [3] state that the phasing rules of syllable-initial position clusters differ from those in syllable-final positions. While the former exhibits the C-centre organisation where the two consonantal gestures are aligned globally with following the vowel in an in-phase relation [5], the consonantal gestures of the latter are organised locally in an anti-phase relation with the preceding vowel and they exhibit less gestural overlap [7, 32]. Some studies confirmed the C-centre organisation for certain clusters such as [23, 8, 33] for English, [20] for Italian, and [18] for Georgian, and even in clusters across word-boundary [36], and partially for onset clusters in Romanian [34]. Experiments on Arabic clusters did not confirm such organisation [16]; however, studies on TLA have confirmed that onset clusters exhibit more gestural overlap compared to coda clusters where the two gestures allow for epenthetic vowel [35, 37, 38].

Language perception plays a crucial role in determining the degree of gestural overlap. Specifically, language perception has priority over gestural overlap, especially in less frequent words. Chitoran *et al.* [11] conducted a study to examine the relationship between gestural overlap and perceptual recoverability in Georgian consonant clusters. Their results have shown that less overlap is preferred in syllable-initial position to enhance perception. Other studies have reached the same conclusion (e.g. [29, 3]. Another factor affecting gestural overlap is word frequency. Here more overlap is expected in words with high frequency [31].

The shape of the vocal tract of the speaker in addition to his age and gender can influence the way consonantal gestures are coordinated [30]. The acoustic differences between the speech of males and females directly result from their physiological differences, such as the size and the dimensions of the vocal tract [39]. These differences are manifested in the speed of the articulators and the duration of the vowel [40]. In a study conducted to investigate the role of gender in shaping out linguistic and stylistic conventions, Whiteside [41] found evidence that men tend to produce shorter utterances particularly in sentence-final positions. He attributes this variation to the observation that men tend shorten both vowels and consonants, whilst women tend to speak slower and to pronounce segments fully.

Several studies investigated the relationship between the dimensions of the vocal tract, the velocity of the articulators and the amount of displacement. For example, Kuehn and Moll [25] confirmed that larger displacements and greater articulator velocity have been observed in subjects with more extensive vocal tracts. In addition, Byrd's [6] results from working on the TIMIT database agree with previous results that men speak faster than women. Byrd [6] also found that more significant variability has been noticed amongst women.

The articulation rate is another factor which can influence gestural coordination. As the articulation rate increases, the duration of segments (consonants, vowels or syllables) decreases [17, 14, 1]. In addition to the duration of segments, the articulation rate can influence the degree of overlap. An in-

crease in speaking rate increases the amount of gestural overlap [4]. In normal production of stop consonants, the articulators can form a closure and maintain it. However, at a fast articulation rate, and due to their high velocity, the articulators might fail to execute the same gestures achieved at a normal speech rate. As a result, the duration of the contact is reduced. It follows then that changes in articulation rate affect the achievement of the target place of articulation, segments' duration of, the velocity of articulators [17] (p. 148). These factors can determine inter-gestural overlap and reduce the degree of constriction and overlap between the gestures [12] (p. 82). However, it is essential to note that articulation rate is influenced by the nature of articulators involved. For example, the velocity of the lower lip and the tongue-tip is not the same as the tongue-back and the upper lip with the former being faster. Thus, an increase in articulation rate will have different effects on the velocity of these articulators [22] (p. 105).

Although several studies concluded that articulatory gesture show greater overlap in fast articulation rate (e.g. [4, 10], and shorter segment duration [17, 14, 1], some studies such as [26, 25, 12] claim that the timing of certain gestures remains relatively the same regardless the change in articulation rate. In addition, the relationship between articulation rate and overlap is not always easy to pinpoint because speaking rate is not always related to gestural overlap [15, 44]. For example, gestural coordination of words sometimes remains the same despite changes in articulation rate [19].

Other studies claim that the amount of overlap is actually determined by the speaker, regardless of the articulation rate [12] (p. 95), and [24], and that an increase in articulation rate results in a shorter duration of segments but not necessarily a more gestural overlap [17]. As stated by some studies above, gestural overlap can not only be accounted for by the physiological evidence alone. The fact that speakers choose to assimilate or not in all articulation rates [21] can be taken as evidence that gestural overlap is not always determined by articulation rate.

In conclusion, how two consonantal gestures are coordinated can be influenced by many factors. The place of articulation, including sequence of articulation, has been found to influence the coordination of articulatory gestures. More gestural overlap in has been observed in front-to-back compared to back-to-front articulation. It has also been found that the position of the syllable within the word is another key factor that can determine the degree of gestural overlap. In general, onset clusters exhibit more gestural overlap than coda ones. Moreover, onset clusters exhibit the C-center organisation where the two consonantal gestures are coordinated globally with the succeeding vowel. Other factors that are crucial in determining the gestural coordination pattern are perception, gender of the speaker and articulation rate. Speakers can control the degree of overlap in their speech to ensure they are perceived correctly. For example, male and female speakers have been observed to have distinct durational and spatial patterns, primarily due to their physiological variations. Finally, an increase in articulation rate, which increases the velocity of articulators, leads to shorter segment duration and the possibility of gestural overlap.

3. Methodology

This paper evaluates the C-centre hypothesis by investigating how the articulatory gestures of two lingual stop clusters in TLA are organised. The hypothesis to be tested is that the C-center will be found in word-final clusters because the duration of singleton stops is doubled in word-final position after short vowels.

3.1. Participants and Speech Material

Five male TLA speakers participated in this study. All speakers were born in Tripoli and still living there at the time of the recording. The average age of all speakers is 28 years. The speakers reported no speech disorder of any kind. The data for this experiment consisted of four monosyllable words containing singleton stops in syllable-initial position: /gal/, /tal/, /dam/ and /tˁag/ and syllable-final position: /dag/, /nat/, /ħad/, and /batˁ/. The data contained three monosyllable words with two lingual stop clusters in onset position: /gtal/, /gdar/ and /gtˁaʕ/, and the same clusters in coda position /wagt/, /ʕagd/ and /magtˁ/. All clusters were in back-to-front articulation. These words were recorded in the frame /gu:li_____halba/ "say_____many times". All speakers produced these words three times in normal conversational speech. This means a total of 210 tokens were analysed (14 target words x 5 speakers x 3 repetitions).

3.2. Data Analysis

The data were analysed using two methods: acoustic analysis to measure the duration of the C-centre of singleton stops and two lingual stop clusters in onset and coda positions and statistical analysis to compare these durations and see if there were any significant differences between them. Figure 1 shows how the C-centre for syllable-initial singletons in the word /gal/ and Figure 2 shows how the duration of the C-center was measured in the onset cluster /gt/ in / gtal/.

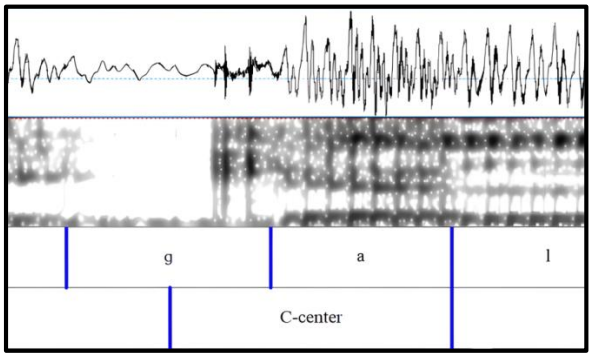


Figure 1. *Shows the measurement of the C-center of /g/ in /gal/.*

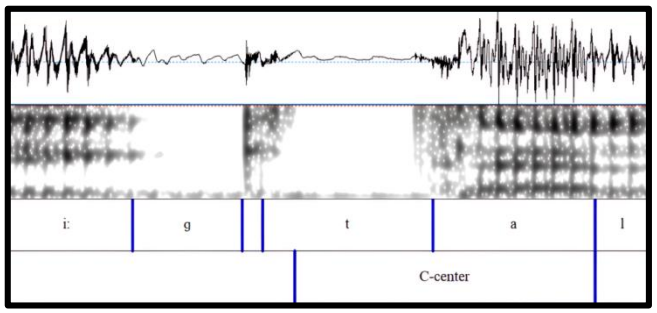


Figure 2. *Shows the measurement of the C-center of the cluster /gt/ in /gtal/.*

When singleton stops were in onset position, the C-center of word-initial was measured from the mid-point of the hold phase (between the onset of closure of the hold phase and the release of the stop) to the offset of the following vowel. The C-center of word-initial two-stop clusters was measured from the mid-point of the two consonantal gestures (between the onset of closure of the hold phase of the first stop and the release of the second stop) to the offset of the following vowel.

As seen in Figure 3, the C-center of singleton stops in coda position was measured from the onset of the vowel to the midpoint between the onset of closure of the stop and its release. The C-center of two-stop clusters in coda position is shown in Figure 4. Here, the C-center was measured from the onset of the preceding vowel to the midpoint between the onset of closure of the first stop and the release of the second [8].

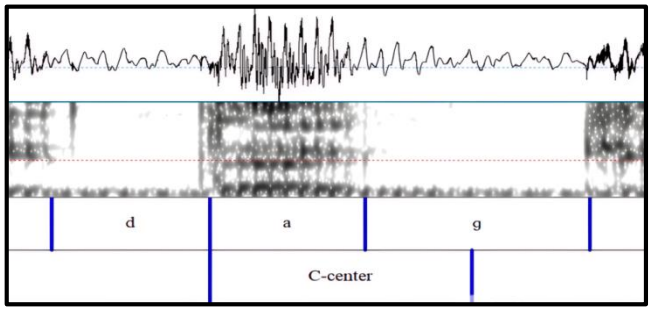


Figure 3. *Shows the measurement of the C-center of /g/ in /dag/.*

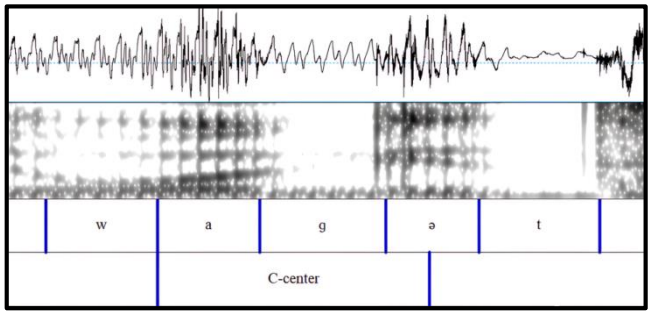
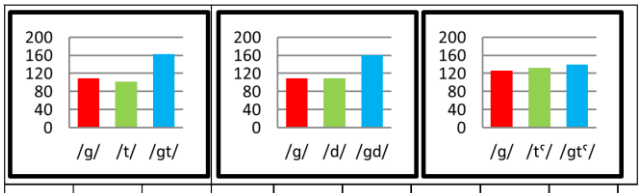


Figure 4. *Shows the measurement of the C-center of the cluster /gt/ in /wagt/.*

Finally, the statistical analysis consisted of descriptive statistics, the Shapiro-Wilk test of normality and Repeated Measures ANOVA to detect any significant differences.

4. Results and Discussions

The duration of the C-center of word-initial singletons and two-stop clusters is presented in Figure 5. The C-center of /g/,/t/,/d/ and /tˢ/ in syllable-initial is 109ms, 102ms, 109ms and 102ms respectively. There are no significant differences between these durations. In the same position, the C-center of the clusters /gt/, /gd/ and /gtˢ/ is 163ms, 160ms and 164ms. There are no significant differences between them too. However, when the C-center of singletons was compared to that of clusters, the results showed significant differences. This means that the C-center hypothesis does not hold for syllable-initial clusters in TLA (P <.005). Despite the finding that /gt/, /gd/ and /gtˢ/ do not exhibit the C-center organisation, the articulatory gestures in these clusters are more cohesive that the close transition between the release of the first stop and the onset of closure of the second stop allowed only intrusive vowels to separate these gestures.

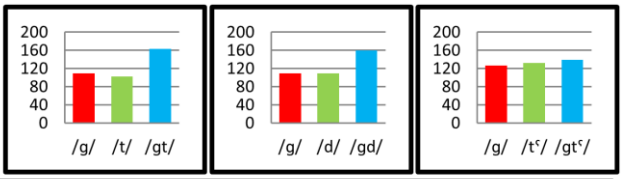


/ g/	/t/	/gt/	/ g/	/d/	/gd/	/ g/	/tˢ/	/gtˢ/
109	102	163	109	109	160	109	102	164

Figure 5. *Shows a comparison between the C-center of the singletons /g/, /t/, /d/ and /tˢ/, and clusters /gt/, /gd/ and /gtˢ/ in word-initial position.*

In coda position, the durations of the C-center of singletons and two-stop clusters are presented in Figure 6. The results show that the C-center lag for syllable-final /g/,/t/,/d/ and /tˢ/ was 126ms, 136ms, 132ms and 132ms respectively. The C-centre lag is significantly longer than the same lag for these singleton stops in syllable-initial. For the clusters /gt/, /gd/ and /gtˢ/, the C-center lag was 143ms and 141msand 139ms respectively. The Repeated Measures ANOVA test results show no significant differences between the C-center lag for syllable-final singleton and two-stop clusters (P > 0.1). This means that these clusters exhibit the C-center organisation. However, when the duration of the epenthetic vowel was added to the overall duration of the clusters, the midpoint of the two gestures shifted, and the results did not show the C-center organisation in the data. The fact that the clusters in syllable-final position have an epenthetic vowel suggests that the two lingual gestures are in an anti-phase relationship, which means that there is less attempt to align them in-phase with the

vowel than there is in onsets.



/ g/	/t/	/gt/	/ g/	/d/	/gd/	/ g/	/tˤ/	/gtˤ/
126	136	143	126	132	141	126	132	139

Figure 6. *Shows a comparison between the C-center of the singletons /g/,/t/,/d/ and /tˤ/, and the clusters /gt/,/gd/ and /gtˤ/ in word-final position.*

5. Conclusion

The main focus of this paper has been testing the validity of the C-center hypothesis on two-stop clusters of TLA. Several factors that influence articulatory timing have been reviewed. These included place and manner of articulation, syllable position, perceptual recoverability, physiological differences and articulation rate. There is an agreement in the literature about the effect of place and manner of articulation, syllable position, perceptual recoverability and physiological differences on the way articulatory gestures are organized. However, results on the influence of articulation rate are not conclusive. As for the C-center, it has been confirmed for some languages but not for others. Concerning the hypothesis, the results of the C-center analysis of TLA two-stoptwo lingual stops clusters show that onset /gt/, gd/ and /gtˤ/ do not exhibit the C-center organisation confirmed for English and other languages. The same results have been found for coda /gt/, gd/ and /gtˤ/. However, when the duration of the epenthetic vowel was deducted, coda clusters exhibited the C-center organisation. These findings suggest that TLA has two different articulatory coordination patterns. Onset coordination patterns in which the two consonantal gestures are cohesive and coda coordination patterns which allow a less cohesive gestural coordination. More systematic and large-scale studies that use more sophisticated tools, such as EPG and Electromagnetic midsagittal articulography (EMA), are needed to support these results. A possible start of future research on timing relations in TLA consonant clusters might be the study of how articulatory gestures of other two-consonant clusters, such as stop + fricative, fricative + stop, fricative + fricative, etc., are coordinated,

Abbreviations

TLA	Tripolitanian Libyan Arabic
EPG	Electropalatography
EMA	Electromagnetic Midsagittal Articulography

Author Contributions

Abdurraouf Shitaw is the sole author. The author read and approved the final manuscript.

Funding

The author did not receive any financial support for the research, authorship, and/or publication of this article.

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] Arvaniti, A. (1999). Effects of speaking rate on the timing of single and geminate sonorants. *Proceedings of the XIVth International Congress of Phonetic Sciences*, pp. 1, 599–602. San Francisco. https://repository.ubn.ru.nl/bitstream/handle/2066/225548/225548.pdf?sequence=1

[2] Bloomfield, L. (1933). *Language*. New York: Henry Holt.

[3] Browman, C. P., & Goldstein, L. (1988). Some notes on syllable structure in articulatory phonology. *Phonetica*, 45(2-4), 140-155. https://karger.com/pho/article-abstract/45/2-4/140/273854/Some-Notes-on-Syllable-Structure-in-Articulatory

[4] Browman, C. & L. Goldstein (1990). Gestural specification using dynamically-defined articulatory structures. *Journal of Phonetics*, 18(3), 299–320.

[5] Browman, C. P., & Goldstein, L. (2000). Competing constraints on intergestural coordination and self-organisation of phonological structures. *Les Cahiers de l'ICP. Bulletin de la communication parlée*, (5), 25-34. https://pascal-francis.inist.fr/vibad/index.php?action=getRecordDetail&idt=14205357

[6] Byrd, D. (1992). Preliminary results on speaker-dependent variation in the TIMIT database. *The Journal of the Acoustical Society of America*, *92*(1), 593-596. https://sail.usc.edu/~dbyrd/Byrd_JASA92.pdf

[7] Byrd, D. (1994). *Articulatory timing in English consonant sequences*. PhD. Dissertation, University of California, Los Angeles. https://www.proquest.com/openview/3f72650a20f85dd09587cf1d06088faa/1?pq-origsite=gscholar&cbl=18750&dis s=y

[8] Byrd, D. (1995). C-Centers Revisited. Phonetica 52, 285–306. https://karger.com/pho/article-abstract/52/4/285/273946/C-Centers-Revisited

[9] Byrd, D. (1996). Influences on articulatory timing in consonant sequences. *Journal of Phonetics*, 24(2), 209–244. https://www.sciencedirect.com/science/article/abs/pii/S009547096900121

[10] Byrd, D. and C. Tan (1996). Saying consonant clusters quickly. *Journal of Phonetics*, 24(2), 263–282. https://www.sciencedirect.com/science/article/abs/pii/S009547096900145

[11] Chitoran, I., Goldstein, L., & Byrd, D. (2002). Gestural overlap and recoverability: Articulatory evidence from Georgian. *Laboratory Phonology*, 7(4-1), 419-447. https://www.degruyter.com/document/doi/10.1515/9783110197105.2.419/pdf?licenseType=restricted

[12] Davidson, L. (2005). Addressing phonological questions with ultrasound. Clinical *Linguistics &Phonetics*, pp. 19, 619–633. https://www.tandfonline.com/doi/abs/10.1080/02699200500114077

[13] Dell, F., & Elmedlaoui, M. (2012). *Syllables in tashlhiyt berber and in moroccan arabic* (Vol. 2). Springer Science & Business Media. https://books.google.com.ly/books?hl=ar&lr=&id=ffj1CAAAQBAJ&oi=fnd&pg=PA13&dq=Syllables+in+tashlhiyt+berber+and+in+moroccan+Arabic

[14] Duez, D. (1999). Effects of articulation rate on duration in read French speech. *In* Sixth European Conference on Speech Communication and Technology. https://www.isca-archive.org/eurospeech_1999/duez99_eurospeech.pdf

[15] Flege, J. E. (1988). The development of skill in producing word ‐ final English stops: Kinematic parameters. *The Journal of the Acoustical Society of America,* 84(5), 1639-1652. https://pubs.aip.org/asa/jasa/article-abstract/84/5/1639/792101/The-development- of-skill-in-producing-word-final

[16] Gafos, A., P. Hoole & C. Zeroual (2011). Preliminary study of Moroccan Arabic word-initial consonant clusters and syllabification using electromagnetic articulography. In Z. Hassan and B. Heselwood (Eds.) *Instrumental Studies in Arabic Phonetics*, pp. 319, 29–45. https://www.torrossa.com/en/resources/an/5084912#page=42

[17] Gay, T. (1981). Mechanisms in the control of speech rate, *Phonetica,* 38, 148–158.

[18] Goldstein, L., Chitoran, I., & Selkirk, E. (2007). Syllable structure as coupled oscillator modes: evidence from Georgian vs. Tashlhiyt Berber. Proceedings of the XVIth International Congress of Phonetic Sciences (pp. 241-244). Saarbrücken. https://sail.usc.edu/~lgoldste/ArtPhon/Papers/Week%2011/TB-G_rev_all_jun11.pdf

[19] Goldstein, L., Nam, H., Saltzman, E., & Chitoran, I. (2009). Coupled oscillator planning model of speech timing and syllable structure. *Frontiers in phonetics and speech science*, pp-239. https://hal.science/hal-01226128/

[20] Hermes, A., M. Grice, D. Mücke and H. Niemann (2008). Articulatory indicators of syllable affiliation in word-initial consonant clusters in Italian. *Proceedings of the 8th International Seminar on Speech Production*, pp. 433-436. https://www.researchgate.net/profile/Martine-Grice/publication/228908145_Articulatory_indicators_of_syllable_affiliation_in_word_initial_consonant_clusters_in_Italian

[21] Heselwood, B., Howard, S., Ranjous, R., Hassan, Z. M., & Heselwood, M. (2011). Assimilation of/l/to/r/in Syrian Arabic. *Instrumental Studies in Arabic Phonetics*, *319*, 63. Hirose, H. and M. Sawashima, (1982). Velocity of articulatory movements in normal and dysarthric subjects. *Folia Phoniatrica et Logopaedica*, 34(4), 210–215.

[22] Hirose, H., Kiritani, S., & Sawashima, M. (1982). Velocity of articulatory movements in normal and dysarthric subjects. *Folia Phoniatrica et Logopaedica*, *34*(4), 210-215.

[23] Honorof, D. N., & Browman, C. P. (1995). The center or edge: How are consonant clusters organised with respect to the vowel. In *Proceedings of the XIIIth International Congress of Phonetic Sciences* (Vol. 3, pp. 552–555). Stockholm, Sweden: Congress Organisers at KTH and Stockholm University. https://www.coli.uni-saarland.de/groups/BM/phonetics/icphs/ICPhS199513_ICPhS_1995_Vol_3/p13.3_552.pdf

[24] Jun, J. (1995). *Perceptual and articulatory factors in place assimilation: An Optimality Theoretic approach*. PhD. UCLA. https://www.proquest.com/openview/e565fd88f42b3498d4203267df5ca007/1?pq-origsite=gscholar&cbl=18750&diss=y

[25] Kent, R. and R. Netsell (1971). Effects of stress contrasts on certain articulatory parameters. *Phonetica*, 24(1), 23–44.

[26] Kent, R. & K. Moll (1975). Articulatory timing in selected consonant sequences. *Brain and Language*, 2, 304-323. https://www.sciencedirect.com/science/article/abs/pii/S0093934X75800721

[27] Kochetov, A. and L. Goldstein (2005). Position and place effects in Russian word-initial and word-medial clusters. *Journal of the Acoustical Society of America,* 117(4), Pt. 2. 2571.

[28] Kuehn, D. and K. Moll (1976). A cineradiographic study of VC and CV articulatory velocities. *Journal of Phonetics*, 4, 303-320. https://www.sciencedirect.com/science/article/pii/S0095447019312574

[29] Kühnert, B., Hoole, P., & Mooshammer, C. (2006). Gestural overlap and C-center in selected French consonant clusters. In *7th Speech Production Seminar*. (Ubatabu, Brésil). https://hal.science/hal-00149250/

[30] Laver, J. and P. Trudgill (1991). Phonetic and linguistic markers in speech. In J. Laver (ed.), *The Gift of Speech: Readings in the analysis of speech and voice*. Edinburgh: Edinburgh University Press. 235-264.

[31] Lin, S., P. Beddor and A. Coetzee (2011). Gestural reduction and sound change: An ultrasound study. In *ICPhS XVII: Proceedings of the 17th International Congress of Phonetic Sciences*. 1250-1253. https://www.internationalphoneticassociation.org/icphs-proceedings/ICPhS2011/OnlineProceedings/RegularSession/Lin,%20Susan/Lin,%20Susan.pdf

[32] Marin, S. and M. Pouplier (2008). Organisation of Complex Onsets and Codas in American English: Evidence for a Competitive Coupling Model. *Proceedings of the 8th International Seminar of Speech Production*, Strasbourg. https://d1wqtxts1xzle7.cloudfront.net/79162737/MarinPouplierIssp2008-libre.pdf?1642689194=&response-content

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

[34] Marin, S. (2011). Organisation of complex onsets in Romanian. In *Proceedings of the 9th International Seminar on Speech Production, Montreal* (pp. 179–186). https://journals.humankinetics.com/view/journals/mcj/14/3/article-p380.xml

[35] Plug, L., Shitaw, A., & Heselwood, B. (2019). Inter-consonantal intervals in Tripolitanian Libyan Arabic: Accounting for variable epenthesis. *Laboratory Phonology: Journal of the Association for Laboratory Phonology*, *10*(1). https://eprints.whiterose.ac.uk/143089/8/122-2941-1-PB.pdf

[36] Pouplier, M., & Marin, S. (2008). Articulatory coordination in German and English onset and coda clusters. *The Journal of the Acoustical Society of America*, *123*(5_Supplement), 3329-3329.

[37] Shitaw, A. (2013). Gestural phasing of tongue-back and tongue-tip articulations in Tripolitanian Libyan Arabic. *Leeds Working Papers in Linguistics and Phonetics*, *18*, 114-131. https://www.latl.leeds.ac.uk/wp-content/uploads/sites/49/2019/05/ Shitaw_2013.pdf

[38] Shitaw, A. E. (2014). *An Instrumental Phonetic Investigation of Timing Relations in Two-stop Consonant Clusters in Tripolitanian Libyan Arabic* (Doctoral dissertation, The University of Leeds). https://etheses.whiterose.ac.uk/7445/1/An%20Instrumental%20Phonetic%20Investigation%20of%20Timing%20Relations%20in%20Two-stop%20Consonant%20Clus-ters%20in%20Tripolitanian%20Libyan%20Arabic.pdf

[39] Simpson, A. (2001). Dynamic consequences of differences in male and female vocal tract dimensions. *Journal of the Acoustical Society of America*, pp. 109, 2153–2164.

[40] Simpson, A. (2002). Gender-specific articulatory-acoustic relations in vowel sequences. *Journal of Phonetics*, 30(3), 417–435.

[41] Whiteside, S. (1996). Temporal-based acoustic-phonetic patterns in read speech: Some evidence for speaker sex differences. *Journal of the International Phonetic Association,* pp. 26, 23–40.

[42] Watson, J. (2002). The phonology and morphology of Arabic. Oxford: Oxford University Press.

[43] Zhao, S. (2003). *Gestural overlap of stop-consonant sequence.* PhD. Dissertation, Massachusetts Institute of Technology. https://dspace.mit.edu/handle/1721.1/29728

[44] Zsiga, E (1994). Acoustic evidence for gestural overlap in consonant sequences. *Journal of Phonetics*, pp. 22, 121–140. https://www.sciencedirect.com/science/article/pii/S0095447019301895