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# The Spatiotemporal Variables as a Domain for Gestural Overlap of Consonant Sequences in Modern Standard Arabic

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**Abstract:** *Segments both consonants and vowels are the basic linguistic units in the hierarchical prosodic structure. They are asymmetrically distributed to form syllables, feet and words. When they are adjacent, consonant segments may form well-formed or ill-formed sequences. Ill-formed ones are harmful or difficult to be produced as a result a gesture of sequential segments submits to lenition or reduction so as to be overlapped to reduce its difficulty. The primary goal of this study is to examine how consonant segment gestures are drawn in relation to their perceptual components in the phonological component of grammar, specifically how the spatial and temporal dimensions of articulators are used. This phonological representation needs to specify certain positions in the movement track of gestures that are onset time, target or constriction, level off period and the offset time. Gestural overlap of adjacent segments in prevocalic, intervocalic or postvocalic positions depends on the point at which the onset time of C2 gestural landmark starts during the movement track of C1 gestural landmarks. To provide an appropriate setting for coordinating interactions between the dynamic aspects of gestures, these gestures satisfy perceptual recoverability. For the purpose of perceptual recoverability, data analysis relies on insights from articulatory phonology (Browman and Goldstein, 1986) to describe how these dynamic gesture variables impact the creation of those clusters*.

**Keywords:** spatiotemporal variables, domain, gestural overlap, consonant sequences, modern standard Arabic

## INTRODUCTION

Articulatory phonology, a trend of phonological theory, deals with lexical units in terms of physical interrelated real events and the characterization of systems and patterns in which these units or gestures enter (Browman and Goldstein, 1992). In normal speech, segments the most important phonological units are perceived in a connected form due to the overlap of their articulatory gestures (Browman and Goldstein, 1989, 1990). The abstract property of spatiotemporal coordinated movements of the articulators that are organized into larger contrastive units within which the temporal relations are considered the dynamic dimension of linguistic form that the phonological knowledge refers to (Gafos, 2002).

Since each unit of phonological representation or gesture has internal temporal structure to form spatiotemporal event (Browman and Goldstein, 1986), gesture is dynamic in a sense its states or landmarks, the internal temporal structure of the gesture, change in time. Gestures pass through four temporal relations of overlap which

are the landmarks; onset, target, release and offset that clear up the internal temporal structure of the gesture. As the temporal structure is accessible to phonological grammar such as temporal coordination relations of overlap between gestures of different segments, there is synchronization between one landmark in the temporal structure of the first gesture and another in the temporal structure of the second gesture.

Because the temporal patterning is the variable aspect of speech (Gaitenby, 1965 and Klatt, 1976), coordination of systematic articulatory patterns that shows the temporal variability is sensitive to recover the intended linguistic units from the acoustic signal. It is characterized by expressing timing relations in terms of dynamics and phasing. Temporal overlap of consonant gestures depends on some phonological properties such as position of the consonant sequence ( onset, intervocalic, coda) where onset consonant gestures show less temporal overlap than that of intervocalic or coda (Byrd, 1996a) whether they are satisfying or violating sonority profile and the order of place of articulation; front-to-back order as in labial-coronal, coronal-dorsal and labial-dorsal places and back-to-front order as in dorsal-coronal, coronal-labial and dorsal-labial places. Front-to-back order allows more overlap than back-to-front as the latter's C2 constriction precedes its C1 constriction and C1 gesture is hidden by C2 gesture. Differences in positions of consonant sequences and order of place of articulation have influenced the gestural coordination that the listener needs in terms of perceptual recoverability. The less the perceptual recoverability of C1 compromised, the more the gestural overlap in its position will be.

**Research problem**
In connected speech form, speakers face some sort of difficulties in manipulating some of adjacent segments as they violate phonotactic parameters of prevocalic, intervocalic and postvocalic positions of these sequences.

**Research aim**
Verbal gestural overlap in spatiotemporal variable domain that result in hiding, blending, assimilation or insertion aimed at facilitating connected speech to communicate meaningful messages.

**Research objectives**
1-To specify the directionality and place of both adjacent segments of a sequence that violate language specific phonotactics and constitute difficulty in in pronouncing these sequences.
2-To make speech more connected and speaker more fluent.

**Research questions**
1-What does consonantal adjacency result in?
2-What is the environmental in which movements are coordinated?
3-What do the abstract features of coordinated movements stand for?
4-What is the realization of speech sounds conditioned by?
5-What affects gestural overlap?

In connected speech sounds, phonemic adjacency constrains phonetic manifestation so consonantal adjacency in prevocalic, intervocalic and postvocalic positions is in need of accurate coordination of the movements of the articulators that results in deletion, assimilation, blending and insertion. The movements of articulators in the oral cavity during a point of time that represent the spatiotemporal environment are coordinated and the abstract features of these coordinated movements are called verbal gestures. During speaking, fast or casual, these verbal gestures are overlapped so gestural overlap may be increased or reduced depending on the variables of time and space.

When one articulator does two different gestures in two different closure locations, gestures are overlapped. Since the two different events are in the same articulatory tier or structure, movements of the same articulator are disturbed so the two overlapped gestures are blended as in /ʔun.θa:/ 'female'.

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There are some factors that affect the degree of gestural overlap; 1) the place of articulating two adjacent consonants C1C2 assures that the closure time of C2 starts before the closure time of C1 hence front-back sequences are more overlapped than back-to-front ones so in /mab.da?/ 'principle', the gesture of /b/ is hidden by that of /d/. 2) In Arabic, word internal sequences as well as boundary sequences are both equally overlapped. If two coordinated landmarks change in favorer of the time of the first gesture, more overlapped is fulfilled so a change in moment rate gives enough motivation for a change in coordinated movements. 3) sequences in more frequent words are more overlapped.

**Gesture specification**

Gestures are specified by task dynamics, the motion of tract variables for forming and releasing constrictions by set of articulators that are organized in coordinated structures. It has two dynamic dimensions; the spatial dimension that has two parameters, the constriction location that is specified by the tract variables which are independent of each other to separate a gesture for each variable and the degree of that constriction as well as the temporal dimension which computes the time domains or land marks starting from the time point of the onset movement of the articulators towards the target, the point in time when the articulator achieves the target which is the constriction location that is held for some time, the plateau, and the point in time when the articulator releases. Finally, the point in time when the activity of the gesture vanishes or offsets.

When one of the internal temporal landmarks of one gesture is synchronous with specified landmark of another gesture, the two gestures are in coordinated relation through which gestures of different segments will be overlapped, in another words achieving the target of the first gesture is synchronous with the onset movement of the second gesture. Degree of overlap can be measured by the proportion of the coextensive C1 target with the unfolding C2 onset gesture in accordance with the following formula, overlap= 1- (C2 onset- C1 target)/ C1 plateau. More than 1 means more overlap in a sense C2 onset unfold before C1 target or closure phase. Less than 1 means less degree of overlap that is C2 onset unfolds after C1 target exactly in the center of C1 plateau. At 0 means C2 onset occurs at the same time of C1 release whereas less than 0 means no overlap between the two gestures as C2 onset occurs after the release of C1. This can be shown in figure (1) that shows the phonological representation of the two gestures taken from Gafos, Zeronal and Roon, 2010.

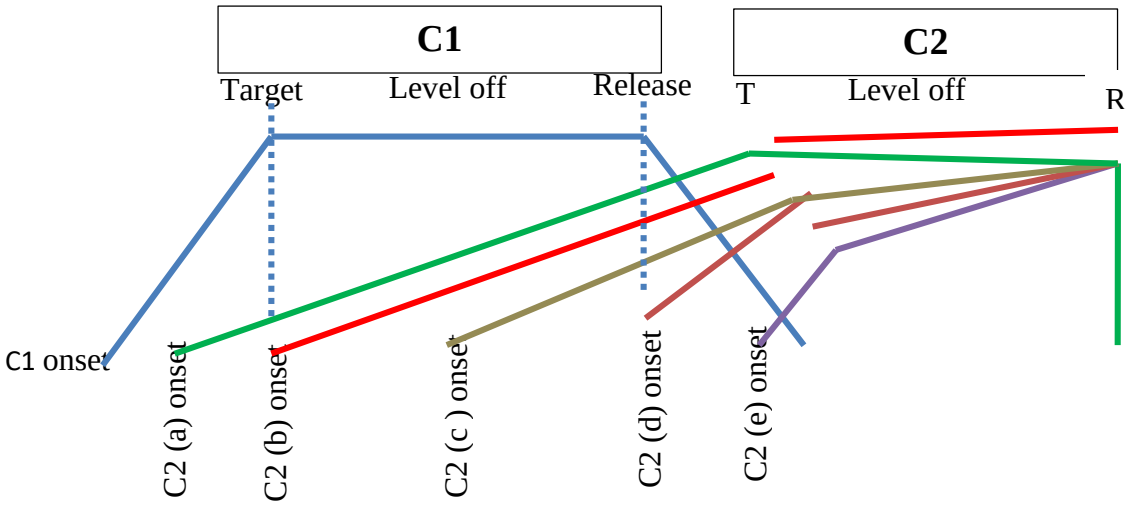


**Figure (1) Degrees of overlap**

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Phonetic realization of connected speech sounds is specified by the contiguous segments that may form well or ill- formed clusters in pre, post or intervocalic position. Asymmetrical relationship between segments of these clusters is represented by the abstract properties of these segments each of which is characterized by its place of articulation and duration that may make these gestures overlap (Catford, 1977). Speakers of any language tilt to ease of producing these sequences through assimilation (Browman, 1995) due to complete or partial overlap of the target gesture compared with the temporal extension of the trigger gesture. The process of overlap is affected by the variables of frequency and rate as the high the speed of pronouncing, the more the overlap will be.

**Arabic phonemes**

Modern Standard Arabic is characterized by 28 consonant segments that are divided into two groups, fourteen Shamsy letters (/t/, /ŧ/, /d/, /dˢ/, /Ɵ/, /ɚ/, /ɚˢ/, /s/, /ʂ/, /z/, /S/, /l/, /r/, /n/) and fourteen Qamary letters (/b/, /k/, /q/, /ʔ/, /f/, /x/, /ɣ/, /ɦ/, /ç/, /h/, /J/, /m/, /w/, /Y/ ) on the basis of their effect on the segment /l/ of the prefixal definite article [ʔal], 'the'. Speakers of MA for instance always assimilate the segment /l/ of the definite article /ʔal/ 'the' before the Shamsy letters. In fact the segment /l/ is not deleted from its position in the syllable but it is phonologically co-articulated due to the reduction in the internal structure of the segment so as to be overlapped (Hardcastle, 1985) with the juxtaposed Shamsy letters as in /ʔal.ʃams/ → /ʔaʃ.ʃams/ 'the sun' the segment /l/ is totally assimilated into /ʃ/ in the context of the following /ʃ/ as a result they form geminated segments or long segment rather than a sequence as in figure (1) C.

In homorganic stops of MA as in /mak.tab/ 'office', the closure release of /k/ is delayed until the closure of /t/ is formed (ladefoged, 2001) as a result /k/ is formed only and /t/ is released forming long segment instead of a sequence due to their overlap like the previous example.

MA intervocalic sequences of two heterorganic voiced alveolar nasal and bilabial stop (n-b) form a harmful clusters as in the word /yan.bu:ç/→ /yam.bu:ç/ 'fountain', the alveolar nasal is bilabialized by the the bilabiality of the following voiced bilabial stop so /n/ is not deleted but assimilated due to the lenition or reduction of its gesture to form homorganic or two adjacent segments at the same place of articulation to soften the difficulty of pronouncing them. The time of onset movement for /b/ starts at the period of /m/ constriction location due to the overlap (Nolan, 1992) of the two segments as in figure (1) b.

In order not to be harmful, adjacent segments (Byrd and Tan, 1996) of MA sequences, back-to-front or front-to-back, have to be in places of articulation separated by a step or more. In case they are of adjacent places, one of them is submitted to lenition or reduction so as the two are overlapped partially or totally (Zsga, 2000) depending on the position C2 gestural landmark, onset, takes in the movement track of C1 gestural landmark, the target. If we take for instance the word /man.faɚ /→ /maŋ.faɚ/ 'gate', /n/ is assimilated into the allophonic variation [ŋ] in the context of the following /f/ due to the reduction of its internal structure and becomes labio-dentalized nasal instead of alveolar one. Acoustically (Zsga, 1994), the onset landmark position of /f/ gesture comes before the target landmark position of /n/ gesture altering its alveolarity into labiodentality of /f/ that results in a sequence overlap as in the phonological representation in figure (1) C2a.

In case onset time of C2 gestural land mark follows the release time of C1 gestural landmark, gestures of C1 and C2 are in very weak overlap, in a sense they are synchronously produced one after the other as in the following phonological representational figure of the word /yaʂ.qɪŧ/ 'fall down' in which /q/ is perceived after the release time of /ʂ/ as a result the gestures are harmlessly produced and spontaneously perceived as in figure (1) C2e.

**Dynamics of gestural overlap**

The way different articulatory movements or gestures are coordinated or working together in time to produce clusters of consonants is the dynamics of gestural overlap. The dynamics controls the kinematics of verbal gestures is the stiffness of that gesture and the extent or degree to which these gestures are overlapped temporally

is specified by the overlap measures so gestural stiffness and overlap measures give deep understanding to the dynamics of speech production. Overlap measures of a consonant sequence such as stop- lateral (C1C2) are specified by four assorted temporal intervals, each determined by a landmark from C1 (release or offset) and one from C2 (onset or target). The four overlap measures are labelled by horizontal curly brackets and computed by subtracting the time stamp of C1 landmark from the timestamp of C2 landmark as in the following figure taken from Uu Shihao and Kuberski Stephan.

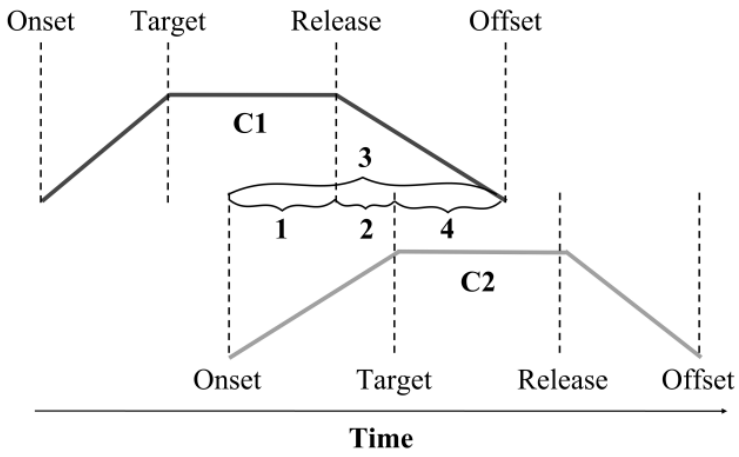


Figure (2) Overlap measures.

Stiffness parameters can regulate verbal gestural overlap in sequences of consonants as in the above mentioned sequence (C1C2), C1 opening stiffness and C2 closing stiffness. Closing stiffness of C2 has mor important effect on overlap than opening stiffness of C1.

## CONCLUSION

It is concluded that some segments of consonant sequences in MA that are harmful are just like the physical substance. They are not perished or created but altered from shape to another so segments of MA that are adjacent in inter or post-vocalic position of a syllable can form ill-formed sequences as a result they are partially or totally assimilated due to their overlap. Speakers of Arabic appeal to such process to avoid difficulty in pronouncing these sequences and to satisfy fluent, interpretable speech. Frequency of words containing such sequences and the rate of pronouncing them affect the degree of their overlap that is proved by the spectrographic analysis of selected words and diagrams that show the phonological representation of the overlap.

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