COARTICULATION IN APHASIA: PRELIMINARY FINDINGS FROM ARABIC

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ABSTRACT

There are still crucial gaps in our knowledge about Arabic- speaking aphasics' coarticulation patterns. This study examines the coarticulation patterns of Arabic speakers with Broca's aphasia's speech patterns, and compares the results to those of the control subjects, using Phono-Lab software for the acoustic analysis of the formant values. The participants were speakers of Palestinian Arabic. Consonant-vowel syllables were presented in a carrier phrase. The control subjects and Broca's aphasics demonstrated different coarticulation patterns. The results suggest that Broca's aphasics demonstrated inefficient and imprecise timing of the articulatory movements of the adjacent segments. The results indicated that speech therapy programs should take the complexity of the words used when designing such programs into account.

Keywords: Coarticulation in Arabic aphasic speakers, Arabic language, acoustic analysis, formant movements, Palestinian Arabic, speech pathology.

INTRODUCTION

It is a well-known fact that speech sounds are not produced in isolation, but in highly complex configurations and sequences. Coarticulation refers to the articulatory overlapping, both temporally and spatially, of adjacent consonants and vowels in connected speech (Öhman, 1966; Duez, 1992, Lehiste, 1972; Sussman, Duder, Dalston, & Cacciatore, 1999). For example, in the pronunciation of the word 'bu' ([du]), a speaker will begin the articulatory overlap by rounding the lips in anticipation of the rounded vowel [u] before the stop [b] is released (Ladefoged & Johnson, 2006; Mok, 2013).

Research has shown that coarticulation refers to the mature motor control of articulators during connected speech, while the lack of coarticulatory adjustments and dynamic transitions of the articulators when speaking reflects deficiencies in motor planning and programming (Fowler and Saltzman, 1993; Ziegler & Maassen 2007; Derrick, Stavness, & Gick 2015). Daniloff and Hammarberg (1973) indicated that coarticulation could be seen as a manifestation of the interaction between the articulatory and acoustic features of a segment, thus demonstrating the impact of the phonetic context on a particular segment. Studies of speech motor control have demonstrated that several coarticulatory mechanisms take place during speech production, including the tongue, the larynx, the velopharyngeal and articulatory subsystems, the lips and the jaw (Hardcastle and Hewlett 1999). In essence, two main types of coarticulation have been addressed: Perseveratory coarticulation runs from left to right and anticipatory coarticulation runs from right to left (Öhman, 1967; Keating, 1985; Guenther, 1995). However, anticipatory coarticulation has been investigated intensively because it is related to the articulatory planning of upcoming speech sounds in terms of producing well-coordinated speech segments that overlap in time during the process of speech production (Modarresi, Sussman, Lindblom, & Burlingam, 2004).

The coarticulatory processes also differ according to whether they are more active or passive in nature. The process is described as active if it is motor planned, programmed and controlled. However, the process will be passive if it is mainly generated by the physical properties of the articulators and is not initiated by motor planning. For example, when producing the syllable [do], the speakers will begin lip-rounding at the consonant [d] in anticipation of the rounded vowel [o]. However, when producing the syllable [di], no lip-rounding will occur.

Coarticulation can be seen as indicative of the correlation between the articulatory and acoustic properties of a segment, a consonant, or a vowel that is found to be functionally different in a segmental context, thus reflecting the dynamic transitions between the adjacent segments (Katz, Kripke, & Tallal, 1991; Frnetani & Recasens, 1993). However, it is worth mentioning that languages demonstrate various patterns and directions of coarticulation (Hardcastle & Hewlett 1999; Manuel, 1990).

Research has revealed controversial results concerning coarticulation in aphasia, particularly in terms of the extent of anticipatory coarticulation between groups of fluent and non-fluent aphasic patients compared to normal control subjects (Katz, Machetanz, Orth, & Schoenle 1990; MacNeilage, & Hutchison, 1988; Katz 2000; Hallowell 2017; Haley, Smith, Wambaugh, & Wambaugh, 2019; Webster & Morris, 2019). For example, in an earlier study, Katz' (2000) acoustic and perceptual analysis of monosyllabic stimuli produced by anterior and posterior aphasic subjects reported no evidence of a deficit in anticipatory coarticulation.

Electromyography (EMG) studies have shown that patients with Broca's aphasia demonstrate anticipatory coarticulation patterns (Sussman et al, 1988). However, Tuller and Story (1988) found that Broca's aphasics were partially unable to conduct anticipatory labial coarticulation compared to normal speakers. Similar findings have also been reported by Ziegler and von Cramon (1985). Moreover, other results reported by Mayer (2005) revealed a significant reduction in vowel-to-vowel anticipatory coarticulation in the speech of Broca's aphasics. In fact, there is some acoustic evidence that the acoustic parameters are actually correlated with coarticulation.

The acoustical effect of this gestural overlap can be seen clearly in the values of the formant frequencies at the boundary of [d] and [u]. Specifically, the second formant frequency at the boundary of [d] demonstrates a significant correlation with the vowel target, hence reflecting anticipatory articulation. Furthermore, lip-rounding has been found to be associated with lowering of the formant frequencies. Further evidence that the formant frequencies are related to the length of the vocal tract has been provided. Since lip-rounding takes place at the end of the vocal tract, a lowering in the formants is noticed. The lip-rounding effect is seen more clearly in the second (F2) and third (F3) formants than it is in the first (F1). Generally speaking, F1 is related to a vowel's height. The higher the vowel, the lower F1. However, F2 generally corresponds to the backness of a vowel. The farther back the vowel, the lower the F2.

The aim of this study was to investigate the speech patterns of Broca's aphasics who spoke Palestinian Arabic and to compare them to the control group. To best of the author's knowledge, this is the first study to investigate the coarticulation patterns of Arabic-speaking Broca's aphasics. It examined the coarticulation patterns of the aphasic subjects under study in a spontaneous multisyllabic phonetic environment with bilabial and fricative initiations. The formant values for F2 and the F3 were measured. The results, including the formant values and the coarticulation patterns, will be discussed and compared with findings pertaining to other languages.

METHODOLOGY

Participants

Five male aphasic subjects, who were native speakers of Palestinian Arabic and lived in the West Bank, with an average age of 51.42 years (range= 47-56 years), participated in the study (Adam, 2014). They were diagnosed with mild to moderate Broca's aphasia. The diagnoses were based on an adapted version of the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1983) and the Bilingual Aphasia Test (Jordanian-Arabic version; Paradis 1987). The time post-onset ranged from one to eight years and their levels of education ranged from 10 to 15 years. The subjects were predominately right-handed and had suffered a single, left-hemisphere lesion. All the speakers had normal hearing with no evidence of dysarthria, cognitive deficits, or visual impairments. Five native speakers with no language or speech impairments served as the control group. They were predominately right-handed and were roughly matched to the aphasic subjects in terms of age and education.

Procedure and Analysis

The speech sample included a word list of the target vowels (/u/) with fricative initials embedded in CVC utterances. Carrier sentences were used to initiate the words in order to produce the target vowels at a normal pitch and volume. The examiner provided the stimulus words, and each subject was instructed to repeat the tokens using the expression "ʔi ħki" ("Say"). The subjects were instructed to repeat the sentence as clearly and naturally as they could. If an aphasic subject was unable to produce the target word, the experimenter produced the token and asked the subject to repeat it. If the aphasic subject would not attempt to repeat it after the experimenter's modeling of the target word, that token was set aside and attempted once again at the end of the session. Real words were used whenever possible; otherwise, nonsense words matching the same structure of real words were provided. There were 300 tokens in total (10 words x 3 repetitions x 10 subjects). For the purposes of the study, repetition tasks were used in order to minimize the effects of language comprehension and reading difficulties, in addition to any problems with the motor planning required for intelligible responses (Kempler & van Lancker, 2002).

Vowel duration was measured in milliseconds (ms). Vowel onset was defined from the point at which the aperiodic energy was accessed until the onset of periodic energy was above 1000 Hz. Participants' responses were recorded in a quiet room using a high-quality microphone positioned around 15 centimeters from the participants' mouths. The formant frequencies F2 and F3 were measured automatically using Phono-Lab (Metoui, 1995). Formants were measured 10 times for each vowel, and the data were recorded using a sampling rate of 16Hz at 16bits. The mean average of the formants obtained from the normal speakers was considered as a point of reference.

RESULTS AND DISCUSSION

Table 1 provides the F2 and F3 values produced by the control subjects. The acoustic analysis clearly shows the formant transitions of the vowel [u] after the fricative [ʃ]. As shown in Figure 1, lowering of the F2 to about 1600Hz can be noticed. This indicates strong acoustic evidence for lip-rounding during the production of [ʃ] in anticipation of the vowel [u]. Furthermore, the transition of [u] to [b] was characterized by the lowering of F2 and the raising of F3.

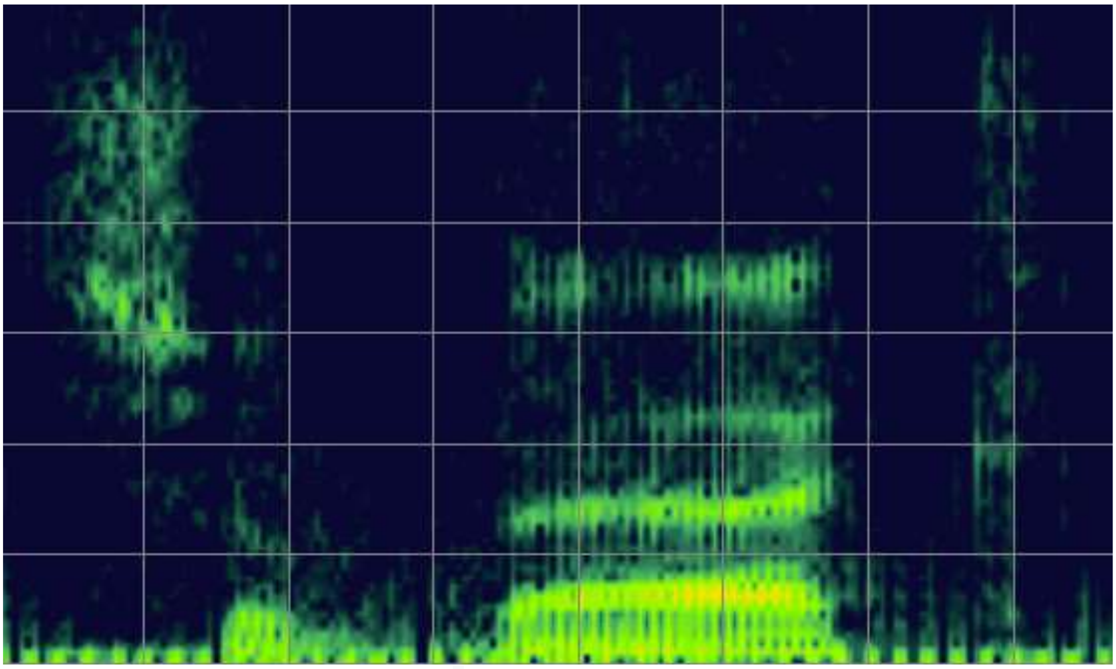

Figure 1. Spectrogram of the word [ʃuba:k] 'window' as produced by one of the control subjects.

Control Speakers	F2	F3
C1	1620	2872
C2	1650	2869
C3	1668	2887
C4	1633	2890
C5	1642	2882

Table 1. F2 and F3 values (Hz) in the phonetic environment [ʃu] for five control speakers (S), indicating normal coarticulation patterns.

By contrast, the aphasic speakers demonstrated different coarticulation patterns and formant values from those the control subjects. For example, Figure 2 shows the differences from the productions of the control subjects. It can clearly be seen that the spectral shape produced by the Broca's aphasics was different. Furthermore, the transition from [ʃ] to [b] was also characterized by an abruptness in the amplitude. Moreover, the energy spread across a wide bandwidth in contrast to the control speakers. The intensity average for the aphasics' productions of [ʃ] was 57dB, whereas it was 66.2dB for the normal speakers, displaying low pressure in Broca's productions.

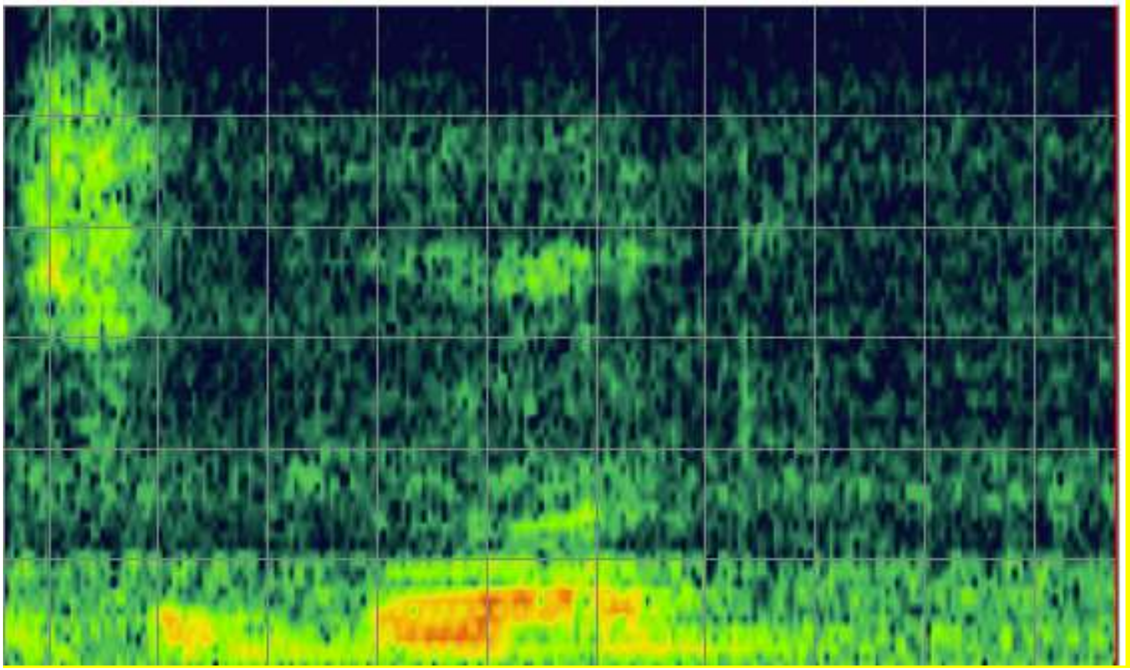

Figure 2. Spectrogram of the word [ʃ uba: k] as produced by an aphasic subject.

The spectrograms of the Broca's aphasics revealed weak concentrations of energy compared to those of the control speakers, whose spectrograms exhibited dark areas even at high frequency ranges. Accordingly, the normal speakers exhibited these dark areas in the frequency range of 3000Hz, whereas they were distributed randomly for the aphasic speakers. Therefore, it is difficult to speak of formant transitions, particularly from [b] to [a], compared to the normal patterns. However, it is worth highlighting that a transition from [a] to [k] can be seen. The lack of dynamic movement in the transitions suggests a lack in the movement of the tongue, thus indicating coarticulatory limitations.

Furthermore, the results showed a significant increase in F2 and F3 as produced by the Broca's aphasics in the same phonetic environment as that of the normal speakers.

Aphasic Speakers	F2	F3
B1	1865	3110
B2	1988	3218
B3	1890	3165
B4	1869	3190
B5	1970	3199

Table 2. F2 and F3 values (Hz) in the phonetic environment [ʃu] for the five Broca's aphasia subjects under study (B).

If we examine the changes between the F2 and F3 values produced by the Broca's aphasics compared to the control subjects, it could be difficult to find coarticulatory patterns being produced by the Broca's aphasics. Therefore, this anticipatory coarticulation requires the lip-rounding to begin during consonant production preceding a rounded vowel. Accordingly, the lack of formant frequency lowering in the environment [bu] or [ʃu] could suggest that these patients realized [u] independently of the phonetic context. Furthermore, the tendency toward a centralization of the vowels and the tightly packed formants could suggest coarticulatory limitations in the prevocalic environment.

Given the fact that coarticulation might be considered to be a reliable factor of studying speech intelligibility through conducting articulatory adjustments and keeping to the spatiotemporal aspects of the speech production, it is perhaps not surprising that the anterior aphasics' inability to maintain fine-grained adaptations and modifications in articulators make their speech less intelligible. Overall, these findings shed light on the nature of the errors made by Broca's aphasics. They demonstrate initiation problems at the level of the utterance or single sound, suggesting that sound structure and motor complexity will be challenging for those patients due to the fact that this requires more motor control planning in order to make accurate productions.

This preliminary study has provided direct evidence to support the role of motor coordination in processing abilities for speech production and timing. Accordingly, anticipatory coarticulation requires simultaneous coordination and fine programming of more than one independent articulator, which is most likely distorted in the anterior aphasics. The findings of the current study are supported by those of many previous studies of other languages, demonstrating that anticipatory coarticulation was not remarkable in the speech of Broca's aphasics when compared to the speech of normal speakers.

CONCLUSION

The results of current study suggest that patterns of coarticulation in aphasics' speech are somewhat complex. Specifically, the speech of Broca's aphasics displayed a lack of formant frequency lowering in the environment of [bu] when compared to the normal speakers, who experienced a lowering in the formant frequency. The results suggest that Broca's aphasics demonstrated inefficient and imprecise timing of the articulatory movements of the adjacent segments. This implies spatiotemporal deficits in the speech production process. Furthermore, their anticipatory errors could be related to a deficit in the laryngeal abduction-adduction mechanism. In addition, the results lead to the conclusion that Broca's aphasics display deficits in the interarticulatory organization of consonantal sequences, thus reflecting impairments in the dynamic transitions between adjacent segments in a particular context. Furthermore, the findings of the current study suggest that methods of speech therapy should focus on the integration level between the sounds while establishing a hierarchical complexity. That is, speech pathologists should take the complexity of the words into account by progressing from monosyllabic to disyllabic words, and so forth.

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