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EPG Study of the Fricative Consonants [s] and [ʃ] in Uyghur

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Abstract: The principal aim of this investigation was to explore articulatory properties of two fricatives in Uyghur, in order to gain insight the differences of place of articulation and the influences of surrounding vowel. To this end, articulatory effects of adjacent vowel [a, i, u] were measured at four different time points in CV syllable. Linguopalatal contact patterns derived from electropalatographic recordings were used in this study. The articulatory mechanisms of sibilant fricatives /s/ and /ʃ/ in Uyghur were investigated in this paper, so as to find that /s/ was alveolar while /ʃ/ was alveopalatal in constriction place formed in oral cavity. In terms of coarticulatory effect of following vowel on the production of fricatives, the former was affected by rounded, back vowel/ u / while the latter was affected by front, high vowel/i/. In terms of front-back dimension, articulatory movement of both fricatives in alveolar region was most stable while it was vulnerable to articulatory effect of vowels in palatal region. In terms of different articulatory times (phases), the point of maximum contact was the most stable one for both fricatives.

Keywords: EPG, Fricative Consonants, Place of Articulation, Uyghur

1. Introduction

Modern Uyghur has an inventory of twenty-four consonant phonemes [1] and seven pairs of voiceless and voiced counterparts. Consonant /s/ is voiceless, alveodental fricative and consonant /ʃ/ are voiceless with alveopalatal fricative [13]. Another opinion on the description and distinction between these two consonants is that, /s/ is apical-alveolar that characterized with higher spectral COG value around (6455Hz) for male and (6532Hz) for female speaker and /ʃ/ is palatal-alveolar with lower spectral COG (3963Hz, 4542Hz) for male and female speaker respectively. Meanwhile, the influence of following vowel is different in terms of acoustic points of view [13]. This shows the unclear understanding on the above fricatives discussion, which explores the differences in place of articulation and tongue configuration between two sibilant fricatives [s] and [ʃ] in Uyghur in terms of articulatory phonetics.

Place of articulation in the vocal tract is important cue to describe consonants, that is, the location of place of greatest constriction. Similar consonant segments which have comparable places of passive articulation, differing in the shape taken by the active articulator, especially the tongue. In particular, a difference is usually made between segments articulated with the tongue tip up (apical) and those with the tip down and the blade making contact on the upper surface (laminal) [1]. Fricatives differ from sonorant consonants and vowels as well as semivowels in formant structure. They are produced by forming a constriction in the vocal tract that causes turbulence frication which in turn generates noise-like sound [2]. The gesture forming the constriction of fricative /s/ has a greater degree of articulatory precision for making with both lingual and dental sources [3], and a variation of one millimeter in the position of the target for the crucial part of the vocal tract can build a great deal of difference. There has to be very precisely shaped channel for a turbulent airstream, for example, resonances of appropriate [s] could be invoked with an electrical circuit that modeled a 5-mm lingua-palatal constriction and a 10-mm front cavity [4]. The articulatory differences for sibilant consonants /s/ and / ʃ /is that a 5-mm front cavity length can produce [s]-like noise; a 15-mm cavity can produce [ʃ]-like noise [5].

[1] In some literature [12], the number of consonants is twenty-five, in fact glottal plosive /ʔ/ has no functional load in Modern Uyghur, so twenty-four is more appropriate one according to function of this phoneme

Fricative sounds may be characterized by the turbulence generated at the constriction itself, or they may be characterized by the high velocity jet of air formed at a narrow constriction to strike the edge of some obstruction such as the teeth. The latter type is sibilants [6], whose fricatives are stable consonants at production level in different contexts. The sibilants also have an advantage in perceptual level because of their greater amplitude in the higher frequencies in relation to surrounding vowels [7].

1.1. Articulatory Property of [s, ʃ]

X-ray trace shows that the main pronunciation difference between /s/ and/ ʃ/ is the amount of space between the tongue and teeth. The tongue tip is just behind the teeth for /s/, sometimes resting against the lower teeth, holding the tongue blade against the alveolar ridge, forming a narrow channel. The tongue tip is raised for /ʃ/, forming a slightly wider channel against the posterior part of the alveolar ridge. A significantly large cavity can exist between the tongue and teeth [3, 5, 7]. This study explored an investigation on the articulatory characteristics of sibilant fricatives in one Uyghur speaker. The following were one of the particular interest: As for the articulatory property of the contrast between the sibliant fricatives /s/ and /ʃ/, the greater amplitude of [s] and [ʃ] due to the presence of an obstacle at the lower teeth, some 3cm downstream from the noise source at the constriction. This obstacle can increase the turbulence of the airflow and thereby its amplitude, which was one of the characteristic features of sibilant fricatives [5, 9]. The likelihood of responses being labelled [s] was greater when the EPG contact was in the first row. For responses to be labelled [ʃ], there had to be either a wide groove at the front row, or a narrow groove at the back rows. Overall, it seemed that groove width manipulation was more important than place-of-articulation in listeners' perceptions of noise [8, 16]. In terms of EPG contact patterns, there was greater posterior EPG contact for [ʃ] than for [s], while the latter was not necessarily more variable than the former in German [11].

The above observation raises the differences in place of articulation and tongue configuration between two sibilant fricatives [s] and [ʃ] in Uyghur.

1.2. Effects of Vowel Context on [s] and [ʃ]

With respect to vowel context including /a, u, i/, a change in the third and fourth formants results in variations in the higher frequency ranges of the spectrum beyond 4KHz. Either a change in lip protrusion and or a change in constriction position have an impact on the length of the front cavity (region between constriction and lip opening), which in turn affects the frequency of the spectral peak (usually at about 3KHz). For a constant constriction, more lip protrusion makes the front cavity longer in length and thus lowers the frequency of the spectral peak. Less lip protrusion can make the front cavity shorter and raise the spectral peak. For constant lip positions a more advanced constriction position and raises the frequency of the spectral peak with retracted lower constriction position [5]. Research shows that articulatory movement and frequency spectrum of consonant /s/ are affected by vowel environment [4, 5, 9, 15]. X-ray and MRI studies found that the place of articulation of fricative/s/ is less affected by the peripheral vowels, but the tongue dorsum that does not participate in the formation of constriction is vulnerable to the coarticulation of vowels [7]. EPG study found that the tongue palate contact of the main articulation of /s/ was relatively stable with strong articulatory constraint [10, 15]. Therefore, it is not easy to be affected by the vowel environment, but bringing a strong coarticulatory effect on the surrounding vowels. The influence of vowels on the spectrum of consonant /s/ is mainly shown near second format, which is positively correlated with the lingual palatal contact area in different vowel environments [16].

Uyghur has coronal fricative consonants [s] and [ʃ] has common articulatory characteristics that they are produced with the tip or blade of the tongue to contact with the upper side of the oral cavity from the teeth to the palate. Uyghur is understudied language in terms of Experimental Phonetics and Phonology, it's vital to collect the preliminary data to model the contrasts between [s] and [ʃ] with EPG recordings to obtain information about the changing pattern of linguo-palatal contact for these sounds when followed by three extreme vowels [a, u, i].

2. Methods

2.1. Subjects

One male Uyghur native speaker was recorded, who was around 30s, and had no history of any speech, language or hearing disorders.

2.2. Speech Material

The speech material was a list of real monosyllabic words in the CV syllable. The target C consonants included all coronal consonants [s, ʃ] in Standard Uyghur. Speech material was presented to the speaker in a randomized order. 5 repetitions were recorded.

2.3. Experimental Set-Up

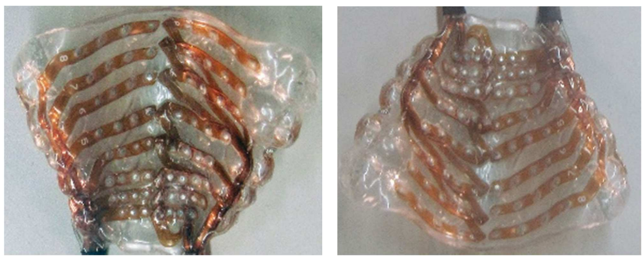

Figure 1. *EPG Palates of the Male Speaker.*

A 62-sensor Win EPG system (Articulate Instruments Limited) was used in this study and the customized EPG pseudo palate was made for the speaker. The 62 sensors were distributed in eight rows and eight columns. The rows were numbered as 1-8 from anterior to posterior, and the columns were numbered as 1-8 from left to right according to the speaker's orientation. Each row had 8 sensors except that the first row had six sensors from column 2 through 7 (see Figure 1).

The rows and columns in the front part were more densely concentrated, because there were more places of articulation differentiated in this area.

Roughly, the first two rows delimited the alveolar area, the third and fourth rows delimited the post-alveolar area, and the rest four rows belonged to the palatal area.

The EPG data were recorded at a sampling rate of 100 Hz. The synchronized mono audio sound was recorded at a sampling rate of 22,050 Hz, with 16 bits per sample.

2.4. Labeling

The EPG data were transformed into the Praat textgrid format, and hereafter, all labeling works were conducted in Praat [17] and analyses were conducted in analysis system developed on Matlab.

For each [s, ʃ] token, the following EPG frames were identified (see Figure 2): (i) the closure frame, C, defined as the frame in which there was a complete line of contacts in a single row, (ii) the release frame, R, defined as the first frame following closure in which there was not a complete line of contacts in any of the rows, (iii) the pre-release frame, PR, which was the frame directly preceding frame R, and (iv) the maximum-contact frame, M, defined as the frame between the closure and released frames with the maximum number of contacts. If two or more frames between C and R had the same maximum number of contacts, the earliest of these frames was labelled as M.

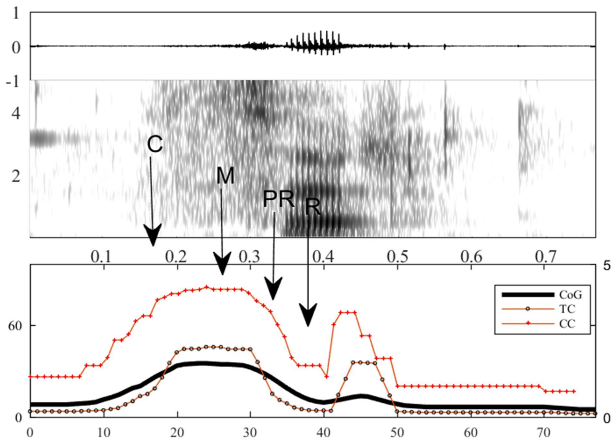

Figure 2. *Four EPG Frames Labelled for Identification.*

3. Results

For each of the frames C, M, PR and R, the linguo-palatal contact patterns for 5 repetitions of [s] and [ʃ] in each vowel context were represented as composite patterns in Figure 3.

To quantify differences in places of articulation, "Center of Gravity " (CoG), Total Contact (TC), Anterior Contact (ANT), Posterior Contact (POS) values were calculated for frames C, M, PR, and R.

The CoG value calculated according to following equation [14]:

$$CoG=(R8*1)+(R7*3)+(R6*5)+(R5*7)+(R4*9)+(R3*10)+(R2*11)+(R1*12)/R8+R7+R6+R5+R4+R2+R1$$

Where R1 is the most anterior row, shown at the top of the EPG frames in Figure 2. Higher CoG values indicate a more anterior tongue-palate position. EPG CoG indicates the location of the main constriction on a front- back dimension in the oral cavity.

Meanwhile, it calculates parameters such as TC (amount of tongue-to-palate contact), ANT (amount of tongue-to-palate contact in front four rows), POS (amount of tongue-to-palate contact in back four rows), so as to investigate the coronal fricatives by comparing the dynamic characteristics of place of articulation and amount of contact during /s/ and /ʃ/ fricatives.

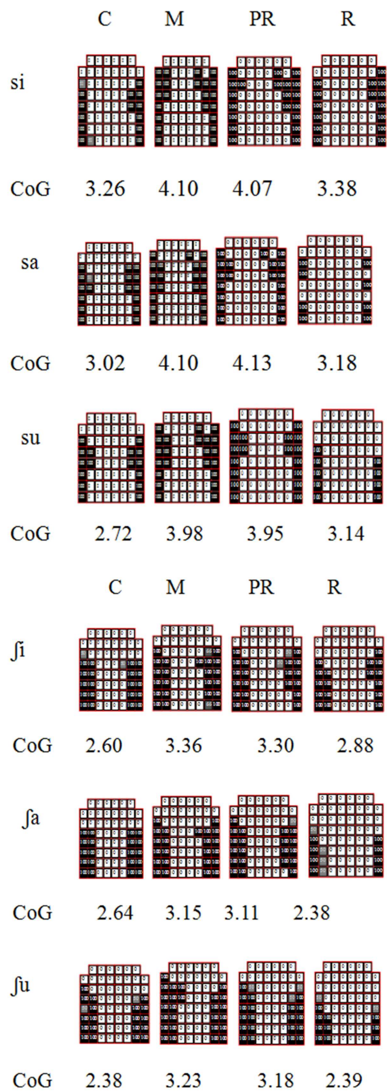

Figure 3. *Composite Frames C, M, PR, R Respectively for [s] and [ʃ] in Different Vowel Contexts.*

3.1. Fricative Consonants /s/

The location of the maximum contact for /s/ was in the front rows except for first row which exhibited no contact in different vowel context. The details of the /s/-/ʃ/ contrast were rather different over the vowels. The speaker showed over more contact in the back 4 rows for /ʃ/ than for /s/. This was confirmed by performing two-way ANOVAs (three vowels * four articulatory phases) separately.

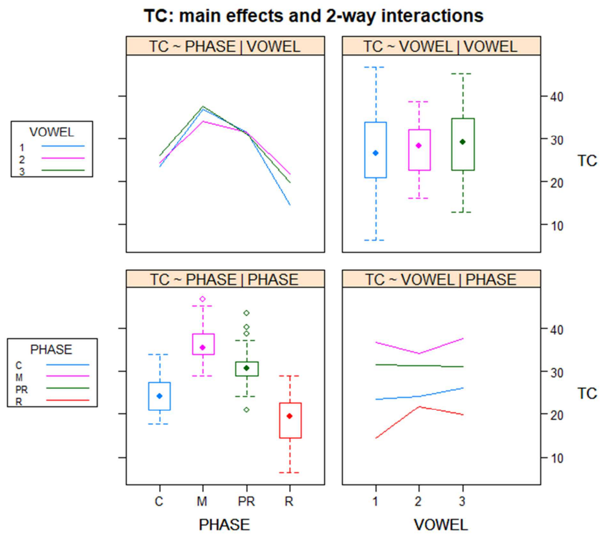

Figure 4. *TC: Main Effects and Interactions.*

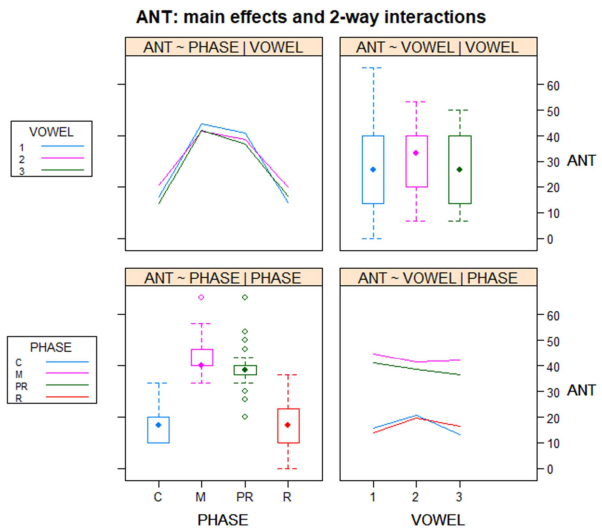

Figure 5. *ANT: Main Effects and Interactions.*

As for TC, different phases yielded significant effect at p<0.001 and 2-way interactions (phases and vowels) yielded significant effect at p<0.01 on total contact index (TC). At the phase of maximum contact, the tongue-palate contact reached its highest point in the context of back vowel/ɑ/ and /u/ while contact was more less at the release in vowel /ɑ/. In terms of vowel effect, the tongue-palate contact increased with the movement of tongue dorsum raising of high vowels /u, i/ while the contact decreased in the low vowel /ɑ/, the significant effect was at p<0.05.

As for ANT, different phases yielded significant effect at p<0.001 and the main effect of vowels and interactions of phases and vowels showed no effect (p=0.29, p=0.15 respectively). It can be seen from Figure 4, at the point of maximum contact and pre-release, its contact was much more than at the closure and release phase. In the front vowel of /i/, the tongue-palate contact of front 4 rows increased with the advancement of tongue dorsum of vowel /i/, while in the back vowels, it made less contact with the tongue dorsum lowering of /ɑ/ and /u/.

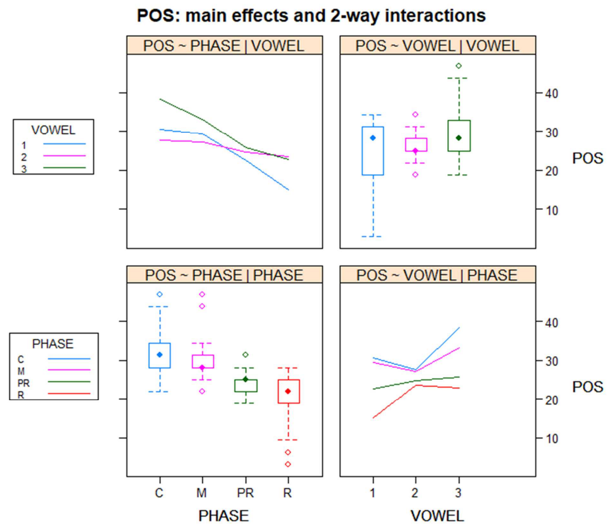

Figure 6. *POS: Main Effects and Interactions.*

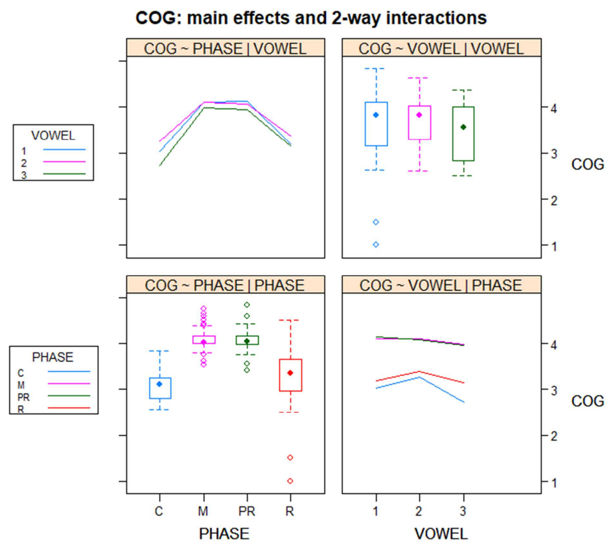

Figure 7. *COG: Main Effects and Interactions.*

AS for POS, different phases and vowels yielded highly significant effects at p<0.001 and interactions of phases and vowels also yielded significant effect at p<0.05. At the closure phase, POS index was in the sequence of /u/>/ɑ/>/i/ for the point of maximum contact and from pre-release to release point, POS index decreased as the vowel context changes in the sequence of /u, i/>/ɑ/. As for different phases, in the closure and point of maximum contact, POS index was higher than PR and R. As for different vowels, the POS index was higher in the back vowel context of /ɑ, u/ than front vowel /i/.

As for COG index, different phases yielded highly significant main effect at p<0.001 and the main effects of vowels at p=0.06

while interactions of vowel and phase showed no significant effect (p=0.65). At the point of maximum contact and PR, constriction place was most anterior than the closure and release point. It was obviously that, different vowels had a minimal effects on the constriction place op

f fricative consonant /s/ at least in front-back dimensions in oral cavity.

3.2. Fricative Consonant /ʃ/

The location of the maximum contact for / ʃ / was in the row with most constriction varies more widely, from row 3 to row 4. As for TC, different phases and 2-way interactions (phases and vowels) yielded highly significant effect at $p<0.001$ on total contact index (TC). At the point of maximum contact in the vowel context /i/, its tongue-palate contact was much more higher than other articulatory phases and vowel contexts. Obviously, vowels had significant effect at $p<0.01$, there was no difference between back vowels /ɑ/ and /u/, but the front, high vowel /i/ increased the consonant’s contact.

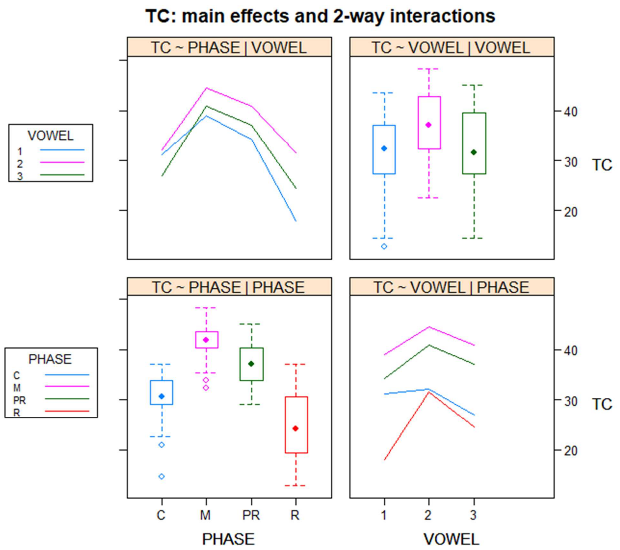

Figure 8. *TC: Main Effects and Interactions.*

As for ANT, different phases yielded highly significant effect at $p<0.001$ and interactions of phases and vowels showed effect at p=0.01 but no effects of vowels (p=0.16). At the point of maximum contact and pre-release, its contact was much more than at the closure and release phase. In the front vowel of /i/, the tongue-palate contact of front 4 rows increased with the advancement of tongue dorsum of vowel /i/, while in the back vowels, it made less contact with the tongue dorsum lowering of /ɑ/ and /u/.

AS for POS, different phases and vowels yielded highly significant effects at $p<0.001$ and interactions of phases and vowels also yielded significant effect at $p<0.01$. At the point of maximum contact, POS index was in the sequence of /i/>/ɑ, u/, namely, the tongue-palate contact in the back 4 rows was in the sequence of M>C>PR>R in the vowel context of /i/>/u/>/ɑ/. As for different vowels, the POS index was higher in the front vowel context of / i / than back vowel/ɑ, u/.

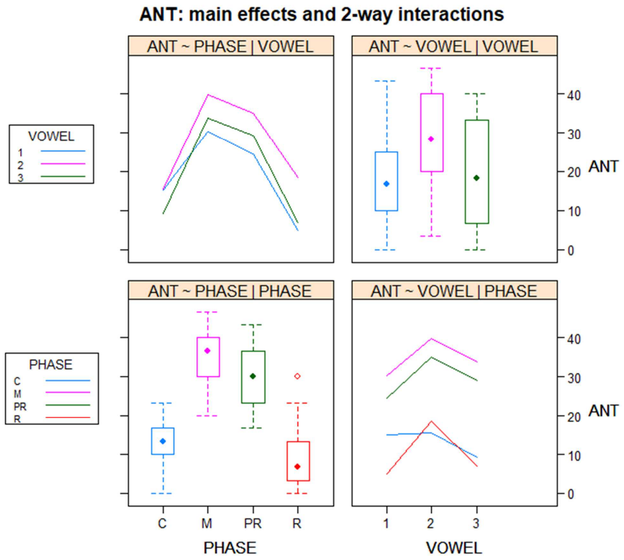

Figure 9. *ANT: Main Effects and Interactions.*

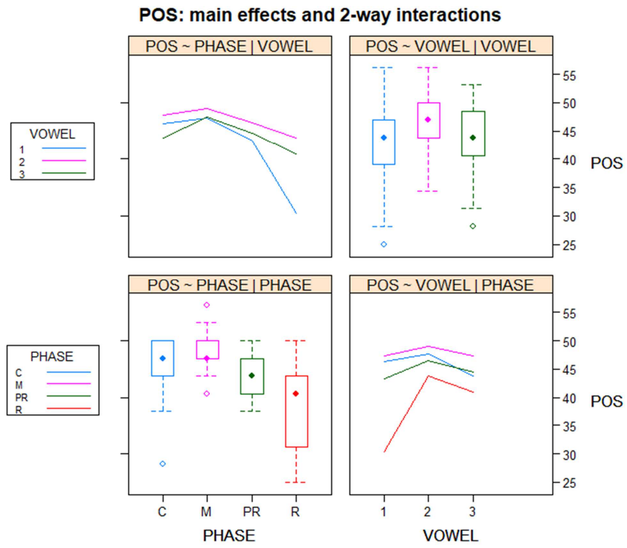

Figure 10. *POS: Main Effects and Interactions.*

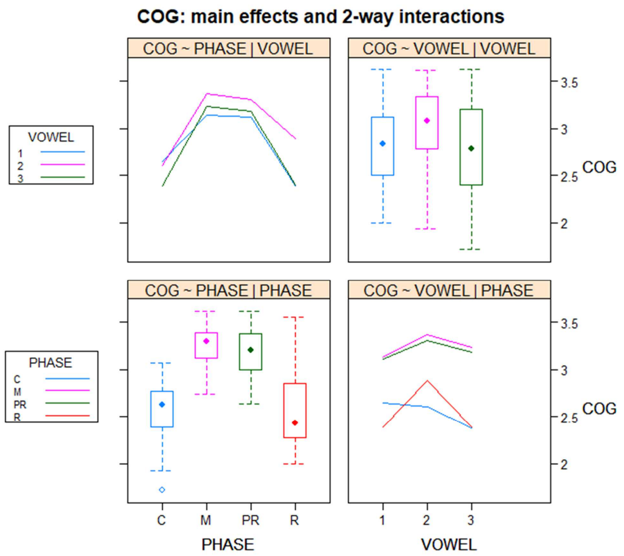

Figure 11. *COG: Main Effects and Interactions.*

As for COG index, different phases yielded highly significant main effect at $p<0.001$ and the main effects of vowels at $p=0.98$ while interactions of vowel and phase showed less significant effect ($p=0.10$). At the point of maximum contact and PR, constriction place was most anterior than the closure and release point. Apparently, different vowels showed less effects on the constriction place of fricative consonant /ʃ/.

4. Conclusion

We have investigated the articulatory mechanisms of sibilant fricatives /s/ and /ʃ/ in Uyghur. Former is alveolar while latter is alveopalatal in constriction place formed in oral cavity. In terms of coarticulatory effect of following vowel on the production fricatives, former is affected by rounded, back vowel/ u / while latter is affected by front, high vowel/i/. In terms of front-back dimension, articulatory movement of both fricatives in alveolar region is most stable while it is vulnerable to effects of vowel in palatal region. In terms of different articulatory times (phases), the point of maximum contact is the most stable one for both fricatives.

Acknowledgements

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