EPG BASED RESEARCH ON TONGUE POSITION AND ITS CONSTRAINT OF WORD-INITIAL CONSONANTS IN STANDARD MONGOLIAN IN CHINA

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ABSTRACT

This paper discusses issues including tongue position, tongue movement space, constraint etc. of Mongolian word-initial consonants. The experimental result shows that word-initial consonant tongue horizontal movement space is constrained by constriction position and is in conformity with the rule that front consonant leads to smaller tongue movement space; higher consonant leads to smaller tongue vertical movement space. Generally speaking, consonants' tongue vertical variation scope is bigger than tongue horizontal variation scope.

Keywords: EPG (electropalatograph), Standard Mongolian consonants in China, tongue position, constraint

1. INTRODUCTION

In the end of 1950th, Cenggeltei and Coyijongjab studied Mongolian voiced and voiceless consonants by using kymograph, oscillograph and plastic palate and corrected the viewpoint that Mongolian consonants [p, t, k] were voiced [3]. In *Modern Mongolian Grammar* [4] (written by Cenggeltei and published in the end of 1970$^{th)}$, Cenggeltei explored Mongolian consonants' static tongue-palate contact area and side view of oral articulation gesture using static palate photographing and X-ray photographing. Although these researches enhanced people's perceptual knowledge about Mongolian consonants articulation gesture and articulation position, they did not resolve quantitative description of consonants articulation gesture and articulation position. By using EPG, we can acquire and display real-time dynamic palate position of segments of utterance, which demonstrate minor variances of tongue-palate contact and avoided defects of static tongue-palate contact research and acoustic analysis. In recent years, using EPG, researchers have achieved some quantitative research results of standard Mongolian consonants articulation manner and position. [1, 5, 7, 8, 9, 10, 12].

In this paper we explore issues including tongue position, movement space & constraint etc. of standard Mongolian consonants [n, l, s, ʃ, t^{h}, t, tʃ^{h}, tʃ, j] in the word initial position.

2. APPROACH

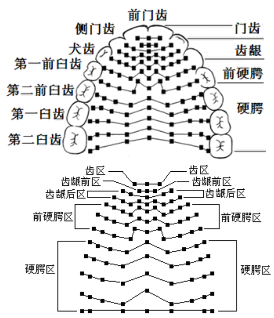
2.1. Experiment materials

Total of 370 monosyllabic, 242 disyllabic and 30 trisyllabic words cover high-frequency syllabic type such as CV, CVC, CVCC, and VC in Mongolian. The speakers are two male adults: W (teacher of affiliated middle school of Inner Mongolian Normal University, from Shuluun Höh Banner) and H (researcher of Chinese Academy of Social Sciences, from Khorchin). This paper mainly applies W's data. H's data is also referred to deal with special situation and problems.

2.2. Description of experiment equipment and articulation position

This experiment applied KAY's model 6300 EPG with 96 electrodes and Multi-speech 3700, and Mini Speech Lab of Nankai University. Electronic palate is divided into 12 rows (R1, R2…R12, from top to bottom) and 11 columns (C1, C2…C5, from left to right and right to left, plus C6, which is in the middle). 96 electrodes of EPG and palate areas distribution have been shown in figure 1 ([17]).

Figure 1: 96 electrodes of EPG and palate areas distribution.



2.3. Descriptive consonants tongue position approach

In order to conduct statistics and analysis of dynamic EPG data, Recasens [13] and Fontdevila [6] designed a set of effective tongue-palate contact indexes, CA and CC. CA represents consonant tongue forwardness. The bigger the value, the more forward the tongue position. CC represents centralness. The bigger the value, the higher the tongue position. Based on Recasens and Fontdevila's calculation principles, Zheng Yuling and Liu Jia proposed a revised calculation method for 96 electrodes EPG, which better reflect consonant constraint's height variance. The CA and CC formulas are as followings (details see over [11, 17]):

(1)CA=LOG(1*R12/7+10*R11/9+100*R10/9+1000*R9/9+10000*R8/9+122222*R7/11+1466664*R6/11+17599968*R5/11+172799686*R4/9+959998356*R3/5+3455993722*R2/3+13823974888*R1/3+1)/LOG(18431966517+1)

(2)CC=LOG(1*C1/10+11*C2/10+97*C3/8+1091*C4/10+12001*C5/10+66006*C6/5+1)/LOG(79208+1）

The standard deviation of CA and CC indicate consonants' constraint (or anti-coarticulation) in forward-backward (horizontal) dimension and high-low (vertical) dimension, respectively. The standard deviations of CA and CC and their constraint maintain negative correlation: the higher the standard deviation, the weaker the constraint.

Two-dimensional graph with CA as horizontal axis and CC as vertical axis can reflect consonant phoneme movement trajectory (we call it as tongue movement physiologic space) and provides scientific evidences for research on co-articulation rules. By watching the graph, we can observe different behaviors of phoneme variants of consonant as well as relative relation of different consonant phonemes.

In addition, we also applied CD (Constraint Degree,

(3) CD＝1/sum Std (sum Std= CA Std.+ CC Std))

to represent general variances of tongue position in horizontal and vertical dimension, which is tongue movement physiologic space. Apparently, the bigger the sum Std, the smaller CD, and the weaker the constraint. ([17]).

3. RESULTS AND DISCUSSION

3.1. Relations among consonant tongue position, tongue movement physiologic space and constraint

Figure 2 demonstrates such relations. We generalize them as 6 relations. There are three relations in horizontal dimension: 1) relation between tongue horizontal position and its variance. 2) Relation between tongue horizontal position and its constraint.3) Relation between constraint and tongue horizontal position variance. There are also three relations in vertical dimension: 4) relation between tongue vertical position and its variance.5) Relation between tongue vertical position and its constraint.6) Relation between constraint and tongue vertical position variance.

Figure 2: Relations among word-initial consonant tongue position, tongue movement physiologic space and constraint.

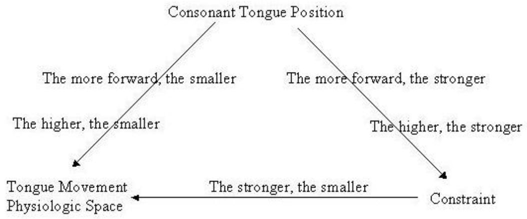
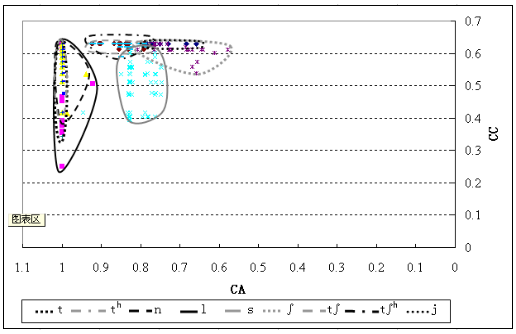


Table 1 shows average and standard variance of CA and CC as well as CD value. Figure 3 shows word-initial consonant tongue movement physiologic space[1].

Table 1: Average and standard variance of CA and CC as well as CD value of word-initial consonant.

Consonant	CA ave.	CA std.var	CC ave.	CC std.var	CD	Case
n	0.9979	0.0102	0.5685	0.0686	12.69	38
l	0.9945	0.0203	0.4122	0.1028	8.12	14
j	0.7622	0.0348	0.6286	0.000005	28.76	20
s	0.8106	0.034	0.4975	0.0626	10.36	65
ʃ	0.7254	0.0536	0.616	0.0192	13.74	40
t	0.9997	0.0003	0.5606	0.0692	14.38	43
tʰ	0.9997	0.0003	0.5642	0.0567	17.54	54
ʧ	0.8512	0.028	0.6273	0.0045	30.69	60
ʧʰ	0.8454	0.0328	0.6251	0.0077	24.66	47

Figure 3: Word-initial consonant tongue movement physiologic spaces.



3.2. Relation between tongue horizontal position and its variance

By watching table 1 and figure 3, we find that 9 word-initial consonants are sorted as follows (from biggest variance to smallest): [ʃ, j, s, tʃʰ, tʃ, l, n, t, tʰ]. This sequence is just reverse to consonants tongue position sequence (from forward to backward): [t, tʰ, n, l, s, tʃ, tʃʰ, j, ʃ] [1]. The more forward the consonant ([t] or [tʰ], for example), the smaller its horizontal activity space, more concentrated its phoneme variant. On the contrary, the more backward the consonant ([ʃ], for example), the bigger its horizontal activity space, more scattered its phoneme variant. Apparently, consonant tongue horizontal activity scope is restricted by its constriction horizontal position. We generalize it as:

more forward the consonant, the smaller the variance; more backward the consonant, the bigger the variance.

3.3. Relation between tongue position and its constraint

By watching table 1 and figure 3, we find that consonants are sorted as follows (from big constraint to small constraint): [t, t^h, n, l, tʃ, $tʃ^h$, s, j, ʃ]. This sequence is just same to consonants tongue position sequence (from forward to backward): [t, t^h, n, l, s, tʃ, $tʃ^h$, j, ʃ] [1]. The more forward the consonant ([t], for example), the bigger constraint, more concentrated its phoneme variant. On the contrary, the more backward the consonant ([ʃ], for example), the weaker its constraint, more scattered its phoneme variant. Apparently, consonant tongue's horizontal constraint is related with its horizontal constriction position. We generalize it as: more forward the consonant the stronger the constraint, more backward the consonant the weaker the constraint. Based on standard variance of CA, we categorize word-initial consonants into three levers: strong, middle and weak. Consonants [t, t^h] have the strongest constraint. Standard variance of their CA is below 0.01. Consonants [n, l, tʃ, $tʃ^h$, s, j] have the middle constraint; standard variance of their CA is between 0.01-0.04. Consonants [ʃ] has the weakest constraint, standard variance of its CA is greater than 0.05. The followings are sorting results: [t, t^h] (strong), [n, l, tʃ, $tʃ^h$, s, j] (middle), [ʃ] (weak).

3.4. Relation between constraint and tongue horizontal position variance

Above analysis (3.2 and 3.3) show that consonants constraint is sorted as follows (from strong to weak): [t, t^h, n, l, tʃ, $tʃ^h$, s, j, ʃ]. This sequence is just reverse to consonants tongue horizontal position variance sequence (from big to small): [ʃ, j, s, $tʃ^h$, tʃ, l, n, t, t^h]. The bigger constraint, the smaller the horizontal position variance, more concentrated the phoneme variant. On the contrary, the smaller the constraint, the bigger the horizontal position variance, more scattered the phoneme variant.

3.5. Relation between tongue vertical position and tongue vertical position variance

By watching table 1 and figure 3, word-initial consonants are sorted as follows (from big variance to small variance): [l, t, n, s, t^h, ʃ, $tʃ^h$, tʃ, j]. This sequence is just reverse to consonants tongue vertical position sequence (from big to small): [j, tʃ, $tʃ^h$, ʃ, t, t^h, n, s, l]. [1]. The higher the consonant ([j], for example), the smaller the activity space, more concentrated its phoneme variant. On the contrary, the lower the consonant (j), for example), the bigger the activity space, more scattered its phoneme variant. Apparently, tongue movement activity in vertical dimension is restricted by its vertical position of restriction.

3.6. Relation between tongue vertical position and constraint

By watching table 1 and figure 3, we find that word-initial consonants are sorted as follows (from strong constraint to weak): [j, $tʃ^h$, tʃ, ʃ, t, n, s, t^h, l]. This sequence is just same to consonants tongue vertical position sequence (from high to low): [j, tʃ, $tʃ^h$, ʃ, t, t^h, n, s, l]. The higher the consonant ([j], for example), the stronger constraint, more concentrated its phoneme variant. On the contrary, the lower the consonant ([l], for example), the weaker its constraint, more scattered its phoneme variant. Apparently, consonant tongue vertical constraint is related with its vertical constriction position. We generalize it as: higher the consonant the stronger the constraint, lower the consonant the weaker the constraint. Based on standard variance of CC, we categorize word-initial consonants into three levers: strong, middle and weak. Consonants [j, $tʃ^h$, tʃ, ʃ] have the strongest constraint, standard variance of their CC are below 0.02. Consonants [t, n, s, t^h] have the middle constraint, their standard variance of CC are between 0.05-0.07. Consonant [l] has the weakest constraint. The standard variance of its CC is greater than 0.1. The followings are sorting results: [j, $tʃ^h$, tʃ, ʃ] (strong), [t, n, s, t^h](middle), [l] (weak).

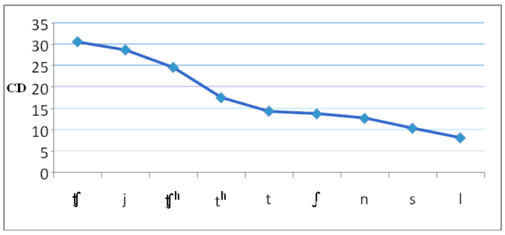
3.7. Relation between constraint and vertical variance of tongue position

Above analysis (3.5 and 3.6) show that constraint is sorted as follows (from strong to weak): [j, $tʃ^h$, tʃ, ʃ, t, n, s, t^h, l]. This sequence is just reverse to tongue vertical position sequence (from high to low): [l, t, n, s, t^h, ʃ, $tʃ^h$, tʃ, j]. The stronger the constraint, the smaller the vertical dimension variance, more concentrated the phoneme variant. On the contrary, the weaker the constraint, the more scattered the phoneme variant.

3.8. Constraint of word-initial consonants

Constraint is an accurate index to indicate general variation of tongue position in vertical and horizontal dimensions. By watching table 1 and figure 3-4, we find that constraint is sorted as follows (from strong to weak): [tʃ, j, $tʃ^h$, t^h, t, ʃ, n, s, l]. In terms of constraint, word-initial consonants can be categorized into three levels: strong, middle and weak. Consonants [tʃ, j, $tʃ^h$] have strong constraint (CD>20), small movement physiologic space and concentrated phoneme variant. CD of consonants [s, n, ʃ, t, t^h] is between 10 and 20. Consonant [l] has small CD (less than 10).

Figure 4: Comparison of constraint of Mongolian word-initial consonants.



3.9. Consonant tongue position variance in horizontal and vertical dimensions

By watching table 1 and figure 3 we find out differences of variance between horizontal and vertical dimensions. For example, except [ʃ], all consonants CA standard variances are below 0.04. Standard variances of CC of consonants [l, t, n, s, t^h] are higher than 0.04. Consonants with high tongue position, like [tʃ, $tʃ^h$, tʃ, j], their CC standard variances are below 0.04. Above data indicate that variance scope of word-initial consonants' (except [tʃ]) in vertical dimension is larger than that in horizontal dimension.

4. CONCLUSION

Based on above analysis, we have made these preliminary conclusions:

4.1. Relation between consonant tongue position and tongue movement physiologic space

Consonant tongue position adheres to the rule that forward consonant leads to smaller tongue movement physiologic space, higher consonant leads to smaller tongue movement physiologic space.

4.2. Relation between consonant tongue position and constraint

Consonant tongue position adheres to the rule that forward consonant leads to stronger constraint; higher consonant leads to stronger constraint.

4.3. Relation between constraint and tongue movement physiologic space

Constraint adheres to the rule that stronger constraint leads to smaller tongue movement physiologic space (horizontal and vertical dimensions).

4.4. Constraint of word-initial consonant

Consonants can be divided into three levels: strong constraint, middle constraint and weak constraint. Consonants [tʃ, j, $tʃ^h$] have biggest CD (CD>20), smallest tongue movement physiologic space and dispersion, most concentrated phoneme variant. Consonants [s, n, ʃ, t, t^h] have middle CD (10<CD<20). Consonant [l] has smallest CD, biggest tongue movement physiologic space and dispersion**,** most scattered phoneme variant.

4.5. Consonant tongue position variance

Generally speaking, except [ʃ], word-initial consonants have bigger vertical variation than horizontal variation.

5. ACKNOWLEDGEMENTS

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[1] Mongolian consonants tongue movement space pattern is basically same with Mongolian Consonant Pattern ([1]), indicating consonant physiological space pattern is very stable. Phonetic pattern is systematic including phonetic features, variant type, distribution, relativeness and phonotactics. ([16])