Perceptual Features of Long-Short Vowel Contrast in Mongolian

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In phonology, whether there are other criteria for the classification of long and short vowels besides the distinction of word meaning is the focus of research on the length of vowels from a modern phonetic point of view. This paper experiments on the long and short vowels of Mongolian from hearing and perceptual perspectives, and explores the process of perceptual decoding concerning vowel duration. The research found that: (1) Long and short vowels differ significantly in the range and boundaries at the level of auditory sense. (2) At the cognitive level, the brain's process of assorting long and short vowels is distinct conspicuously. (3) Word meaning has a great influence on vowel type perception.

Keywords: Mongolian, long-short vowel contrast, perceptual features

1. Introduction

In the Mongolian vowel system, long-short vowel contrast has phonemic functions. For example, the semantic distinction between words "ᠠᠪ" (/ɐw/, take) and "ᠠᠪᠤ" (/ɐ:w/, father) is only expressed by the different duration of vowel /ɐ/. Phonetic studies on Mongolian long and short vowels are numerous, chiefly focusing on the following two aspects. One is the study of vowel segments, which mainly involves the phonological induction of Mongolian dialects (Yuzhu B & Mθngheboyin 2011: 67-150; Tuya 2009), the exploration of vowel acoustic features (Qoijungjab 1989; Zanden 2009; Huhe 2021), and the cross-dialectal acoustic comparison of vowels (Bayarmend 2014: 50-73). Another is the exploration of suprasegmental features. It focuses on prosodic functions of vowel duration in Mongolian and the interactive patterns of vowel duration over segments and suprasegmental. (Aomin 2022: 6-12).

By and large, existing vowel studies have yielded new insights and discoveries about vowel system induction and acoustic characteristics of vowel length in Mongolian dialects. Current evidence (Huhe & Qoijungjab 1999) showed that Mongolian long and short vowels differ not only in duration but also in tongue position; according to the specific performance of the vowel length in the speech flow, vowels can be divided into four categories: super-long vowels, long vowels, short vowels and super-short vowel (Yurong 2012); Haschimeg (Haschimeg 2021) summed up the law of vowel duration change in Mongolian. Aomin (Aomin 2018) unearthed the prosodic function of non-syllabic vowels. However, the vowel duration of Mongolian long and short vowels needs further discussion, thereinto, the perceptual category and boundary of Mongolian long-short vowel contrast remain untouched issues from the perspective of perceptional phonetics.

According to the statistical analysis of the contrasted acoustic features between Mongolian long and short vowels, we could conclude that: First, there are three cases of factors that may cause vowel duration change at the lexical level: the vowel inherent features, syllable features, and adjacent consonants. Among them, the effect of inherent vowel features on vowel duration is not statistically significant, while syllable features are. Specifically, a negative correlation manifests between syllable length and vowel duration, and short vowel duration is shortened more than that of long vowels. The influence of adjacent consonants on vowel duration is complex. Generally, voiceless consonants shorten vowel duration while voiced consonants lengthen it. However, this rule is greatly impacted by word meaning, which could induce an opposite influence direction. Secondly, there is an effect polarization on vowel duration at the lexical level: vowel inherent features prolong the vowel duration more in meaningful words than in meaningless words; syllable features shorten the vowel duration greater in meaningful words than in meaningless words. Based on this finding, the present study explored the perceptual features of long-short vowel contrast in Mongolian through consecutive auditory discrimination experiments and Event-related Potential experiments, abbreviated as ERP, is a special type of brain evoked potential that intentionally assigns a special psychological meaning to a stimulus, utilizing the brain potential caused by multiple or diverse stimuli. It reflects changes in the neuro electrophysiology of the brain during the cognitive process, also known as cognitive potentials. It is also a brain potential recorded from the surface of the skull when exploring the cognitive processing characteristics of the speech problem.

2. Method

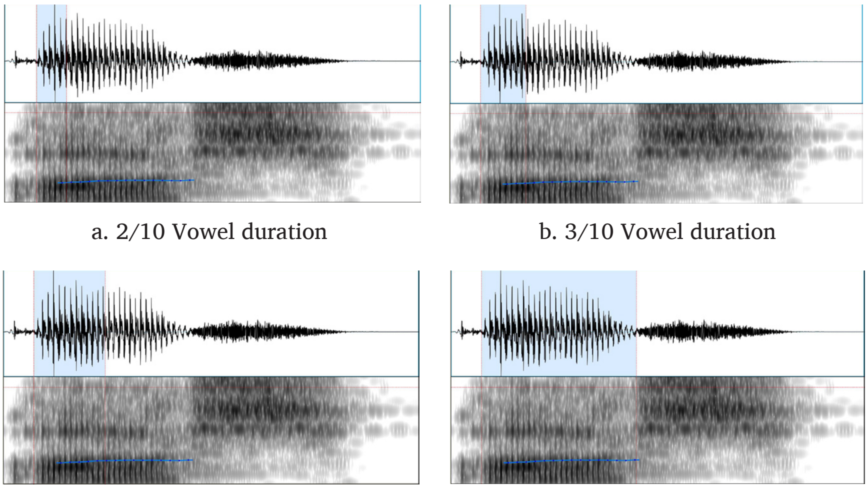
2.1 Corpora

1. Consecutive auditory corpus: For investigating the auditory perception and boundary domain between long and short vowels, the continuous auditory perception experiment based on the linear test method (F Shi 2019: x) was conducted on CVC-structure long vowel words which covered 30 meaningful words and 28 meaningless words in the corpus, which have been introduced in detail in other papers (Aomin & Yibel 2022), so it will not be repeated here. A total of 920 stimulus sounds were obtained by the synthesis method of stimulus sound. Figure 1 lists the spectrogram of the synthesized stimulus sound of the word /pɔːs/.

2. ERP experimental corpus: 25 monosyllabic words with long-short vowel contrast in the same context (consonants adjacent to vowels are the same) were selected from the basic corpus. The perceptual experiment is divided into three parts: “distinguishing vowel type experiment, which is executed by original duration stimulus sound,” “distinguishing word meaning experiment, which is executed by original duration stimulus sound as well,” and “judging vowel type experiment, which uses continuum stimulus sound duration,” hereinafter referred to as experiment 1, experiment 2 and experiment 3, respectively.

2.2 Subjects

Twenty subjects participated in two experiments, including 10 males and 10 females, those were all from the Mongolian standard pronunciation area, and all speakers are undergraduates and postgraduates who hold the first-class certificate of the Mongolian Standard Pronunciation Test. None of



a. 2/10 Vowel duration b. 3/10 Vowel duration

c. 5/10 Vowel duration d. 10/10 Vowel duration

Figure 1. Different vowel duration phonogram of the word /pɔːs/

S: meaningful				L: meaningful			
S		L		S		L	
ʧʰom	[illegible]	ʧʰoːm	meaningless	mom	meaningless	moːm	[illegible]
ʧʰɐm	[illegible]	ʧʰɐːm	meaningless	--	--	--	--
mas	[illegible]	maːs	meaningless	--	--	--	--
mos	[illegible]	moːs	meaningless	--	--	--	--
sɐp	[illegible]	saːp	meaningless	--	--	--	--
səp	[illegible]	səːp	meaningless	--	--	--	--
səm	[illegible]	səːm	meaningless	--	--	--	--
sɔm	[illegible]	sɔːm	meaningless	--	--	--	--
sos	[illegible]	soːs	meaningless	--	--	--	--
pɪʧʰ	[illegible]	pɪːʧʰ	meaningless	--	--	--	--

Table 1. Corpus of ERP Experiment 1 and Experiment 2

the speakers had a long history of living in other dialect areas before high school.

Short vowel		Long vowel	
nʊr	ᠨᠣᠷ	nʊːr	ᠨᠠᠭᠤᠷ
pɐr	ᠪᠠᠷᠰ	pɐːr	ᠪᠠᠭᠠᠷ
pos	ᠪᠣᠰ	poːs	ᠪᠣᠭᠣᠰᠤ
tʃʰʊtʃʰ	ᠴᠣᠴᠢ	tʃʰʊːtʃʰ	ᠴᠣᠭᠣᠴᠢ
tʃʰur	ᠴᠤᠷ	tʃʰuːr	ᠴᠤᠤᠷ
xəl	ᠬᠡᠯ	xəːl	ᠬᠡᠪᠯᠢ
tʃɔk	ᠵᠣᠭ	tʃɔːk	ᠵᠠᠭᠤᠭ

Table 2. Corpus of ERP Experiment 3

2.3 Experimental equipment

1. Continuum experiment: Experimental recording was completed in the speech lab of Mongolian Studies, Inner Mongolia University. Main recording equipment includes a DELL computer, Cool Edit Pro professional recording software, PRAAT software, and an AKG headset. The auditory experiment was completed in a quiet classroom with Lenovo computers, headphones and the xPerception tool (Aomin & Yibel 2022).

2. ERP experiment: This experiment was done in the speech lab utilizing a set of SynAmps' Model 18050 with 128 channels made in Australia. Related devices include a power supply box, control box, amplifier by a head box, stimulation sound presentation computer, data acquisition computer and electrode cap. The consumables needed for the experiment include EEG cream, scrub cream, cotton swabs, flat needle tubes, and tapes.

2.4 Experimental method

1. Continuum experiment: In the auditory discrimination experiment, the linear test method was used. Among the factors of vowel duration, intensity and pitch, only the first one was changed while all the others remained the same. The PRAAT software was used to synthesize stimulus sounds. Steps are as follows: First, Divide long vowel duration into 10 average points by using the continuum method. Secondly, 1/10 vowel duration is gradually extended by VD/10 × n15. A total of 58*14 stimulus sounds were obtained eventually.

2. ERP experiment: Before the experiment, all subjects were asked to adjust their sitting posture in the most comfortable state and wear 128

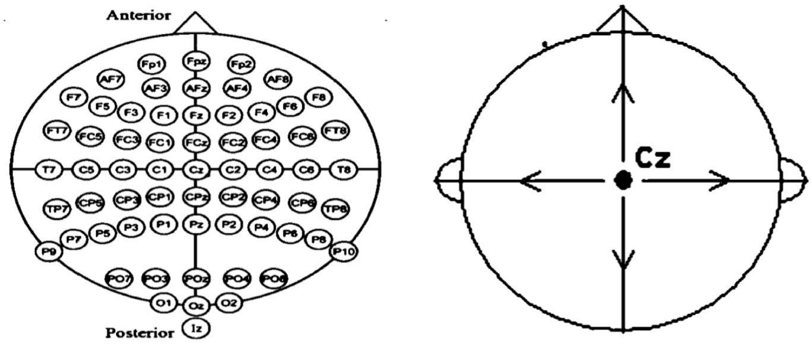
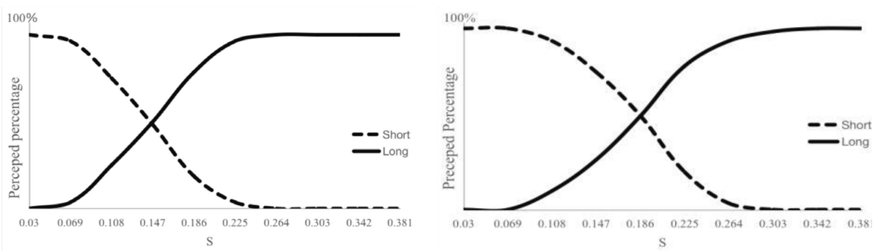


Figure 2. Electrode lead diagram (left) and electrode cap-wearing diagram (right)

conductive caps suitable for their own head circumference. The electrode cap was worn from front to back, and the correct position of the CZ point was confirmed, then the EEG paste was inserted, and all electrode impedance is ensured to be lower than 5.0 KΩ. Figure 2 shows the electrode lead diagram and the electrode cap-wearing diagram.

3. Perceptual features of vowel continuum

In Figure 3, 11600 auditory judgment results from 40 listeners are listed. The vertical axis in the figure represents the percentage of long and short vowels, and the horizontal axis represents the long vowel continuum duration which is 10 points. The dotted line in the figure is the judgment curve for short vowels, and the solid line is the judgment curve for long vowels. The total number of stimulus sounds used for perceptual judgment is



a. meaningful words b. meaningless words

Figure 3. Consecutive perceptual results of long and short vowels

5600 for experimental meaningful words as shown in Figure 3a and 6000 for meaningless words as shown in Figure 3b. The result of auditory judgment can be summarized in the following 2 aspects.

3.1 Long vowels and short vowels have different auditory boundaries and categories

On the whole, as the vowel segment duration increases gradually, the proportion of long vowels increases as well. However, remarkable discrepancies are observed in auditory boundaries and categories between long and short vowels. Details are as follows. First of all, the auditory boundary for long and short vowels in Mongolian is 5/10. When the duration of long vowels is shortened by half, a noticeable impact on the perception of vowel type would be exerted. When the duration of a long vowel exceeds half of its own length, most listeners perceive it as a long vowel. This result also indicates that duration is the primary phonetic parameter for classifying Mongolian long and short vowels. Listeners basically rely on duration to determine which category the vowel belongs to. Second, the auditory category of short vowels is broader than that of long vowels. Based on the data in Figure 3, the slopes of two judgment lines were calculated using the long and short vowel categories as independent variables. It was found that the slopes of the long vowel judgment curve in Figure 3a were 0.32 and the short vowel judgment curve was 0.24, while the slopes of the long vowel judgment curve in Figure 3b were 0.28 and the short vowel judgment curve was 0.24. This result fully demonstrates that the auditory category of short vowels is larger than that of long vowels.

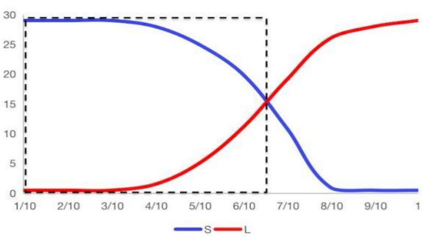
3.2 Word meaning affects the auditory judgment of vowel types

By comparing the trend lines of auditory judgment in Figure 3a and Figure 3b, it is immediately observed that word meaning affects the auditory category of long and short vowels. Word meaning has an influence on the auditory judgment of long-short vowels in Mongolian. When the stimuli are meaningful, the perceptual range of auditory category for long vowels is 2/10-9/10 interval and 2/10-8/10 for short vowels, while in meaningless stimuli, the auditory category ranges for long and short vowels are 2/10-7/10 and 2/10-6/10 respectively. Second, meaningful words enlarge the scope of vowel discrimination. When experimental words are meaningful, the auditory judgment curve for vowel types is relatively flatter than for meaningless words. Thus, word meaning is also an important factor in determining vowel type besides duration.

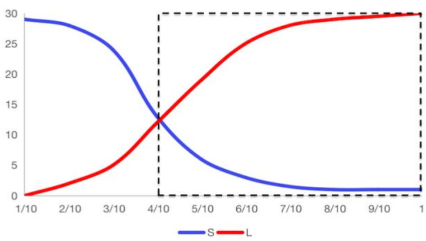
3.3 The interaction between vowel type and word meaning affects auditory discrimination

All the experimental words are re-examined in two cases based on the actual influence of word meaning on the judgments of vowel categories and duration patterns: long vowels in meaningful words correspond to short vowels in meaningless words and short vowels in meaningful words correspond to long vowels in meaningless words. For example, the word /tɐt/ (habit) is meaningful, but /tɐ:t/ is meaningless, and the word /nɐk/ is meaningful, but /nɐ:k/ (paste) is meaningless. Figure 4 presents the categorical statistics, where Figure 4a shows the listening results for meaningful short vowel experimental words for which the corresponding long vowel words are meaningless, and Figure 4b shows the listening results for meaningful long vowel experimental words for which the corresponding short vowel words are meaningless.

Such a result suggests that there is a complementary relationship between word meaning and vowel duration during the process of vowel type judgment. When the experimental words are meaningful, listeners discriminate between long vowels and short vowels based on vowel duration; when given words are meaningless, listeners first judge the vowel type based on their primitive knowledge of the mother tongue. This is evidenced by the fact that in Figure 4a, the perceptual category of short vowels 1/10-6.5/10 is larger than that of long vowels 6.5/10-1 due to the short vowels carrying meaning, the same situation is revealed in Figure 4b, the perceptual category 4/10-1 is larger than 1/10-4/10 due to the long vowel words are meaningful.



a. short(meaningful) – long(meaningless)



b. short(meaningless) – long(meaningful)

Figure 4. Listening results of vowel types under different classification conditions

4. Vowel cognitive features

Based on the analysis of the perceptual features between long-short vowel contrast in Mongolian, this paper further explores its brain cognitive process on the strength of the Event-related Potential experiment. The key conclusions are as follows.

4.1 There is a big difference in N100 and N400 values in the cognitive process of long-short vowel contrast

Figure 5 shows the ERP average waveform of short and long vowels FZ, CZ, and PZ.[1)] By comparing the waveform trends of long and short vowels, it can be seen that the ERP average waveform curves of short vowels and long vowels FZ, CZ, and PZ have the same trend on the whole. The average waveform of short and long vowels, FZ and CZ, showed a negative wave, i.e., N100 wave, between 75 and 150ms. The N100 activity of FZ and PZ waves was not obvious, but the N400 wave appeared between 350 and 450ms, in which long vowels have relatively higher peaks than short vowels. The differences in the cognitive processing of long and short vowels in Mongolian can be summarized in three aspects. First, the amplitudes of long and short vowels N100 and N400 are inversely proportional. The N100 waves induced by FZ and CZ were significantly larger than the N400 waves. Even in the ERP waveform of the FZ, no activity is found in N400. However, in the ERP waveform of PZ, it can be observed clearly that the amplitude of N400 is larger than that of N100.

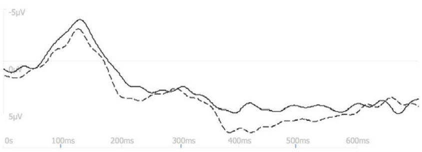
These results suggest that the amplitudes of evoked N100 and N400 are inversely proportional when the brain distinguishes between long and short vowels.

Second, the positive and negative amplitude regions of long and short vowels vary. When the brain makes judgments about short vowels, the evoked N100 amplitudes are bounded by AF8, AF4, F3, FC5, C1, CZ, and OZ electrodes. The electrodes on the right side of the boundaries show positive amplitudes, while the electrodes on the left side show negative amplitudes; electrodes F8, FC6, C4, CP2, P2, CP1 and C5 form the demarcation lines of

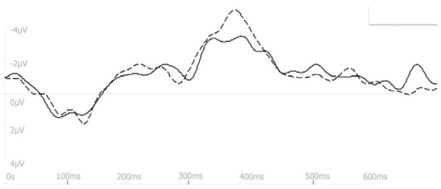
1) The electrodes of FZ, CZ and PZ are located in the frontal midline, central line and parietal midline of the brain,which is representative, so the average waveform of these three electrodes is selected.

the induced N400 amplitude. Electrodes above this limit induce positive amplitudes and electrodes below this limit induce negative amplitudes. AF7, AF3, AF4, FC6, C6, CP3, and C5 were the dividing lines when the brain judges the N100 evoked by long vowels. Electrodes above this limit induce positive amplitudes and electrodes below this limit induce negative amplitudes. When N400 is induced, the electrodes such as AF4, F5, FC5, C3, CP3, P2, and CP4 are the boundaries, and positive amplitudes appear above the boundaries and negative amplitudes appear below the boundaries. These features are prominently manifested in the 2D topography of N100 and N400 evoked by long and short vowels shown in Figure 6.

Third, the brain areas that perceive long and short vowels are different. The positive N100 amplitudes evoked by long vowels were on the left side of the brain, and the negative N100 amplitudes were on the right side of



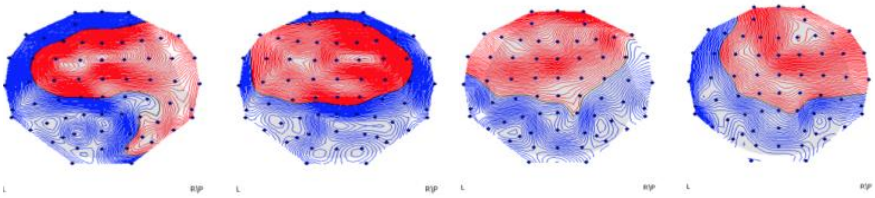
a. FZ electrode



b. CZ electrode

c. PZ electrode

Figure 5. ERP average waveform of short and long vowels



a. Short vowel N100 | b. Long vowel N100 | c. Short vowel N400 | d. Long vowel N400

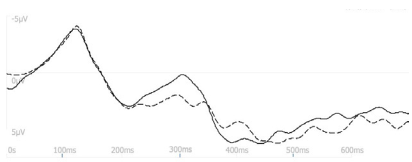
Figure 6. 2D topographical map of long and short vowels N100 and N400

the brain. The positive N400 amplitudes evoked by long vowels were on the right side of the brain, and the negative N400 amplitudes occurred on the left side. The positive amplitude of N100 appeared on the right side of the brain and the negative amplitude appeared on the left side when recognizing short vowels; the positive amplitude of N400 was on the left side of the brain and the negative amplitude was on the right side.

4.2 Word meaning has a significant effect on the cognitive processing of long and short vowels

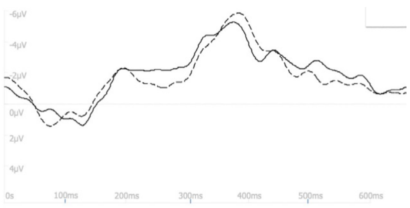
The experimental words were divided into two groups for ERP experiment featuring meaningful and meaningless words, and a significant effect of word meaning on the amplitude of N400 was proved. First, the brain evokes a larger N400 when there is a meaningless word than that evoked by a meaningful word. ERP wave forms for FZ, CZ and PZ for meaningful and meaningless words, as in Figure 7, show that the N400 waves in ERP experiments reflect the cortical perceptual processing of language, so that brain-evoked N400 is not evident when the experimental word is a meaningful word that does not violate semantics; when there is a meaningless stimulus sound that violates semantics, the cerebral cortex will induce a larger N400 wave. This result shows that word meaning determines the amplitude of the N400 wave.

Second, when judging whether a word has meaning or not, the positive amplitude and negative amplitude areas induced by the brain are opposite.



a. FZ electrode

b. CZ electrode



c. PZ electrode

Figure 7. A mean waveform comparison of meaningful and meaningless word stimuli

According to the anteroposterior position of the topographic map, the positive amplitudes induced by N100 and N400 appear in the anterior position of the brain, while the negative amplitudes are distributed in the inferior position of the brain. By comparing the left and right positions in a topographic map, the positive amplitude of N100 induced by a meaningless stimulus is located on the brain's right side, while the negative amplitude is on the brain's left side; when the stimulus is a meaningful word, its positive amplitude locates on the brain's left side, while the negative amplitude is on the right side. When the stimulus sound is a meaningless word, the positive amplitude of N400 appears on the brain's left side, while the negative amplitude appears on the right side; when the stimulus sound is a meaningful word, the positive amplitude of N400 appears on the right side, and the negative amplitude occurs on the left side.

5. Conclusion

This paper explores the perceptual features of long-short vowel contrast in Mongolian monosyllabic meaningful and meaningless words. The preliminary results state clearly that there are obvious differences in the auditory categories and boundaries between long and short vowels. By and large, the auditory category of short vowels is larger than that of long vowels. Besides, remarkable discrepancies between the long and short categories of vowel discrimination in the brain are observed as well at the cognitive level. The N100 and N400 amplitudes evoked by the perception of long and short vowel categories are inversely proportional, and the positive and negative amplitudes of the long and short vowel categories locate in different regions of the brain. Furthermore, word meaning has a great influence on vowel type perception. On one hand, word meaning affects vowel type processing in the brain. Specifically, word meaning has a conspicuous effect on the amplitude of N400. The N400 evoked by the brain regarding meaningless words is larger than that evoked by meaningful words. On the other hand, word meaning expands the scope and boundaries of vowel perception and hearing.

Compared with the existing acoustic features of vowels, our study finds out that there is no unity among the perceptual features, auditory patterns and acoustic performance of vowel type. Although the pattern of short vowels and long vowels in the acoustic and auditory categories is 1:2, that is, the boundary of the duration ratio between long and short vowels in the auditory category is at 1/2, the acoustic duration of short vowels is half shorter than that of long vowels. However, the high consistency (95%) of the duration distribution pattern between long and short vowels does not help to distinguish vowel types in perception and brain processing. This is evidenced by the large confusion areas between long and short vowels shown in Figures 3 and 4. Therefore, it is urgent to carry out an in-depth study of long-short vowel contrast from the perspective of cognitive linguistics.

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