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The Acoustic Realization of Preaspiration in Khalkha Mongolian

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1. Introduction

1.1 Preaspiration in Khalkha Mongolian

In Khalkha Mongolian (henceforth "Mongolian"), there are two contrastive series of stops and affricates (obstruents).[1] From phonetic and phonological perspectives, the two series have traditionally been described using the terms "strong–weak" (*čanga–sɵl* in Mongolian), "fortis–lenis," or "tense–lax." In the Cyrillic script used for Mongolian and its standard transliteration, strong–weak obstruents are rendered as shown in (1). Letters in parentheses occur only in loanwords and onomatopoeic words.

(1)	Cyrillic letter	transliteration[2]
strong (fortis, tense)	(п), т, (к), ц, ч	<(p), t, (k), ts, č>
weak (lenis, lax)	б, д, г, з, ж	<b, d, g, dz, ǰ>

There is little doubt that the contrast is based on different laryngeal features. However, it is not entirely clear whether the distinguishing feature is voicing or aspiration (or both). Although a number of studies have reported the basic phonetic characteristics of each sound (Stuart and Haltod 1957, Luvsanvandan 1964, Poppe 1970, Tsoloo 1976, among others), there is little consensus on which distinctive feature is key.

In recent years, Svantesson and Karlsson have conducted acoustic analyses, based on which they claim that <p, t, ts, č> and <b, d, dz, ǰ> are distinguished by the presence or absence of aspiration (Svantesson et al. 2005, Karlsson and Svantesson 2011, 2012, Svantesson and Karlsson 2012). According to their analysis, strong obstruents <p, t, ts, č> are phonologically as well as phonetically aspirated /pʰ, tʰ, ʦʰ, ʧʰ/, whereas weak obstruents <b, d, dz, ǰ> are unaspirated /p, t, ʦ, ʧ/. <g> is, on the other hand, regarded as voiced stops /g, ɢ/ because these sounds function phonologically as voiced consonants from the perspectives of phonotactics and sonority (see Svantesson et al. 2005: 65–68).[3]

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[1] Mongolian fricatives (/s/ and /x/) do not have the tense–lax opposition. In this paper, the term "obstruent" thus refers only to stops and affricates.

[2] In this paper, < > represents the transliteration of Cyrillic script. See the Appendix for the system of transliteration.

[3] <k> is not regarded as a phoneme in Svantesson and Karlsson's studies.

Svantesson and Karlsson (2012) also show that the realization of aspiration varies according to position:

> In word-initial position, aspiration is realized as postaspiration; if an aspirated consonant is preceded by a voiced segment in the same utterance, however, there is preaspiration as well. In word-medial and final position, aspiration is realized as preaspiration. (Svantesson and Karlsson 2012: 463)

They claim that preaspiration is realized as clearly audible aspiration noise and at least partial devoicing of the preceding segment (Svantesson et al. 2005: 14, Svantesson and Karlsson 2012: 455). Figure 1 illustrates the waveforms and spectrograms of word-medial /tʰ/ [ʰt] and /t/ [t]. The arrow in the figure shows the preaspiration.

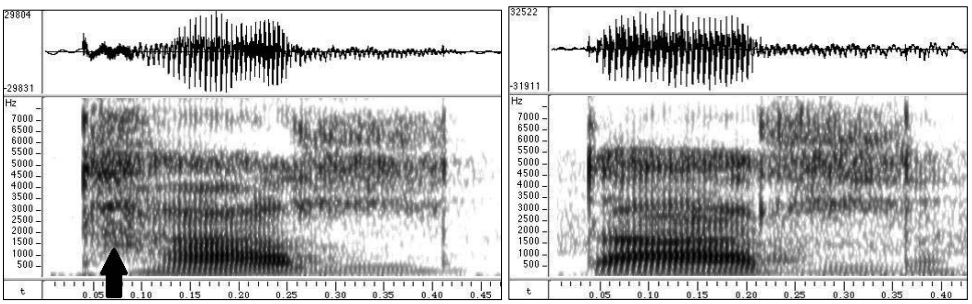

Figure 1. Word-medial /tʰ/ [ʰt] (left) and /t/ [t] (right)
(Svantesson and Karlsson 2012: 459 Figure 2, arrow added)

1.2 Research questions

Although the series of studies by Svantesson and Karlsson have revealed the phonetic realization of strong and weak obstruents in Mongolian, there is room for further research on the acoustic properties of these sounds. The most important issue is that almost all the data in Svantesson and Karlsson's acoustic analyses are for obstruents preceded by a short vowel or else a liquid *l, r* (e.g., /ʊrtʰ/ 'short' and /ʊrt/ 'front'); acoustic data on obstruents preceded by another segment, such as a long vowel or a nasal consonant, are lacking. The kind of segment preceding the aspirated obstruent is likely to affect the realization of preaspiration. In general, devoicing of long vowels, including diphthongs, seems to be less common than that of short vowels.[4] For example, high vowel devoicing in Japanese can be applied to short vowels ([kukaɴ] ~ [kṵkaɴ] 'section'), but never to long vowels (*[kṵ:kaɴ] 'space'). It is natural, therefore, to assume that the frequency and degree of

[4] Long vowels and diphthongs are similar with respect to prosodic structure; both have two morae and bear the nucleus of a heavy syllable within themselves. In the following text, the term "long vowel" includes diphthongs.

vowel devoicing as a manifestation of preaspiration in Mongolian differs according to the length of the preceding vowel. Similarly, it is questionable whether nasals followed by an aspirated obstruent are truly pronounced with aspiration noise and/or devoicing, and whether the contrast between aspirated and unaspirated obstruents can be perceived by means of aspiration noise and/or devoicing, because nasals with aspiration noise and voiceless nasals are phonetically uncommon and perceptually not salient.

In short, preaspiration in Mongolian is anticipated to be realized differently according to the phonological environment. This study aims to determine the phonetic and acoustic realization of aspirated obstruents preceded by a short vowel, a long vowel, and a nasal consonant, respectively, in comparison with their unaspirated counterparts.[5]

2. Method

2.1 Production experiment

A production experiment was conducted to clarify the phonetic variety of preaspiration. The target words were real Mongolian words with word-medial strong obstruents <p, t, k, ts, č> preceded by either a short or a long vowel, including a diphthong, or a nasal consonant. Words with word-medial weak counterparts <b, d, g, dz, ǰ> were used for comparison. The target and comparison words are shown in Tables 1 and 2, respectively.

The words were read in the carrier sentences (2).

(2) a. <..... gedeg nʲ jʊʊ we?> 'What is .....?'
b. <bi ..... geǰ xelsen.> 'I said .....'

The production experiment was conducted as follows: One of the words and the carrier sentences were displayed on a computer with Cyrillic orthography, and the participants immediately read the word inserted in the carrier sentences. This procedure was repeated three times per participant, with the order of stimuli randomized per trial. As a result, six tokens were obtained per word from each participant.

[5] The realization of preaspiration in other environments should also be addressed in future research (for example, in an {obstruent + aspirated obstruent} condition).

Table 1. Target words[6]

	short vowel	long vowel	nasal
<p>	<dzapaas> ‘spare’	–[7]	<kɔmpaani> ‘company’
<t>	<butex> ‘to succeed’ <gʊtal> ‘shoes’	<baatar> ‘hero’	<xantaadz> ‘waistcoat’
<k>	<dekaan> ‘dean’	<fɔɔkʊs> ‘focus’	<ankeet> ‘questionnaire’
<ts>	<bʊtsax> ‘to go back’ <gatsax> ‘to stick’	<baitsaalt> ‘investigation’	<gantsaarlax> ‘to be isolated’
<č>	<ačilt> ‘loading’ <bučix> ‘to surround’	<xʊʊčin> ‘old’	<dzamčin> ‘guide’

Table 2. Words for comparison

	short vowel	long vowel	nasal
<b>	–[7]	–	<sambar> ‘board’
<d>	<budeg> ‘dull’ <gʊdas> ‘mattress’	<aadar> ‘downpour’	<xandax> ‘to face’
<g>	<degee> ‘hook’	<ʊʊgan> ‘eldest’	<tenger> ‘sky’
<dz>	<bʊdzar> ‘dirt’ <gadzar> ‘place’	<aidzam> ‘rhythm’	<gandzaga> ‘saddle-thong’
<ǰ>	<aǰil> ‘work’ <buǰig> ‘dance’	<ʊʊǰʊʊ> ‘wide’	<damǰix> ‘to pass through’

The participants in this experiment were six male native speakers of Mongolian ranging in age from 16 to 19 years. All data were recorded with a digital recorder (ZOOM H4n [WAV, 44.1kHz / 16bit]) and a head-mounted condenser microphone (AKG C520). The recordings were conducted in a quiet room at the Mongolian University of Science and Technology.

2.2 Acoustic analysis

The recorded material was analyzed with Praat (ver. 5.4.13; Boersma and Weenink 2015). Waveforms and spectrograms of each token were observed visually to ascertain how preaspiration of the target words occurred in each phonological environment. Specifically, this study focused on whether aspiration noise was observed on the preceding segment of the obstruents, and whether the preceding segment was devoiced, either partially or fully.

[6] All words that include <p> or <k> are loanwords from Russian. In Mongolian loanwords from Russian, stressed vowels are realized as long vowels, though spelled with a single vowel. In Table 1, stressed vowels in loanwords are written as long vowels for the sake of clarity.

[7] Words with the sequences {long vowel + <p>} and {short vowel + <b>} could not be found, because both <p> and <b> occur in this position in only a few loanwords.

The duration of the aspiration noise and devoicing, however, was not numerically evaluated because sounds change successively over time and it is often difficult to define the boundary with definite and objective criteria.

3. Results

3.1 Preaspiration on short vowels

When an aspirated obstruent is preceded by a short vowel, preaspiration is realized consistently on the vowel. Aspiration noise is observed on the vowel, which is partially or completely devoiced.

First, I deal with preaspiration noise. Many short vowels followed by an aspirated obstruent are realized as vowels with at least partial aspiration noise. More precisely, on the spectrograms they are characterized as having a voice bar but no clear formant structure, and the waveform is quite simple, somewhat similar to a sine wave. Such sounds are viewed as breathy voiced vowels. Figure 2 illustrates a partially breathy voiced vowel and a fully breathy voiced vowel.

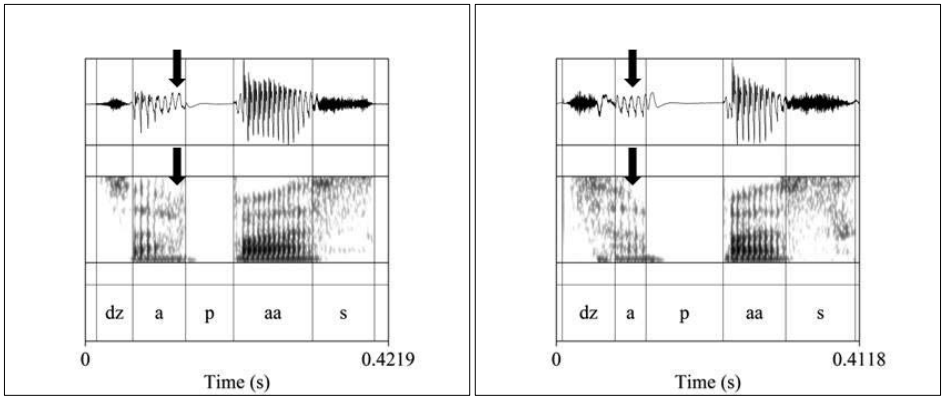

Figure 2. Partially breathy voiced vowel (left) and fully breathy voiced vowel (right)

The acoustic characteristic of breathy voice is that the first harmonic tends to dominate the spectrum, and thus the difference between the amplitudes of the first harmonic (H1) and the second harmonic (H2) is large (Ladefoged and Maddieson 1996: 317–320, Johnson 2012: 170–172). This tendency can be observed for short vowels followed by an aspirated obstruent in Mongolian. Figure 3 shows examples of the mean spectra on the vowel section followed by <t> /t^h/ and <d> /t/.

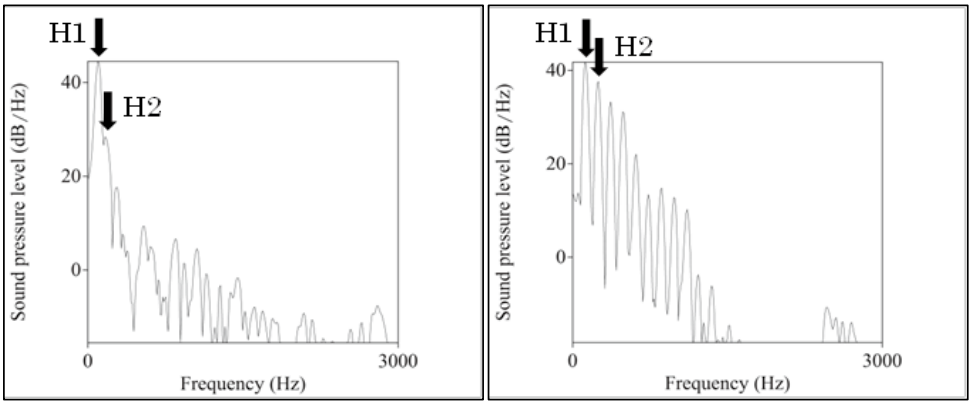

Figure 3. Mean spectra of the vowel section followed by /tʰ/ (left) and /t/ (right)

In addition to breathy voiced vowels, vowel devoicing is a major manifestation of preaspiration. Part or all of the short vowel can be devoiced. Devoiced vowels have neither a voice bar on the spectrogram nor a periodic waveform. Figure 4 shows examples of a partially and a fully devoiced vowel.[8]

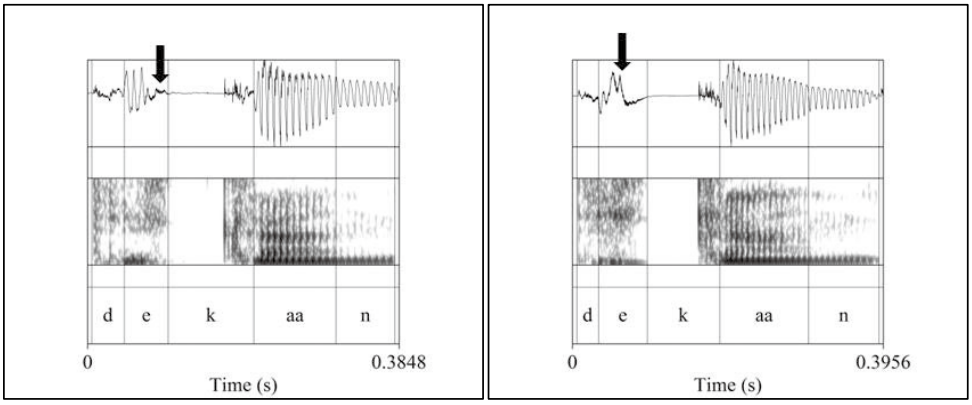

Figure 4. Partially devoiced vowel (left) and fully devoiced vowel (right)

In contrast, vowels followed by a weak obstruent <b, d, g, dz, ǰ> become neither breathy voiced nor devoiced. Instead, in some cases vocal fold vibrations last even after

[8] This sound could be analyzed not as a devoiced vowel but as a voiceless glottal fricative [h], because no periodic waveform is found. It is true that this aspiration noise can sometimes be perceived as more like [h] than a devoiced vowel. However, it is extremely difficult to objectively distinguish [h] from a devoiced vowel. The same holds true for the distinction between a breathy voiced vowel and a voiced glottal fricative [ɦ]. In this paper, glottal fricatives [h]/[ɦ] are not differentiated from devoiced/breathy vowels.

the beginning of the stop closure. Moreover, <b> and <g> are often realized as voiced fricatives [β] and [ɣ] (see Ueta [forthcoming] for phonetic variants of Mongolian obstruents). Figure 5 shows examples of an unaspirated stop <g> ([k] or [g̊]), which has no aspiration noise on the preceding vowel, and a voiced fricative <g> ([ɣ]).

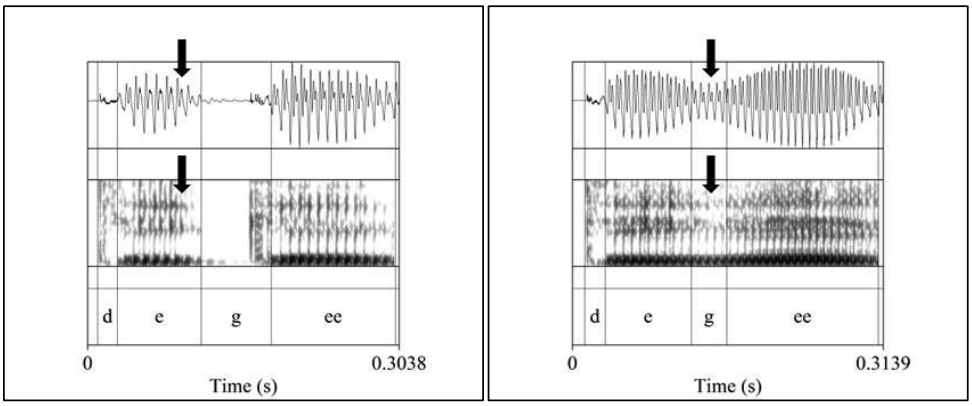

Figure 5. Unaspirated stop <g> (left) and voiced fricative <g> (right)

Thus, it is clear that word-medial aspirated obstruents preceded by a short vowel are characterized by aspiration noise on the preceding vowel, which more specifically is realized as a breathy voiced and/or devoiced vowel. Figures 6 and 7 show how short vowels preceding an aspirated obstruent are realized. The two figures display the relative frequencies of (1) (at least partially) breathy voiced vowels, (2) the gradual change in sound from breathy voiced to devoiced, (3) fully devoiced vowels, and (4) modal voiced vowels, which are neither breathy voiced nor devoiced (in other words, preaspiration is not explicitly realized). In what follows, AM, BB, DG, ES, OB, and ST in the figures indicate the six participants in the experiment.

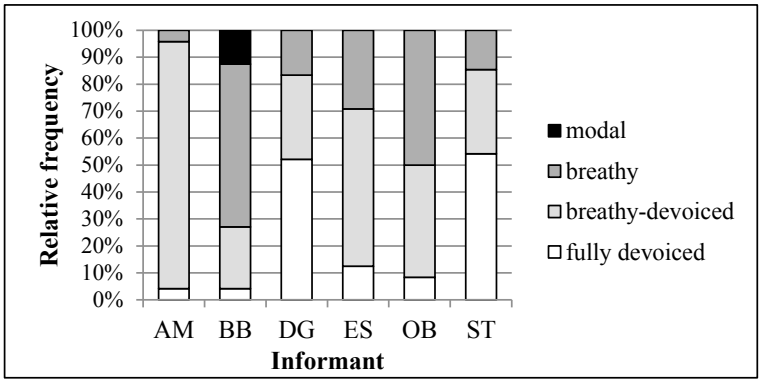

Figure 6. Relative frequencies of four types of realization for short vowels (by informant)

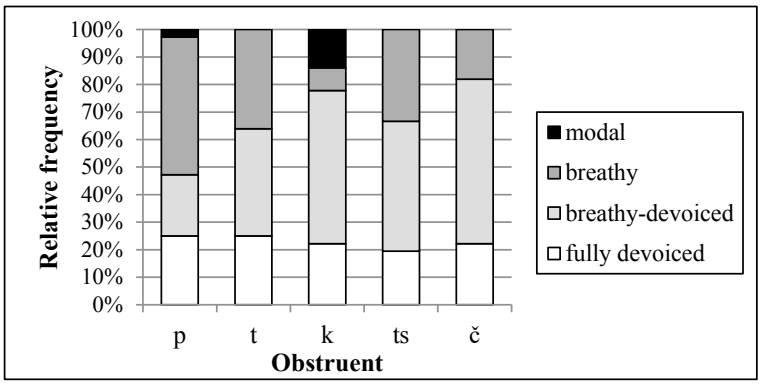

Figure 7. Relative frequencies of four types of realization for short vowels (by obstruent)

Figure 6 shows that the frequency of fully devoiced vowels differed across informants. This is not surprising because whether or not a vowel is fully devoiced is not a matter of phonology. With respect to obstruent type, Figure 7 shows that <p, t, k, ts, č> all caused full vowel devoicing. Modal vowels were observed in the speech of one informant (BB) when the following obstruents were <p> or <k>. This might be related to the fact that <b> and <g> can be intervocalically realized as voiced fricatives [β] and [ɣ], and <p> and <k> can be distinguished from <b> and <g> even without preaspiration (see Ueta [forthcoming] for more details).

3.2 Preaspiration on long vowels

When an aspirated obstruent is preceded by a long vowel, preaspiration is usually realized as a partial breathy voiced section of the vowel.

The proportion of the breathy voiced section of the vowel is much lower than in short vowels, with a duration not more than half that of the vowel. Additionally, unlike short vowels, long vowels are rarely devoiced. There were no cases of a long vowel being

fully devoiced, and when devoicing occurred, the section was extremely short. In some cases, neither breathiness nor devoicing was observed, and often even a remnant of vocal fold vibrations was present in the stop closure. In such cases, preaspiration is not realized at all, and thus the phonetic difference between aspirated and unaspirated obstruents is quite small. It is not clear whether the contrast between them is retained in some way or is neutralized. Figure 8 illustrates a partially breathy voiced vowel and a modal voiced vowel.

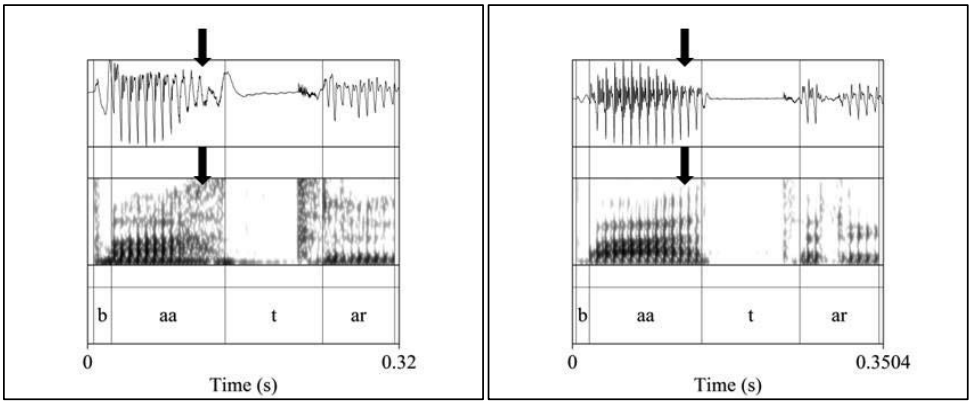

Figure 8. Partially breathy voiced vowel (left) and modal voiced vowel (right)

Cases in which preaspiration was not realized were somewhat common. The relative frequency of each phonetic realization is shown in Figures 9 and 10.

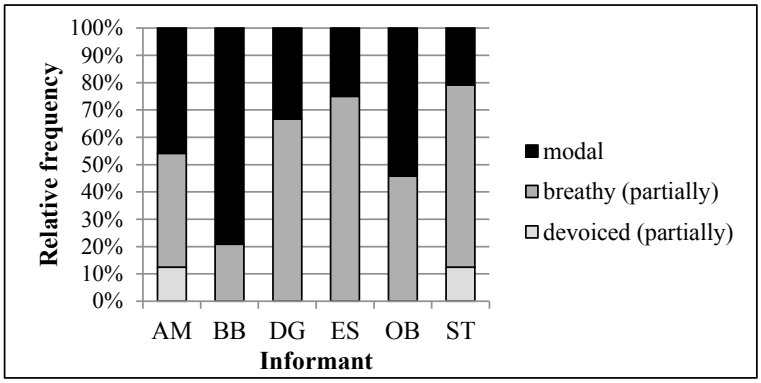

Figure 9. Relative frequencies of three types of realization for long vowels (by informant)

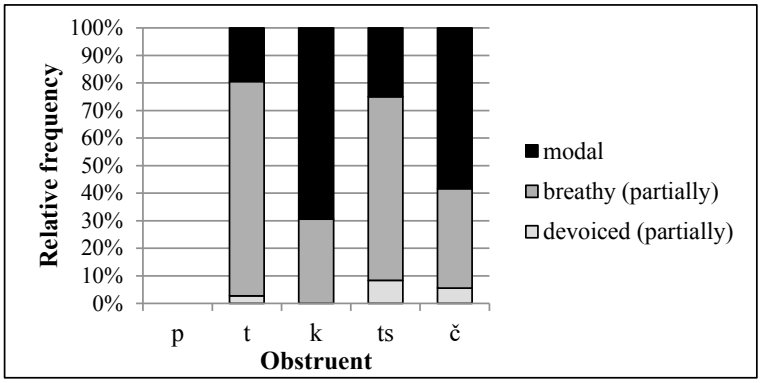

Figure 10. Relative frequencies of three types of realization for long vowels (by obstruent)[9]

The frequency of modal voiced vowels again differed from speaker to speaker. Notably, the same informants who tended to pronounce long vowels as modal voiced vowels (BB and OB) did not tend to pronounce short vowels as devoiced vowels (i.e., they tended to pronounce them as modal and breathy vowels). This suggests a parallelism between breathiness on long vowels and devoicing on short vowels. With respect to obstruent type, <k> again tended to retain the modal voiced of preceding vowels, which might be explained based on the phonetic contrast with <g> [ɣ], as mentioned above.[10]

In conclusion, preaspiration on a long vowel may be characterized as a partially breathy voiced vowel, but it is not always realized. Additionally, little vowel devoicing occurs. Thus, the realization of preaspiration is less salient than in the case of short vowels.

3.3 Preaspiration on nasals

When an aspirated obstruent is preceded by a nasal consonant, the realization of preaspiration is on the whole unclear. Aspiration noise on nasals followed by an aspirated obstruent was observed in two-thirds of the tokens (120 of 180). In these cases, nasals were realized as partially breathy voiced nasals or partially devoiced nasals. However, the section of aspiration noise or devoicing was quite short, and in no case was the nasal fully devoiced. Moreover, aspiration noise was not observed on the nasal in a third of the tokens. Figure 11 illustrates a nasal with and without aspiration noise.

[9] As shown in Table 1, there is no target word with the sequences {long vowel + <p>} in this experiment.

[10] It is not clear why long vowels before <č> do not tend to become breathy voiced. The kind of long vowel (low or high vowels, for example) may also be involved.

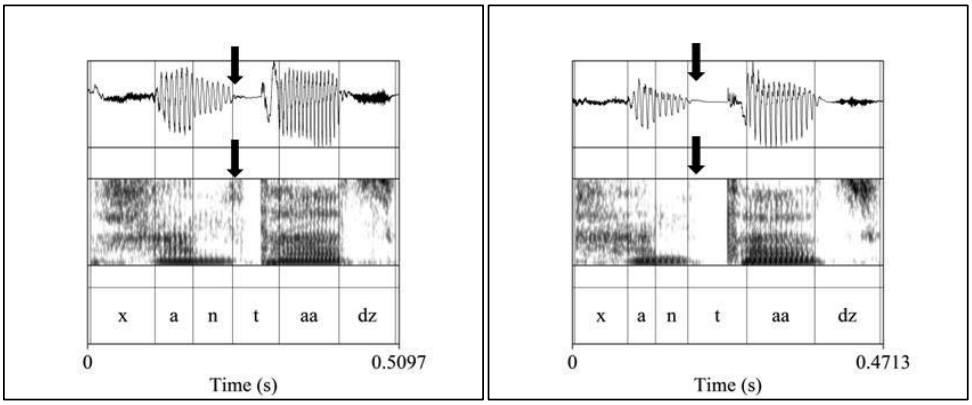

Figure 11. Nasals with aspiration noise (left) and without aspiration noise (right)

It is questionable whether such a short and unclear realization of preaspiration can maintain the contrast between aspirated and unaspirated obstruents.

In sequences with weak obstruents <b, d, g, dz, ǰ> following a nasal consonant, there is naturally no aspiration noise on the nasals, because weak obstruents are not aspirated consonants. However, the duration of the nasals is relatively long and, in contrast, the duration of the stop closure is quite short.[11] In some cases, the nasal section with voicing lasts until the stop release of the following obstruent, meaning that the obstruent can be regarded as voiced. Figure 12 shows the waveforms and spectrograms of <n+d> (/n+t/) sequences with and without a stop closure.

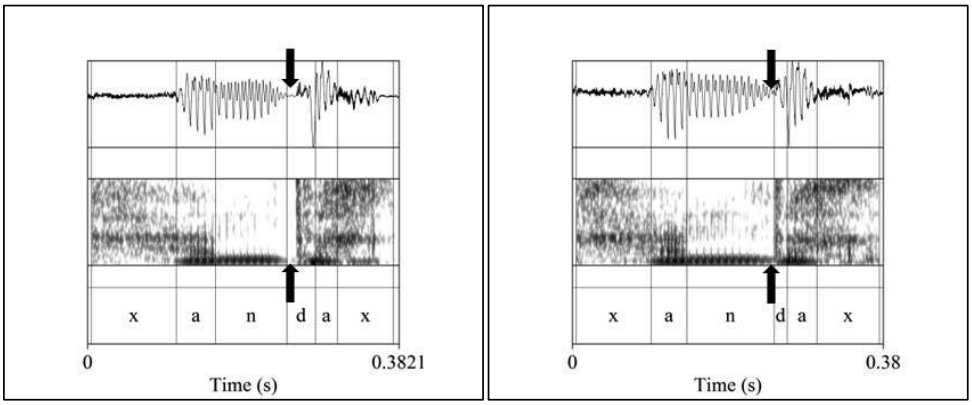

Figure 12. <n+d> (/n+t/) with a stop closure (left) and without a stop closure (right)

[11] In this study, only the section of a stop closure without voicing is regarded as a "stop closure," because it is quite difficult to distinguish a stop closure with voicing from a nasal with voicing.

Figures 11 and 12 clearly demonstrate that the nasal-to-stop-closure duration ratio is much higher in /n+t/ than /n+t^h/.[12] The mean durations of nasals and stop closures for strong obstruents <p, t, k, ts, č> and weak obstruents <b, d, g, dz, ǰ> are shown in Figures 13 and 14. The duration of the stop closure is zero if the voicing lasts until the stop release, as in Figure 12 (right).

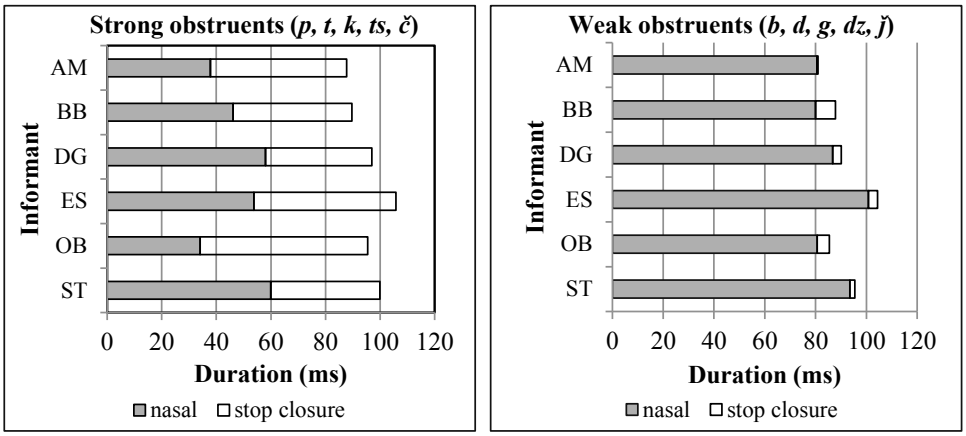

Figure 13. Mean durations of nasals and stop closures for strong (left) and weak (right) obstruents (by informant)

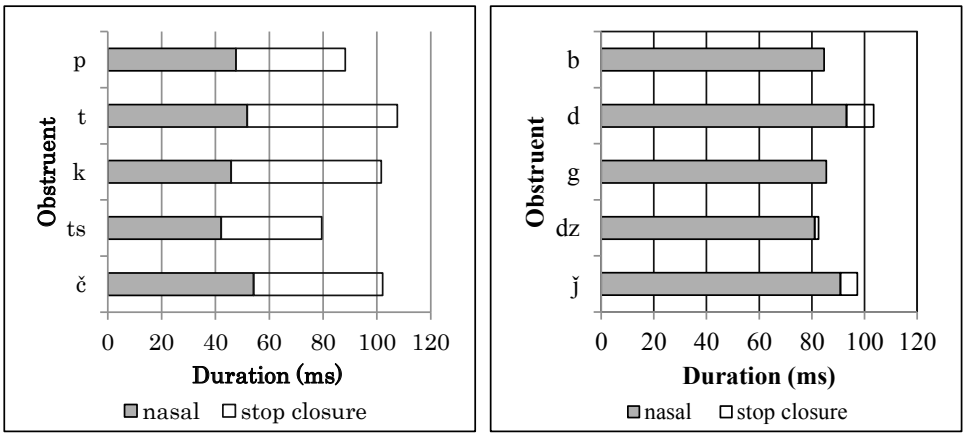

Figure 14. Mean durations of nasals and stop closures for strong (left) and weak (right) obstruents (by obstruent)

[12] The second vowel is long in <xantaadz> and short in <xandax>. One might think that the length of the vowel following <t> or <d> affects the duration of the stop closure. This is unlikely, however, to be the case, because the duration of the stop closure is also much higher in <dzamčin> than in <damǰix>, even though both of them have a short vowel after <č> or <ǰ> (see Figure 14).

Figures 13 and 14 show a clear difference in the mean durations of nasals and stop closures between strong and weak obstruents: Nasals before strong obstruents are constantly much shorter than those before weak obstruents, and stop closures of strong obstruents are much longer than those of weak ones. From the perspective of the nasal-to-stop-closure duration ratio, the ratio is much lower in strong obstruents than in weak ones. This suggests that strong and weak obstruents can be distinguished by the difference in duration ratio rather than the presence or absence of aspiration noise. With respect to obstruent type, <b> and <g> were always realized without a stop closure, namely as fully voiced obstruents. This could support the claim that <b> and <g> are phonologically not unaspirated but voiced obstruents (see Ueta [forthcoming]).

4. Discussion

The phonetic realization of preaspiration in each phonological environment is summarized in Table 3.

Table 3. Phonetic realization of preaspiration in each phonological environment

preceding segment	realization
short vowel	devoiced vowel / breathy voiced vowel
long vowel	partially breathy voiced vowel
nasal	short nasal and long stop closure

When the preceding segment is a vowel, preaspiration is realized as breathy voice and/or devoicing on the vowel. Physiologically, both breathy voice and devoicing are realized by opening the glottis (Ladefoged and Johnson 2011: 148–149). Therefore, it is plausible to assume that strong obstruents in Mongolian have the phonological feature [spread glottis], which corresponds to the action of opening the glottis, while weak obstruents do not have this feature. The phonetic realization of the feature [spread glottis] can be considered successively variable, with the most radical manifestation of [spread glottis] being full devoicing. The relationship between the phonetic realization of [spread glottis] and the type of preceding vowel is schematized in Figure 15.

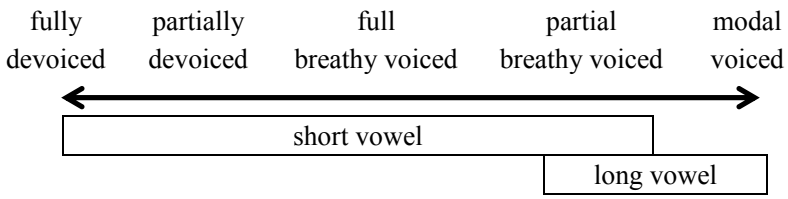

Figure 15. Phonetic realization and preceding vowels

The frequency and degree of vowel devoicing differ according to whether the vowel is short or long. Specifically, full devoicing can occur only in the case of short vowels. One explanation seems to be that at first glance, short vowels have a phonetically short duration, and thus the aspiration noise masks the voicing feature of short vowels. However, this is insufficient to explain why long vowels are rarely devoiced. The fact that long vowels are not devoiced even in the last half section indicates that long vowels are not merely phonetically prolonged vowels but phonologically heavy elements. They bear the nucleus of a heavy syllable and attract a word accent, which is realized as a high pitch in Mongolian, and thus they must be phonetically salient and stable. Preaspiration as the realization of [spread glottis] can potentially threaten the phonetic salience and stability of the preceding vowel by causing it to be breathy voiced or devoiced. In other words, the stability of the vowel conflicts with the realization of [spread glottis]. Long vowels resist the effect of [spread glottis] because of their phonetic stability based on phonological heaviness, and as a result they are usually realized as partially breathy voiced vowels, a relatively moderate manifestation of [spread glottis], or even as modal vowels on which [spread glottis] is not realized. In contrast, short vowels are strongly affected by [spread glottis] because they are not phonologically heavy and thus not phonetically stable.

Preaspiration on nasals is not salient either. Instead, strong and weak obstruents differ greatly with respect to the durations of stop closures and the preceding nasals. As shown in Figures 13 and 14, nasals followed by an aspirated obstruent are shorter in duration than those followed by an unaspirated obstruent, whereas the duration of stop closures is much longer for aspirated obstruents than unaspirated obstruents. This suggests that the [spread glottis] feature of aspirated obstruents is realized not as breathiness or devoicing of nasals but rather as a discontinuation of phonation of the nasal, resulting in a reduction of the nasal section and extension of the stop closure.

In general, the duration of stop closures and preceding segments is known to differ between voiceless and voiced obstruents, as shown in Table 4, and this difference can be an important perceptual cue distinguishing them (Klatt 1975, Catford 1977, Kent and Read 1992, among others).

Table 4. Voicing contrast and duration

	preceding segment	**stop closure**
voiceless obstruent	short	long
voiced obstruent	long	short

If “voiceless” and “voiced” are replaced with “aspirated” and “unaspirated,” respectively, this tendency holds for the duration ratio for aspirated and unaspirated obstruents after nasals in Mongolian. This difference in duration is thus considered to play an important role in distinguishing aspirated and unaspirated obstruents after nasal

consonants in Mongolian.

5. Conclusion

This paper examined the acoustic realization of word-medial aspirated obstruents preceded by a short vowel, a long vowel, and a nasal consonant in Mongolian. The production experiment and acoustic analyses revealed the following:

(3) a. When an aspirated obstruent is preceded by a short vowel, preaspiration is explicitly realized as breathy voice and/or devoicing of the vowel. Short vowels are often fully devoiced.

b. When the preceding segment is a long vowel, preaspiration is mainly realized as partial breathy voice on the last part of the vowel. Vowel devoicing rarely occurs and the realization of preaspiration is less salient than on short vowels. In some cases, neither breathiness nor devoicing is observed. This is probably because the [spread glottis] feature conflicts with the phonological heaviness of long vowels.

c. In nasal-aspirated obstruent sequences, preaspiration is in many cases not salient. Instead, aspirated obstruents are characterized as being preceded by shorter nasals and having longer stop closures than their unaspirated counterparts.

(3a–c) indicate that preaspiration can be realized in various forms according to the phonological environment, and accordingly it is likely that the perceptual cues of the contrast between aspirated and unaspirated obstruents also differ according to the phonological environment.

Appendix

The transliteration system for Cyrillic script

Cyrillic script	а	б	в	г	д	е	ё	ж	з	и	й	к	л	м	н	о	ө
transliteration	a	b	w	g	d	je,jө,e*	jɔ	ǰ	dz	i	i	k	l	m	n	ɔ	ө

Cyrillic script	п	р	с	т	у	ү	ф	х	ц	ч	ш	щ	ъ	ы	ь	э	ю	я
transliteration	p	r	s	t	ʊ	u	f	x	ts	č	š	šč	-	ii	^{j}	e	jʊ, ju	ja

* Cyrillic script e in loanwords is transliterated as <e>.

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Summary

In Khalkha Mongolian, there are two contrastive series of obstruents. Recent acoustic analyses have revealed that this contrast is based on aspiration. Some previous studies have reported that aspiration is realized as postaspiration in word-initial position and as preaspiration in word-medial and final positions. Preaspiration is said to be characterized as clearly audible aspiration noise and at least partial devoicing of the preceding segment. However, almost all the data used in the previous studies are for obstruents preceded by a short vowel; acoustic data of obstruents preceded by other segments are lacking.

This paper examines the acoustic realization of word-medial aspirated obstruents preceded by a short vowel, a long vowel, and a nasal consonant in Khalkha Mongolian. A production experiment and acoustic analyses indicate that preaspiration in Khalkha Mongolian appears in various forms according to the phonological environment: When an aspirated obstruent is preceded by a short vowel, preaspiration is realized as breathy voicing and/or devoicing on the vowel, whereas in the case of long vowels before an aspirated obstruent, it is mainly realized as partial breathy voice on the vowel, which is rarely devoiced. When the preceding segment is a nasal consonant, preaspiration is not salient in many cases. Instead, aspirated obstruents are characterized as being preceded by shorter nasals and having longer stop closures than their unaspirated counterparts.

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