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The Merger between /ʊ/ and /o/ in Khalkha Mongolian:

A Study Based on an Acoustic Analysis and a Perceptual Experiment

Naoki UETA
(Kyoto University)

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1. Introduction

Khalkha Mongolian, henceforth "Mongolian," has seven basic vowels: /i, e, a, u, ʊ, o, ɔ/. Although /ʊ/ and /o/ are considered phonemically contrastive in this vowel system, the phonetic realization of these two vowels is not necessarily clear since their phonetic descriptions differ across previous studies. In addition, there is room for discussion about whether the phonetic characteristics of these vowels are sufficiently different to distinguish each other, and whether they are actually differentiated perceptually by native speakers.

This study reports the results of an acoustic analysis and a perceptual experiment on distinguishing between /ʊ/ and /o/ in Mongolian and makes the following claims:

(1) a. The acoustic characteristics of Mongolian /ʊ/ and /o/ are not sufficiently different to completely distinguish these vowel phonemes.
b. Mongolian /o/ is not perceptually differentiated from /ʊ/ by native speakers; thus /o/ has merged into /ʊ/.
c. The merger of /o/ into /ʊ/ has occurred for both the short and long vowels.

Section 2 confirms the phonemic contrast between /ʊ/ and /o/ and summarizes the description of the phonetic realization of these vowels in previous studies. The following two sections show the methods and results of an acoustic analysis (Section 3) and a perceptual experiment (Section 4) with respect to the distinction of /ʊ/ and /o/. Based on these results, Section 5 discusses the merger between /ʊ/ and /o/ in Mongolian. Section 6 concludes the study.

2. Phonemic Contrast and Phonetic Realization of ʊ and o

Mongolian has seven basic vowels, as shown in Table 1.

Table 1. Target words

Phonemic description	/i/	/e/	/a/	/u/	/ʊ/	/o/	/ɔ/
Cyrillic orthography	и	э	а	ү	у	ө	о

/ʊ/ and /o/, and their long counterparts /ʊʊ/ and /oo/, are phonemically contrastive. This fact is exemplified by minimal pairs:

(2) a. ʊr “artistry” - or “debt” (yp - өp in Cyrillic orthography)
b. ʊʊr “steam” - oor “other” (yyp - өөp in Cyrillic orthography)

However, the phonetic realization of these vowels is not necessarily clear since their phonetic descriptions differ across previous studies. In addition, it is questionable whether these two vowels can be clearly differentiated by native speakers.

Shiotani and Purevjav (2001: 7) explain with Cyrillic letters and phonetic alphabets that ө [ɵ] (/o/ in this study) is pronounced by moving the tongue position forward to some degree from that for у [o] (/ʊ/ in this study), holding the shape of the mouth. They schematize the tongue positions in pronouncing four rounded vowels /u, ʊ, o, ɔ/ (ү, у, ө, о in Cyrillic orthography) as shown in Figure 1.

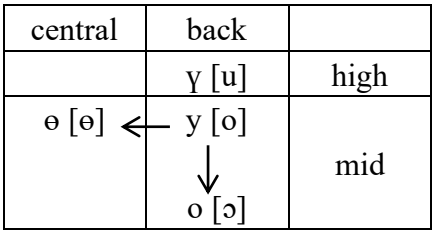

Figure 1. Schematized tongue positions of four rounded vowels
(Shiotani and Purevjav 2001: 7, translated into English)

Jõo (2005) describes in detail the acoustic characteristics of each vowel in Mongolian.[1] He shows that the second formant (F2) of /o/ is higher than that of /ʊ/ (and other rounded vowels) and claims that /o/ is characterized as a central vowel. Figure 2 shows an example of vowel diagrams provided in Jõo (2005). It should be noted that o2, o, u2, and u in Figure 2 represent /o/, /ɔ/, /u/, and /ʊ/ in this study, respectively.

[1] The purpose of Jõo (2005) is to analyze the characteristics of vowel harmony in Mongolian from the perspective of experimental phonetics.

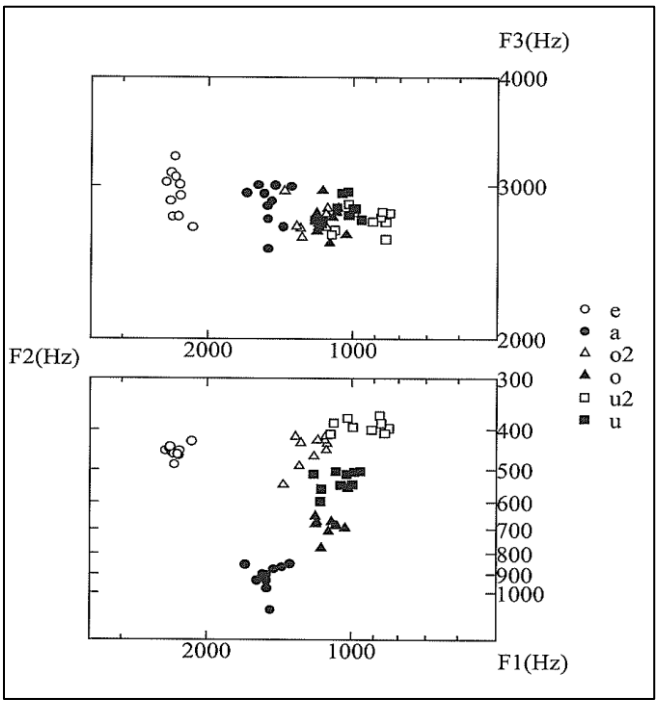

Figure 2. Vowel diagram (Jōo 2005: 75, Figure 2−18)

Based on acoustic analyses, Svantesson et al. (2005) show that /ʊ/ and /ʊʊ/ are both realized as [ʊ] and [ʊː], while short /o/ and long /oo/ are pronounced as [ɵ] and [oː], respectively, and the formant structures of /ʊʊ/ and /oo/ are similar to each other, as shown in Figure 3.

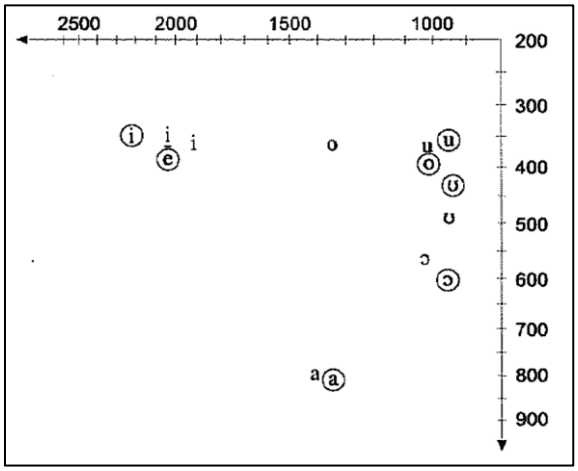

Figure 3. F1−F2 diagram (Svantesson et al. 2005: 4, Figure 1.3)

In Figure 3, the vertical and horizontal axes are the first formant (F1) and the second formant (F2), respectively, and the circled vowels represent long vowels. Figure 3 shows that short /ʊ/ and /o/ are located in quite different areas, while long /oo/ is close to long

/ʊʊ/.

Janhunen (2012) explains the phonetic realization of /ʊ/ and /o/ in some dialects of Mongolian, including Khalkha, with their historical changes: “the original high rounded back vowel (**u*) has been lowered from its velar quality [u] to the higher mid-range quality [ʊ], or even to the mid-high quality [o], which can be additionally pharyngealized” (Janhunen 2012: 31), and “the mid-high front quality [ø] has been centralized to [ɵ], a quality still present in many dialects, and then further fully velarized to [o]” (ibid.: 32). This description implies that both /ʊ/ and /o/ can be pronounced as [o], which suggests that these two vowels have been merging.

Based on acoustic analyses, Ueta (2019) claims that not only short /o/ but also long /oo/ are central vowels to some extent, as illustrated in Figure 4, and thus should basically be described as [ɵ] and [ɵː]. However, Ueta (2019) also points out that the phonetic realization of /o/ and /oo/ is quite different across speakers and that some speakers pronounce /o/ and /oo/ as similar sounds to /ʊ/ and /ʊʊ/, indicating that /o/ and /oo/ have been merging to /ʊ/ and /ʊʊ/, at least in some speakers. Figure 5 shows the mean values and the distributions of F1 and F2−F1 of /ʊ/, /ʊʊ/, /o/, and /oo/ obtained from three native Mongolian speakers, who pronounce these vowels as similar sounds. Figure 5 shows that the areas of /ʊ/ and /o/ overlap.

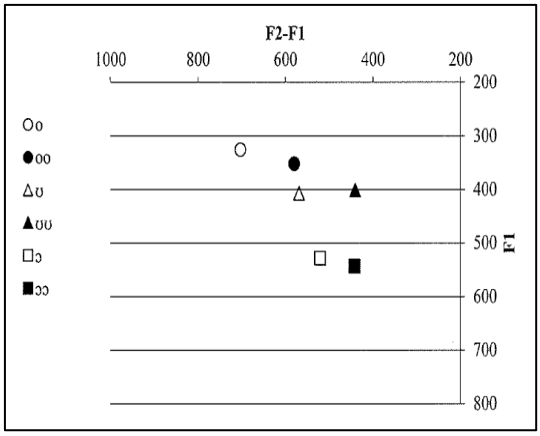

Figure 4. Mean F1 and F2−F1 values (by eleven speakers)
(Ueta 2019: 161, Figure 5-9)

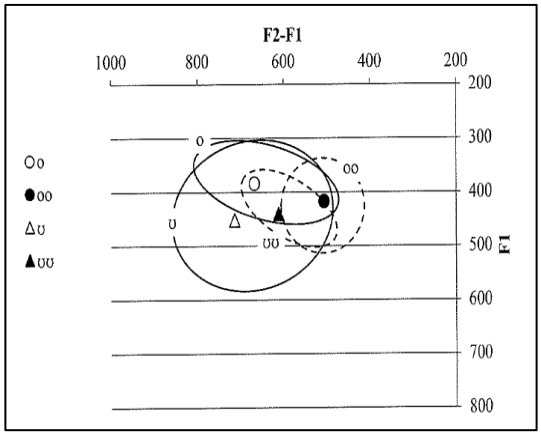

Figure 5. Mean F1 and F2−F1 values and vowel space (by three speakers)
(Ueta 2019: 167, Figure 5-16)

The phonetic descriptions from the previous studies mentioned above are summarized in Table 2.

Table 2. Descriptions of phonetic realization of /ʊ/ and /o/

Previous studies	**/ʊ/**	**/o/**
Shiotani and Purevjav (2001)	[o]	[ɵ]
Jōo (2005)	back	central
Svantesson et al. (2005)	[ʊ]	short: [ɵ], long: [oː]
Janhunen (2012)	[ʊ~o]	[ɵ~o]
Ueta (2019)	[ʊ~o]	short: [ɵ], long: [ɵː] ~ short [ʊ~o], long: [ʊː~oː]

Table 2 suggests that /ʊ/ and /o/ in Mongolian are phonetically similar and are likely to have merged. However, acoustic analyses of /ʊ/ and /o/ have not been sufficiently conducted to clarify to what extent native Mongolian speakers differentiate these two vowels. In addition, little research has dealt with this phenomenon from the perspective of perception; it is still unclear whether these two vowels can be both phonetically and perceptually distinguished. Thus, this present study conducted an acoustic analysis and a perceptual experiment on the distinction between /ʊ/ and /o/, using the phonetic data obtained from a native Mongolian speaker.

3. Acoustic Analysis

3.1 Method of Acoustic Analysis

The acoustic analysis was carried out using real words in Mongolian that form minimal pairs by /ʊ/-/o/ or /ʊʊ/-/oo/. Specifically, the target words were the six pairs shown in (3); each word in (3a) has a short vowel, and each word in (3b) has a long vowel.

(3) a. bʊx “bull” - box “wrestling”
ʊr “artistry” - or “debt”
xʊls “bamboo” - xols “sweat”
b. bʊʊ “gun” - boo “shaman”
ʊʊr “steam” - oor “other”
ʊʊx “to drink” - oox “fat”

The target words (3) were read in isolation (4a) and in two carrier sentences (4b, c) by a female native Mongolian speaker who was born in Ulan Bator in the late 1980s. The target words were listed at random under the condition that a minimal pair was not adjacent lest the speaker should intentionally contrast these two words.

(4) a. ..... (in isolation)
b. *manai aaw ..... gejˇ xelsen*. “Our father said .....”
c. ..... *gedeg nʲ jʊʊ wee?* “What is .....?”

All read sentences were recorded in an anechoic chamber with a digital recorder (ZOOM H4n [WAV, 44.1kHz / 16bit]) and a head-mounted condenser microphone (AKG C520). The recording was conducted in February 2019.

The recorded material was analyzed with Praat (Boersma and Weenink 2020). This study analyzes the first two formants, namely, F1 and F2, of /ʊ/, /ʊʊ/, /o/, and /oo/, since it is well known that vowels can be quite well characterized by F1 and F2 (Catford 2001: 153, Shirai 2004: 141, Ladefoged 2005: 40−48).[2] After the vowel sections of each target word were identified by visually checking waveforms and spectrograms, ten points were marked on every vowel section at regular intervals from the beginning to the end of the vowel section, and the values of F1 and F2 were measured on these ten points with a query function of Praat. During analysis, the formant values extracted on the first and the last points were discarded because the effect of preceding or following consonants, or word boundaries, was quite large at these points.

In this study, it is impossible to explore the difference among speakers, as having been analyzed in Ueta (2019), since the informant was only one speaker. Instead, it elaborates on whether a native Mongolian speaker can distinguish some minimal pairs by /ʊ/ - /o/ and /ʊʊ/ - /oo/, and can differentiate between /ʊ/ (/ʊʊ/) and /o/ (/oo/) on the whole, by precisely observing the formant structures.

3.2 Results of Acoustic Analysis

First, the loci of formants in all target vowels were examined. Figures 6−9 illustrate the movements of F1 and F2 of /ʊ/, /o/, /ʊʊ/, and /oo/, respectively. The numbers of the horizontal axes (2−9) represent the positions on which formant values were extracted. 1 and 10 do not exist in these figures because they correspond to the first and the last points of vowel sections. Three lines are drawn per target word in Figures 6−9 since each was read three times, as shown in (4a−c).

Figures 6−9 show that the F1 values are similar between /ʊ/ (/ʊʊ/) and /o/ (/oo/), while the F2 values are different between them; the F2 values of /o/ and /oo/ tend to be, on the whole, higher than those of /ʊ/ and /ʊʊ/, especially in long vowels. Compared with long vowels, the ranges of F2 values in short vowels are wide, especially in /o/, and F2 values are quite different across words. These suggest that short vowels, in particular short /o/, are unstable with respect to articulation. Figures 6 and 7 also demonstrate that the ranges of F2 partially overlap between /ʊ/ and /o/.

[2] The third formant (F3) is affected by the position of the lips (Ladefoged 2005: 48). It is unlikely that F3 can contribute to the distinction between /ʊ/ and /o/ in Mongolian because both vowels are rounded and the position of the lips are similar. Thus, this study does not focus on the third (and higher) formant.

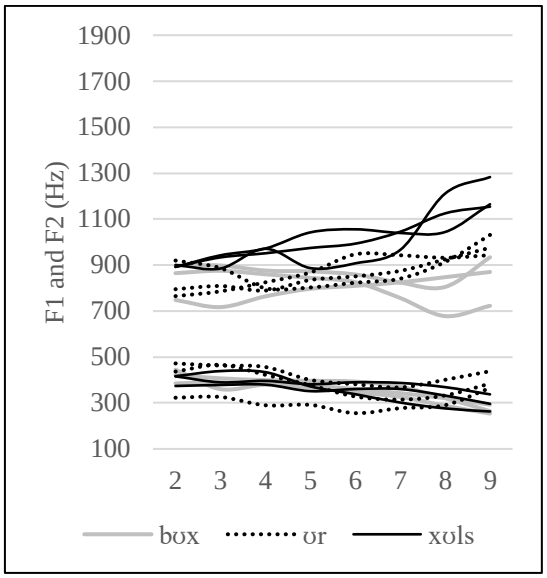

Figure 6. The loci of F1 and F2 of /ʊ/

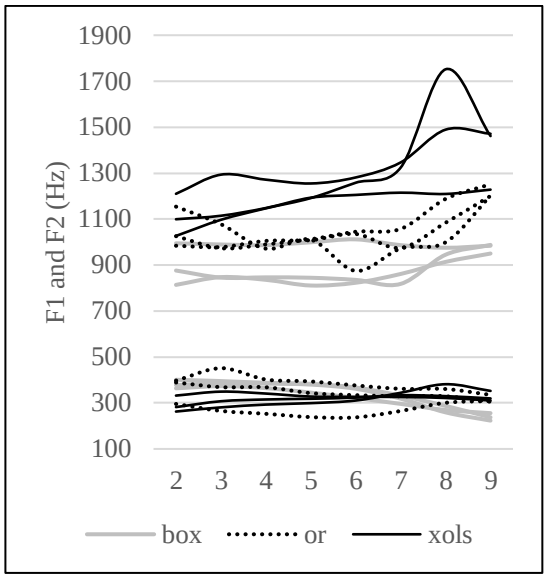

Figure 7. The loci of F1 and F2 of /o/

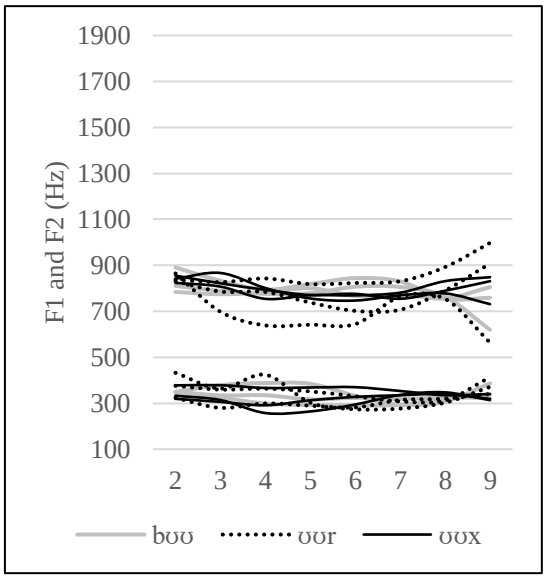

Figure 8. The loci of F1 and F2 of /ʊʊ/

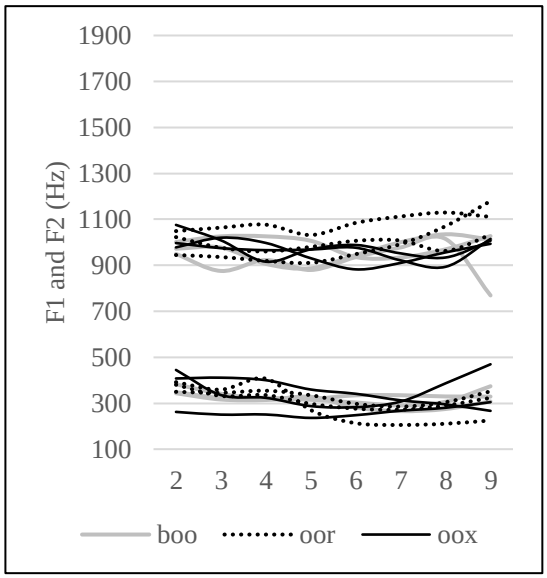

Figure 9. The loci of F1 and F2 of /oo/

Next, typical values of F1 and F2 have been calculated in order to show the static formant structures of each vowel. In Figures 6−9, the formant transitions can be seen in the last part of each graph. It seems that formant structures are relatively stable until point 7; after that, movements become larger. In addition, the effect of preceding consonants sometimes remains at point 2. In other words, points 3 to 6 can be regarded as a section in which formant structures are stable. Thus, the mean F1 and F2 values on points 3−6 were calculated in each target word. The mean F1 and F2 values of each target vowel are shown in Figures 10 (short vowels) and Figure 11 (long vowels).

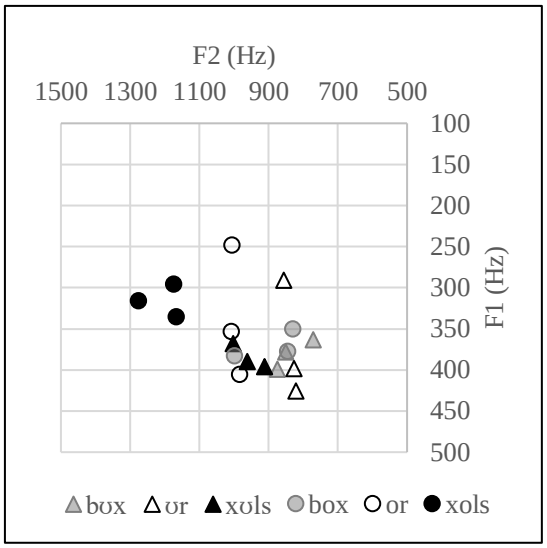

Figure 10. Mean F1−F2 of /ɔ/ and /o/

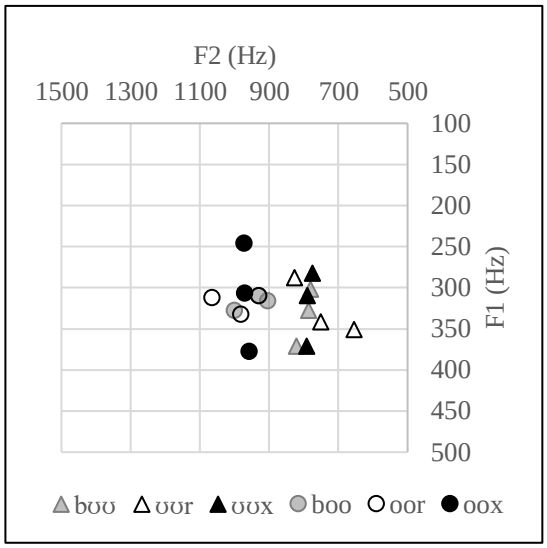

Figure 11. Mean F1−F2 of /ʊʊ/ and /oo/

As shown in Figure 11, long /ʊʊ/ and /oo/ are located in different areas and likely to be distinguished by F2 values. Elsewhere, as shown in Figure 10, the areas of short /ɔ/ and /o/ cannot be clearly divided, although some minimal pairs can be distinguished; the F2 values of *xɔls* are as high as those of *or*, although *xɔls* seems to be differentiated from *xols* by F2 (and F1). Besides, the distributions of *bɔx* and *box* are quite close to each other, and they are considered not to be differentiated by F1 and F2. Statistically, the differences of the mean F2 values are significant not only between long vowels /ʊʊ/ and /oo/ (unpaired *t*-test: $p < .01$) but also between short vowels /ɔ/ and /o/ (unpaired *t*-test: $p < .05$). Figure 10 suggests, however, that the acoustic characteristics of short /ɔ/ and /o/ are not sufficiently different to distinguish these vowel phonemes.

Figure 10 also shows that the F2 values of short vowels, especially /o/, vary widely according to words; for example, the F2 values of *xols* are much higher than those of *box* and *or*. In view of the high F2 values of *xɔls*, F2 values are likely to be relevant to the kinds of preceding consonants.

4. Perceptual Experiment

4.1 Method of Perceptual Experiment

The perceptual experiment was carried out using a subset of the sounds explained in Section 3. Specifically, the target words sections read in the carrier sentence (4c) were cut out and utilized as stimulus sounds. The mean formant values on points 3−6 of the vowel sections in each stimulus sound are shown in Figure 12 (short vowels) and Figure 13 (long vowels); each point corresponds to the counterpart in Figures 10 and 11.

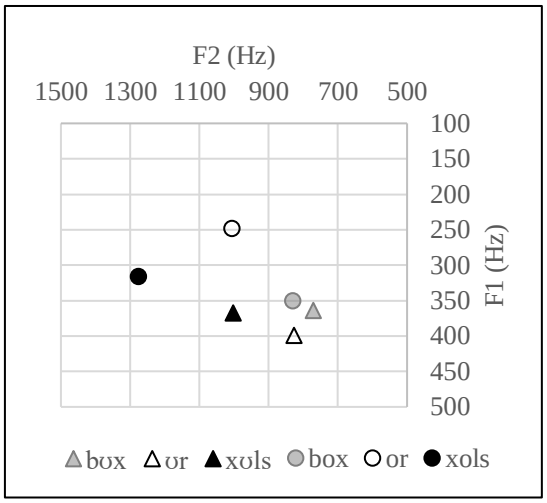

Figure 12. Mean F1−F2 of /ʊ/ and /o/ in stimulus sounds

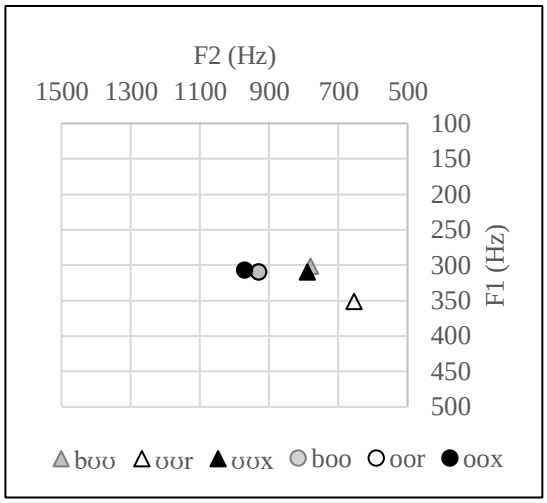

Figure 13. Mean F1−F2 of /ʊʊ/ and /oo/ in stimulus sounds

The purpose of this study was to examine whether native speakers of Mongolian could identify the sounds uttered with the intention of pronouncing /ʊ/ or /o/ by another native speaker. Because the stimulus sounds were recorded by only one native speaker, it was not ensured that the sounds were "standard" or "general" Mongolian pronunciation. However, the sounds were still produced by a native speaker, so these sounds served the purpose of this experiment. Therefore, no acoustic processing was applied to the recorded sounds except the cutting out of the sections.

A judging task was conducted with nine native Mongolian speakers living in Mongolia. They listened to each stimulus sound two times successively and judged immediately which it was of a minimal pair (i.e., a word with /ʊ/ or with /o/). The two choices for every stimulus sound were written in Cyrillic orthography on answer sheets, and the participants were instructed to choose one of them. (5) shows an example of the judging task.

(5) a. [ʊr], [ʊr]: The participants listen to the stimulus sound the speaker uttered with the intention of saying the word *ʊr* two times successively.
b. The participants choose between ур (ʊr) and ор (or) by checking it off with a ✓ on the answer sheet.

The 12 kinds of stimulus sounds, and 38 dummy sounds, were listed at random, under the condition that a minimal pair was not adjacent. After finishing a round of judging, the participants took a short rest and then repeated the task using the same stimulus sounds listed in a different order. In other words, participants judged each stimulus sound two times independently. As a result, the number of tokens obtained from the judging task

totaled 216: 12 stimulus sounds*2 times*9 participants.

4.2 Results of Perceptual Experiment

The results of the judging task are shown in Figures 14 and 15. Figure 14 shows the result for the stimulus sounds uttered by the speaker with the intention of pronouncing /ʊ/ and /ʊʊ/, and Figure 15 shows the result for those uttered with the intention of pronouncing /o/ and /oo/. In what follows, the cases in which the participants chose the vowel that the speaker intended to pronounce are called "correct."

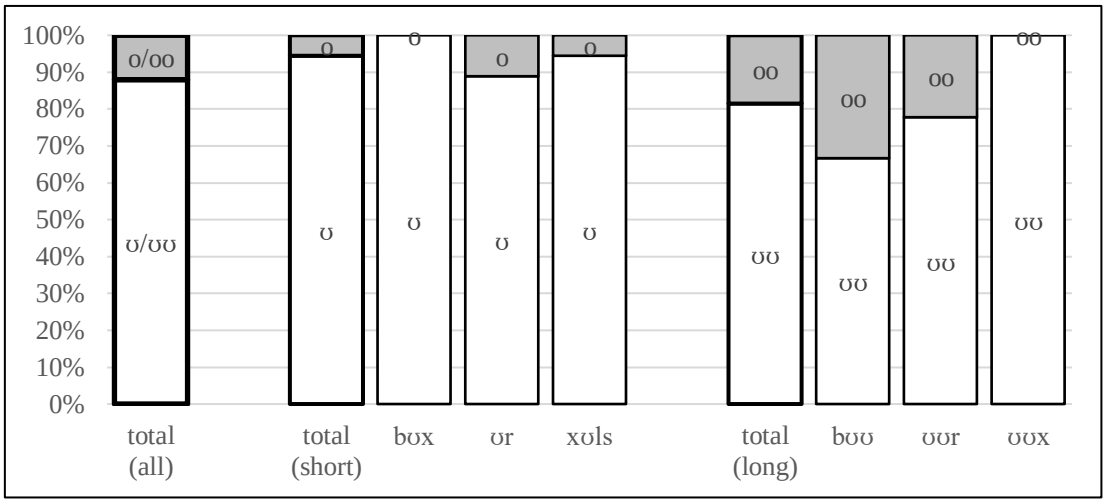

Figure 14. Judging of stimulus sounds /ʊ/ and /ʊʊ/

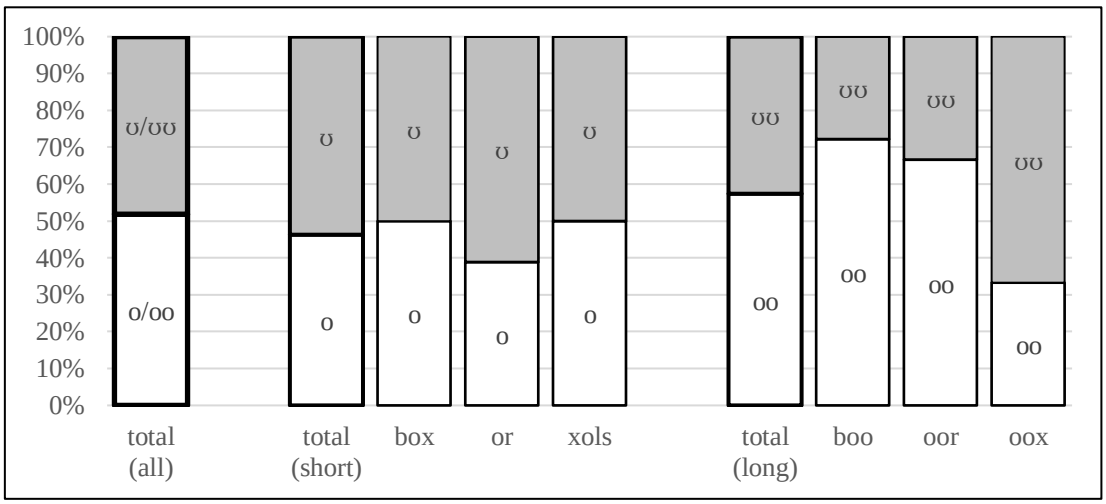

Figure 15. Judging of stimulus sounds /o/ and /oo/

Figure 14 shows that a large proportion (88.0%) of /ʊ/, /ʊʊ/ sounds were correctly perceived. Although the percentage of correct answers for the short vowel /ʊ/ was higher

than that for the long vowel /ʊʊ/, /ʊʊ/ was also correctly perceived at a relatively high rate (81.5%).

Meanwhile, Figure 15 illustrates that nearly half (48.1%) of /o/, /oo/ sounds were incorrectly perceived as /ʊ/, /ʊʊ/. Although the percentage of correct answers for the long vowel /oo/ was higher than that for the short vowel /o/, the value was no more than 57.4%. Considering that the chance level is 50%, since participants were instructed to select from two choices, it can be concluded that /o/, /oo/ sounds cannot be correctly identified and are confused with /ʊ/, /ʊʊ/.

As to the difference between the words, the correct answer rates for *bʊx* and *ʊʊx* were extremely high (100%) while the rate for *bʊʊ* was relatively low (66.7%) in Figure 14, and those for *or* and *oox* were quite low (38.9% and 33.3%, respectively) in Figure 15. It is difficult to provide a valid explanation of these results. It might seem at first glance that the high correct answer rates for *bʊx* and *ʊʊx* are attributed to the fact that the phonetic realization of the consonant /x/ differs according to the vowel harmony. /x/ is pronounced as [x] in words with non-pharyngeal vowels /e, u, o/, while /x/ becomes [χ] in words including pharyngeal vowels /a, ʊ, ɔ/. Namely, the difference in the phonetic realization of /x/ can be a clue to distinguish /ʊ/ from /o/. Nevertheless, this is not a valid explanation of the low correctness rates for the words *xʊls*, *xols*, *box*, and *oox*; on the contrary, *oox* was most frequently confused with *ʊʊx* in this experiment.

In addition, the relationship between formant structures and correct answer rates is also unclear. As shown in Figures 12 and 13, the F2 value of the stimulus sound *xols* is high, and that of *ʊʊr* is low, which mean that *xols* has a more central vowel while *ʊʊr* has a more typical back vowel than others, respectively; further, the correct answer rates for these stimulus sounds could be predicted to be high. However, this is not the case. Similarly, it could be predicted that the correct answer rates for *bʊʊ* and *ʊʊx* would show similar tendencies because the formant values of these two stimulus sounds are very close, as shown in Figure 13. Nevertheless, this is not the case, either; the correct answer rate for *ʊʊx* was extremely high, while that for *bʊʊ* was not.

In sum, the perceptual experiment has revealed that /ʊ/ and /ʊʊ/ are mainly perceived as /ʊ/ and /ʊʊ/, while /o/ and /oo/ are confused with /ʊ/ and /ʊʊ/. It is true that since the stimulus sounds in this experiment were obtained from only one speaker, further investigation is required to clarify whether Mongolian /ʊ/ has generally and completely merged into /o/. The results of this perceptual experiment, however, clarify that the vowels /o/, /oo/, and /ʊ/, /ʊʊ/ cannot be completely distinguished perceptually, and /o/ and /oo/ have merged into /ʊ/ and /ʊʊ/.

5. Discussion

Sections 3 and 4 presented the results of the acoustic analysis and the perceptual experiment, respectively. These results are summarized in (6).

(6) a. Acoustically, long /ʊʊ/ and /oo/ can be distinguished by F2 values, while short /ʊ/ and /o/ cannot be completely distinguished because the F2 values for short vowels are unstable.

b. Perceptually, /o/ (/oo/) has merged into /ʊ/ (/ʊʊ/) and the merger has occurred regardless of the vowel length.

The situation in (6b) is schematized in Figure 16.

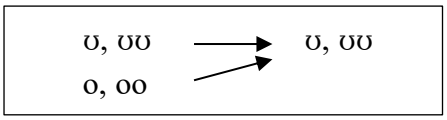

Figure 16. Merger between ʊ and o in Mongolian

As seen in Section 2, previous studies have pointed out that the phonetic realization of /ʊ/ and /o/ is similar. Based on this fact, the results given in (6) should be regarded not as an accident but rather as the reflection of a fact in Mongolian.

It is natural that short /o/ tends to be confused with /ʊ/ in this study because short /ʊ/ and /o/ were not distinguished acoustically in the stimulus sounds, as shown in (6a). However, /o/ was not perceptually distinguished from /ʊ/ even for the stimulus sounds of which the F2 value is quite different from that of the counterpart, for example, *xols* from *xʊls*. Moreover, long /oo/ was also confused with /ʊʊ/ even though the F2 values between /ʊʊ/ and /oo/ tend to be different. These insights suggest that some speakers, including the informant of this study, may recognize /ʊ/ (/ʊʊ/) and /o/ (/oo/) as different sounds and try to distinguish them by different articulation, but the acoustic difference between them is too small for listeners to differentiate one from the other or, to begin with, some listeners cannot distinguish /o/ from /ʊ/, which results in the merger of these vowels. The issue of the relationship between articulation by speakers and perception by listeners awaits further investigation.[3]

As seen above, the merger of /o/ into /ʊ/ has occurred for both short and long vowels. As shown in Section 2, Svantesson et al. (2005) claimed that short /o/ and long /oo/ are pronounced as [ɵ] and [oː], respectively, and the formant structures of /ʊʊ/ and /oo/ are similar to each other. If these claims were true, the merger should have occurred more easily in the long vowels than in the short vowels. The perceptual experiment in this study, however, clarifies that the merger has occurred not only in the long vowels but also in the

[3] This study is based on the Simple Vowel Target Model, which assumes that vowels can be sufficiently defined by a point in the F1−F2 plane. However, it is known that this model is not without limitations or difficulties (Kent and Read 1992: 87−88). It may need to be ascertained whether every Mongolian vowel can be sufficiently identified by only F1 and F2 values with another perceptual experiment.

short vowels to a similar extent. This result runs parallel to the claim in Ueta (2019), which pointed out that /ʊ/ and /o/ have been merging regardless of the vowel length in some speakers. The results in this study lend further support for it from the perspective of perception.

6. Conclusion

This study addressed the merger between /ʊ/ and /o/ in Mongolian from the perspectives of acoustic characteristic and perception. The acoustic analysis in this study confirmed that the realizations of /ʊ/ and /o/ do not, at least in some speakers, exhibit any clear different phonetic characteristics that provide clues for distinguishing these vowel phonemes, and the perceptual experiment revealed that Mongolian /o/ could not be differentiated from /ʊ/ by native speakers. This suggests that Mongolian /o/ has both phonetically and perceptually merged into /ʊ/. In addition, this study clarified that the merger of /o/ into /ʊ/ has occurred for both the short and long vowels.

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Summary

Mongolian has seven basic vowels /i, e, a, u, ʊ, o, ɔ/. Although /ʊ/ and /o/ are considered phonemically contrastive in this vowel system, the phonetic realization of these two vowels is not necessarily clear since their phonetic descriptions differ across previous studies. Further, some studies claim that both /ʊ/ and /o/ can be pronounced as [o]. Thus, there is room for discussion about whether the phonetic characteristics of these vowels are sufficiently different to distinguish each other, and whether they are actually differentiated perceptually by native speakers.

This study addresses the merger between /ʊ/ and /o/ in Mongolian from the perspectives of acoustic characteristic and perception.

An acoustic analysis confirmed that the F2 values of long /oo/ were constantly higher than those of /ʊʊ/, while the F2 values of short /o/ were close to those of /ʊ/; both are unstable. This suggests that the acoustic characteristics of Mongolian /ʊ/ and /o/ are not sufficiently different to completely distinguish these vowel phonemes.

A perceptual experiment on distinguishing between /ʊ/ and /o/ revealed that /ʊ/ was perceived as /ʊ/ at a rate of nearly 90% while /o/ was not distinguished from /ʊ/ in approximately half of the stimulus sounds. This means that Mongolian /o/ has perceptually merged into /ʊ/. In addition, the merger of /o/ into /ʊ/ has occurred for both the short and long vowels to a similar extent. This result runs parallel to the claim in Ueta (2019), which pointed out that /ʊ/ and /o/ have been merging regardless of the vowel length in some speakers. The results of this study lend further support from the perspective of perception.

(ueta.naoki.82x@gmail.com)