Prosodic Studies on the Spoken Corpus of the Khalkha Mongolian Language: Age and Gender Effects on F0 and Speech Rate

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Abstract—**There are many studies on age- and gender-dependent analyses in multiple languages. Still, the fundamental frequency (F0) and speech rate in different age and gender groups with Khalkha Mongolian have not yet been studied. In this investigation, we analyzed the speaker's age and gender effects on F0 and speech rate based on a spontaneous speech corpus of the Khalkha dialect of the Mongolian language. We have discovered some universal aspects of these phonological phenomena and specific relevant characteristics of speech rate change depending on gender. The average speech rate of Khalkha Mongolian is 5.3 syllables per second. The male speakers spoke much quicker than the female speakers. Age and gender affect the F0 and speech rate in particular systematic ways. The F0 of the female and male speakers tended to decrease with age. Also, that elderly male speakers talk slower than elderly female speakers, while young and middle-aged male speakers tend to talk faster than female speakers of the same age.**

Index Terms—**Mongolian language, age, gender, F0, speech rate**

I. INTRODUCTION

In this paper, we analyzed a spontaneous speech corpus of the Khalkha Mongolian language and defined its F0 and speech rate about the different age and gender groups. Previous research on speech rate and F0 of the Khalkha Mongolian has not yet been conducted.

So, based on previous theories and hypotheses, we focused on the following issues of the prosody of Khalkha Mongolian:
    -Do the F0 and the speech rate vary depending on age and gender?
    -What is the average spontaneous speech rate in Khalkha Mongolian?)

A. Theoretical Background

The human language is variable. However, this variability is not chaotic. Investigations on systematic variation can contribute in many domains, such as language acquisition, theories of the sciences of language, speech processing, etc.

The fundamental frequency is essential in communicating information both about speakers' stable characteristics (e.g., monotonous speakers perceived as boring) and about transient speaker emotions or states (e.g., "raising the voice" to signal anger or surprise) (Patterson & Ladd, 1999). Experimental research using physical features has shown that the primary physical correlate of pitch is the fundamental frequency (Patterson & Ladd, 1999; Mennen et al., 2012).

Experimental studies in phonetics and phonology show that F0 (fundamental frequency) is not only the pragmatic semantic structure of speech (Beckman & Venditti, 2010), but also many other factors such as gender, age and social factors. It has been established that it also depends on emotions and feelings (Campbell, 2004; Labov, 2001; Reubold et al., 2010; Foulkes & Docherty, 2006). There are many studies on prosodic variation in F0 across ethnicity and regional accents, not only as a sociolinguistic variable but also as a result of physiological conditions, particularly the effects of age and gender on F0 (Mysak, 1959; Chen, 2005; Deutsch et al., 2009; Hollien, 1987; Hollien & de Jong, 1997; Mueller, 1997; Nishio & Niimi, 2008; Quené 2007, 2008). Gender identity is partly encoded by prosodic patterns and suprasegmental cues. The significant effects of dialect, gender, and passage on prosodic patterns, including the distribution of pauses and the pitch patterns related to prominent syllable and phrase boundaries have been revealed (Cynthia & Rajka, 2011). In a cross-linguistic acoustic study of dissyllabic words produced by Northeastern American English speakers and Parisian French speakers (Pépiot, 2011), cross-gender differences may be obtained from F0 range,

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vocalic formants and H1-H2 intensity variations. And rather than trying to list and prioritize the acoustic features playing a role in the speech gender identification in general terms, he suggested that it would be prudent to consider the influence of the speaker's native language on their identification strategy (Pépiot, 2011). The age-related changes in F1 compensate for physiologically induced decreases in F0, and thus keep the perception distance between F0 and F1 relatively constant (Reubold et al., 2010).

The speech rate difference is commonly interpreted by physiological, anatomical, and sociological factors. Researchers have also long recognized that speech rate varies as a function of individual speaker characteristics (Abercrombie, 1967; Laver & Trudgill, 1979). Regarding the languages of the world, many studies have been conducted to examine the difference in speech rate between female and male speakers. Byrd (1994), Yuan et al. (2006) and Whiteside (1996) suggest that men actually talk slightly faster than women. Heffernan (2007) stated that the men and woman speech variation is caused by a social component and physiological differences. Numerous studies have stated that young adults speak faster than older adults (Smith et al., 1987; Quené, 2008; Verhoeven et al., 2004; Yuan et al., 2006; Jacewicz et al., 2010; Stepanova, 2011). The older speakers produce relatively shorter phrases than younger speakers, and this difference in phrase length may be one of the age-related effects (Quené, 2008).

B. Background on the Prosody of Mongolian Language

The Khalkha dialect is spoken by the majority of the Mongolian population, i.e., estimates range from 84.6% to over 90% (Batzaya, 2007). This is the basic dialect of the Mongolian written language. The Mongolian language is an agglutinative language and belongs to the Ural-Altaic language family according to linguistic typology. We studied the central Khalkha dialect, especially the sub-dialect as spoken by the population of Tuv province and Ulaanbaatar city. The Khalkha dialect consists of 7 vowel phonemes (excluding palatalization and long alternatives) and 17 consonant phonemes. Svantesson et al. (2005) and Karlsson (2014) have studied the phonetics and phonology of the Khalkha dialect and defined it as a language without word stress. However, Tsoloo (2010) studied the Khalkha dialect in according to the methods of acoustic phonetics and proposed it as a language with word stress. The word stress in the Mongolian language is not distinctive, but the it plays a role in vowel harmony, which is important in orthography. Acoustic phonetic studies of Khalkha Mongolian have been conducted by Sainbilegt (2002), Batdorj (2014) and Bulgantamir (2016). There are few studies on the intonational structure of the Mongolian sentence based on acoustic phonology. Luvsanvandan (1967) explained that the intonation is an additional phoneme because it is involved in semantic contrast. After analysis of pitch and duration, he found the following accents in use in modern Mongolian:

-Steep falling accent (declarative sentence)
-Steep rising accent (interrogative sentence)
-Flat accent (imperative sentence)

In the research results (Karlsson, 2014) on the declarative, the interrogative and the imperative sentences read by a total of eight individuals (four males and four females) and the intonational inventory of the Khalkha Mongolian read speech spoken in Ulaanbaatar city, the Khalkha Mongolian has the category of edge-prominence language according the measurements of F0. The intonational structure of Mongolian language sentences according to the autosegmental-metrical theory is as follows:

-Accentual phrase (Prosodic word)
-Intermediate phrase (Prosodic phrase)
-Intonational phrase (Prosodic utterance)

As Karlsson noted, the accent contour in a sentence was defined as having a two-tone LH pitch accent, and in most cases the pitch was measured to be high at the beginning of the sentence and low at the end.

Huhe (2003), from Inner Mongolia, analyzed sentences in the Chakhar dialect of Mongolian through an experimental phonological method, focused on sentence prominences and called the grammatical accent of sentences the 'neutral accent'. The study was based on 32 utterances read by four speakers. He found falling pattern for declarative clauses, steep or sharply rising patterns for interrogative clauses and interjection, and rising or rising-falling patterns for imperative clauses.

II. METHODS

A. Materials, Subjects and Procedure

Our study was based on observations of natural examples coming from a spontaneous speech corpus to ensure ecological validity. We examined speech recordings of 100 speakers spoken in the Khalkha dialect, from a speech corpus that was created by the joint research group of the Mongolian Academy of Sciences and Faculty of Mongolian Studies of Inner Mongolia University, based on field trips to provinces and cities in Mongolia. We analyzed a representative sample of 60 recordings of 9.2 hours that contained 1004 utterances and 22381 words. There were 10 male speakers and 10 female speakers aged 16 to 29 years, 10 male speakers and 10 female speakers aged 30 to 45 years, 10 male speakers and 10 female speakers aged 45 and over. Each person's speech was different from each other so that the first 5 to 15 minutes of the conversation was analyzed. The recordings were made at a location outside the laboratory. We selected recordings that were free of background noise and met our quality criteria.

Speakers talked about their life, their past, present, and all kind of memories. So, the conversations have an emotional expression. It is worth noting that since the speeches were not previously prepared, the main speech was a relatively slow utterance with natural rhythm, intonation and pitch accent, and they contained hesitation and thought pauses.

B. Measurements

The recordings were analyzed using the Praat program (http://www.fon.hum.uva.nl/praat/download_win.html), and the fundamental frequency was calculated automatically. After that, we examined the spectrum and defined manually the segmentation. Then, the fundamental frequency was measured in relation to gender and age. The measurements were based on the research conducted by Patterson (2000) and other researchers (Mennen et al., 2012). The maximum F0 and minimum F0 of the sentence were denoted by H and L, the F0 at the beginning of a sentence by I, the highest F0 at the beginning of a sentence by Hi, the high measure at the end of a sentence by FH, and the low measure at the end of a sentence by FL.

In the second part of our investigation, we examined speech rate variation in spontaneous Mongolian language speech based on the age, gender and utterance length. The purpose of this section was to determine what is the average speech rate of Khalkha Mongolian and how the speech rate is related to age and gender.

III. RESULTS

A. Age and Gender Effects on F0

First, we checked how the mean value of the F0 and its variation depended on age and gender. The average F0 of the speech was measured according to age and gender classification and is shown in Table 1.

In Figure 1 shows the average F0 of male and female speakers utterances.

TABLE 1
MEAN VALUE OF F0 AND STANDARD DEVIATION

Mean Hz	I	Hi	H	L	FH	FL
M	121	134	121	100	135	94
StdDev	21.4	24.3	23.5	18.7	27.2	21.2
F	209	237	213	179	244	170
StdDev	33.5	45.9	39.9	26.3	33.1	24.1

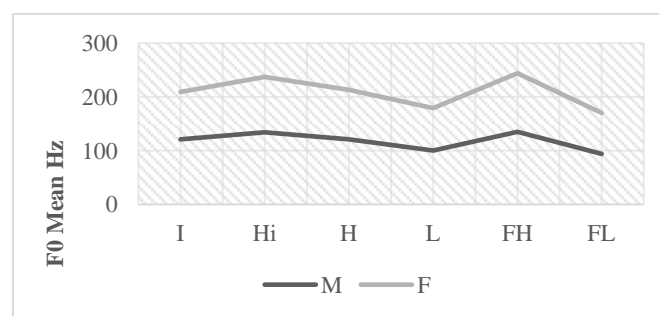Figure 1 shows the average value of F0 measurements for male and female speakers by calculation.

Figure 1 Mean Value of the F0 of the Spontaneous Speech
(Gender classification)

According to the graph, the fundamental frequency of the female speakers is higher than that of the male speakers. Excluding differences in the average of the measurements, the changes in F0 were higher for female speakers than for male speakers. For example, the final high frequency was higher in females than in males. There are some results pointing in this direction, but they are related to the age group. The degree of changes in F0 in association with aging was much greater in females than in males (Nishio & Niimi, 2008). This is related to the fact that female speakers have more emotional expressions than male speakers. It is especially important with regard their negative or positive memories. In addition, we found that gender differences in storytelling tasks were greater, and this was presumably due to differences in the approaches of male and female participants to the task (e.g., expression of emotion, engagement, attitude, involvement with the discourse partner, etc.). However, in another study, the change in F0 in women was less dramatic than that observed in men. The speaking F0 in women remains constant from age of 20 until about the age of 50 as its duration decreases (Honjo & Isshiki, 1980). But these divergent results could be caused by social and cultural factors in distinct linguistic communities. On the other hand, it can be attributed to cross-language differences to either of cultural factors. In our view, the difference in F0 between women can be explained by their emotions; that is, if we observe the topic of our conversation, the difference may be because women talk about difficult times in their lives and their thoughts and feelings, while men talk about events and events.

In Figures 2 and 3, the F0 variation of the pronunciation of male and female speakers is compared and presented based on age classifications as young (16-45 years old) and middle-aged (over 45 years old).
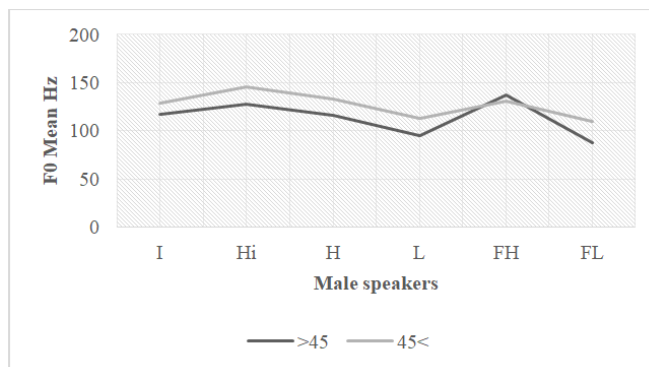
Figure 2 F0 of the Male Speakers (Age Classification)

As shown in Figure 2, male speakers under 45 years of age speak with higher F0 and greater frequency variation; for example, they enhance the final sequence of sentences more than male speakers over 45 years of age. It can also be related to the topic of the conversation and their feelings.
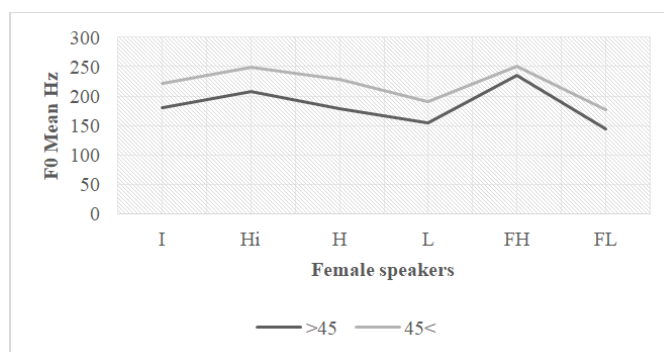

Figure 3 F0 of the Female Speakers (Age Classification)

The results showed that F0 in both men and women decreased with age, but the degree of change was different. Specifically, there is a higher F0 in the speech of speakers under 45 years of age compared to speakers over 45 years old. Also, speakers under 45 tend to raise the final high a bit. In all age groups, including 80-year-olds, F0 tended to decrease markedly with age. The reason for this low F0 by age has been well studied. The decrease in F0 speech may be due to the hormonal changes associated with menopause that lead to vocal cord edema (Kahane, 1983). Edema has been shown to cause an increase in vocal cord mass that contributes to a decrease in F0 in very old individuals (eg, 90 years of age and older) and the change in basal speech frequency is quite significant. (Mueller, 1997). This aspect has also been studied (Pépiot, 2011; Simpson, 2009). They studied two languages English and French by experimental method and obtained similar results.

B. Average Speech Rate

Rate of speech as a suprasegmental feature directly affects the fluency and intelligibility of speech. As analyzed above, scientists have found that speech speed is a complex phenomenon that depends on many different factors such as speech characteristics, living environment, mother tongue, age, gender, education level, and emotions of the speaker. These factors are therefore important for speech-language pathologists to consider when diagnosing and evaluating fluency problems.

Verhoeven et al. (2004) confirmed the traditional view that speech rate is determined by additional linguistic variables, but also suggested that there may be differences in intrinsic tempo between languages. Stepanova (2011) analyzed the Russian speech corpus and found that the average rate was 5.31 syll/s. Jacewiez et al. (2010), Quené (2008) and others scientists have studied speech rate in American English.

In order to compare the speech rate of different languages and to determine if there is a generally accepted average speech rate in each linguistic community, we believe that it is important to determine the speech rate of Mongolian. So, in this study, we determined the average speech rate of Khalkha Mongolian and its change and classified the speakers by age and gender. We show these results in Table 2. In the Khalkha Mongolian, the average rate was 5.36 syll/s for males at 5.37 syll/s and 5.34 syll/s for females.

TABLE 2
THE AVERAGE RATE OF THE SPEECH OF KHALKHA MONGOLIAN

Speech Rate Syll/S	Average	Minimum	Maximum	Std. Dev.
Average	5.36	4.19	8.22	0.78
Male	5.37	4.19	6.66	0.64
Female	5.34	3.61	8.22	0.88
Young	5.56	4.19	6.65	0.57
Middle Age	5.15	3.62	7.15	0.81
Elder	5.37	4.18	8.22	0.87
Young Male	5.62	4.19	6.65	0.68
Middle-Aged Male	5.33	4.55	6.66	0.63
Elderly Male	5.19	4.36	5.96	0.93
Young Female	5.51	4.47	6.09	0.42
Middle-Aged Female	4.97	3.61	7.15	0.93
Elderly Female	5.55	4.17	8.22	1.002

C. Age, Gender and Utterance Length Effects on Speech Rate

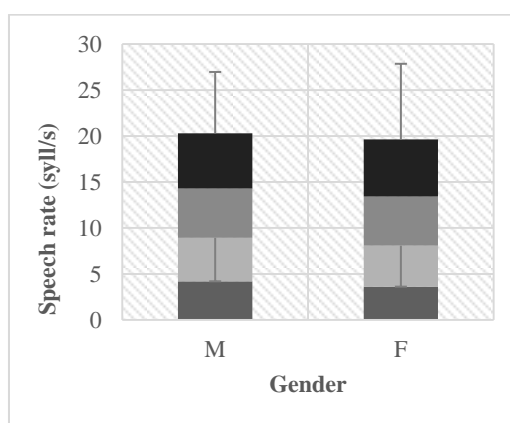Now, let us refer to Figure 4, which shows how the average speech rate varies by gender.

Figure 4 Speech Rate and Gender

According to Figure 4, male speakers speak slightly faster than female speakers. For Mongolian speakers, the average speech rate is 0.02 syll/s. quicker in men than in women. Many researchers have studied the speech rate of the German and Polish languages (Quené, 2008), the English language (Jacewicz et al., 2010), the Russian language (Stepanova, 2011) and the French language (Pépiot, 2011) also suggested that the speech rate of men and women were not much different from each other. But the men speak slightly faster than women, and young people tend to speak faster than older people. They have explained this gender change can be accounted for by factors such as social status and education. For example, Quené (2008) interprets men's faster speech rate as an attempt to demonstrate their social superiority, i.e. according to him, male speakers may express their social dominance by speaking faster than female speakers.

We observed whether speech rate is influenced by age among the 60 speakers, and it was found that the young speakers tend to speak much faster, and the speech rate of middle-aged and elderly speakers was slower. We can see how the speech rate varied depending on the age of the speaker in Figure 5.
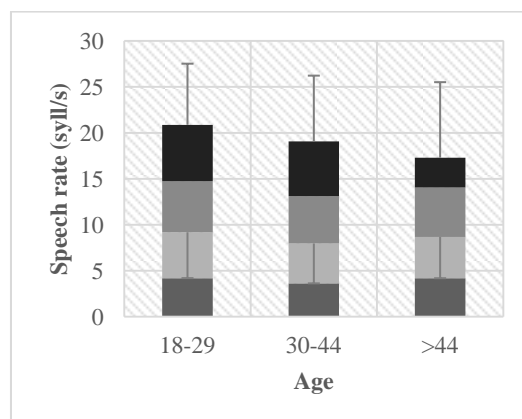

Figure 5 Speech Rate and Age

The results showed that the speech rate of the speakers decreased especially in the over of 30s. When gender and age were taken into account, the young and middle-aged male speakers tend to speak faster than the female speakers. Quené (2008) and Verhoeven et al. (2004) have stated that young adults speak faster than older adults. Voice aging has also been discussed by Smith et al. (1987) and treated more recently by Yuan et al. (2006). According to them, aging affects two main aspects: the anatomy and function of the vocal cords due to muscle and of flexible or soft tissue loss.

With age, the speech rate of the older men became slower than that of the women of the same age. This age- and gender-related variation is explained by the evolution of social status that characterizes in Mongolian society. Because although Mongolian society is patriarchal, Mongolian women have much more freedom and power than women from other patriarchal cultures. Mongolian women, on the other hand, have to endure an important role in the harsh nomadic life. Mongolian women were riding horseback, fighting in battles, tending their herds and influencing their men on important decisions for the Mongolian Empire (Hays, 2008). Still, women are highly valued participants in Mongol society. Despite some negative changes after collapse of the Soviet Union in 1991, it continues to play an important role in the family and economic life. The work is divided almost equally between men and women. According to Rossabi (2020), Hays (2008) and Burn and Oidov (2001), women in Mongolia often benefit from government policies that guarantee equality in education, workplace, and political system. Moreover, in the rural areas, women herders are entitled to a pension, a policy unique in Asia. From the perspective of Mongolian women today, the representation of women in Mongolian history and culture reveals many contrasts formed by both the nomadic culture and a feudal social organization. In contrast to neighboring cultures, they do not convey an image of female subordination. Burn and Oidov (2001) stated that women's social status in Mongolia was affirmed through motherhood. Among pastoral families, the social values attached to women's roles in family and motherhood were rooted in the nature of nomadic pastoral societies. They underlined that the age group differences of young women are more pronounced when the different trajectories of young men and women are taken into account. Thus, the variation in the speech rate of females and males with increasing age may be related to less pronounced social status differences between genders in Mongolia. This hypothesis should be further investigated in more detail in cross-language study.

The speech rate of Khalkha Mongolian was also analyzed in relation to the utterance length. Figure 6 shows that when speaking a long utterance, the speech rate increases. It has been observed that both male and female speech rate increases with the number of syllables (i.e., utterance length). The Mongolian men pronounce long sentences at a higher rate than Mongolian women.
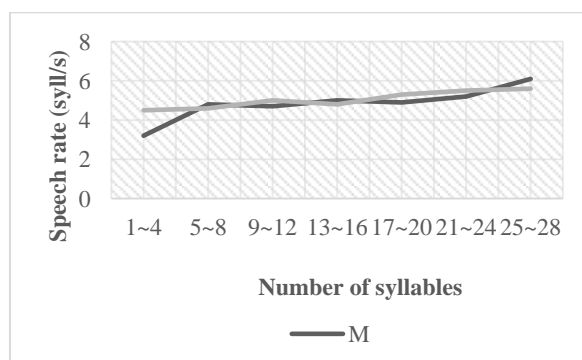

Figure 6 Speech Rate and Utterance Length

IV. CONCLUSION

When the spontaneous speech of the Khalkha dialect of the Mongolian language was analyzed, the measurement of F0 varied according to age and gender. Our results show that women speak with a higher frequency than males. In addition, as age increases, F0 decreases and becomes lower for both men and women. Older adults have overall a lower frequency formant than younger adults. Furthermore, younger adults women have high F0 and older women have low F0. When a change in F0 is observed, female speakers are more likely to express their feelings and attitudes.

The average speech rate of Khalkha Mongolian is 5.3 syllables per second. Male speakers speak faster than female speakers. With age, both men and women speak more slowly. Interestingly, older male speakers speak more slowly than older female speakers, while young and middle-aged male speakers tend to speak faster than female speakers of the same age. We assume that these deviations are due to the Mongolian people's lifestyle, traditions, and social status. Because young and middle-aged Mongolians usually have a higher social status than older adults, and the social status of young males is stronger than that of females. On the other hand, with age, differences in social status between men and women become less pronounced and in some cases the older women become the main decision makers in family relationship. The speech rate variation related to the age and the gender may depend in part on the language community.

Based on the previously mentioned studies and observations of the literature and our results, we can affirm that the reason for the difference cross-gender and cross-age acoustic features may vary between languages in terms of their linguistic, social, and cultural characteristics. To confirm such results, we must take into account that such further

investigation would be based on number of studies conducted by different authors, across different language communities and using different methods.

ACKNOWLEDGEMENTS

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