Interaction between hearing and speaking due to aging

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ABSTRACT

Elderly people have some difficulties in achieving smooth speech communication. Hearing loss is a well-known phenomenon due to aging, although some elderlies do not accept subjective symptoms. The hearing loss by aging gradually occurs in a middle-aged period, and is remarkably confirmed in the high frequency region for the elderly over seventy years old. Aging effect in individual hearing ability varies widely with living environment and working experience. On the other hands, aging also affects articulation. It is possible to roughly estimate speaker's age. It implies the existence of subjective features, which characterize the utterance by elderly. It has been reported that breathiness is one of the most important characteristics of the elderly voice. The author has already confirmed that the subjective hoarseness could be explained by energy lift in high frequency over 4 kHz. In this paper, interaction between hearing and speaking due to aging is considered based on the concept of speech chain.

INTRODUCTION

Advanced nations are experiencing rapid increases of aging population. Other nations will be faced with the same problem in near future. Aging causes a fatal problem in speech communication. Difficulty in speech communication triggers a withdrawal from community, and increases lone elderly people. In practice, hearing ability is generally degraded in proportion to age over 20 years old. An absolute threshold of hearing ability has been widely examined, and the statistical distribution of the hearing thresholds has been modeled as a function of age [ISO 2000]. In short, aging causes high-frequency deafness. In our daily life, the high-frequency deafness induces misunderstanding consonants rather than vowels, because most of consonants have dominant energy in high frequency. The degree of the hearing loss depends on their living and working experiences. People, who live and work in highly noisy environments, for example, suffer from hearing loss even in younger generation. The hearing loss by aging seriously decreases our ability in both understanding consonants and separating a target sound source under noisy conditions. It is difficult for elderly people to achieve smooth speech communication under noisy and reverberant environments [Ryan et al 1985]. Hearing loss by aging, however, is commonly prominent in elderly adults over 70 years old [Pedersen 1989; Yasuda 2009].

Speech communication is established with the interaction between hearing and speaking. Hearing loss by aging has been investigated in a wide range of viewpoints. On the other hands, aging effects to uttered speech are not investigated sufficiently. It is, however, possible to roughly guess speaker’s age, when you hear

an utterance by an elderly speaker. It suggests that a speech signal contains subjective factors with age perception. In this paper, acoustical characteristics of Japanese words uttered by elderly speakers are investigated with age-related subjective factors.

This paper proposes the hypothesis about the interaction between hearing and speaking by aging. The gross relationship between the hearing loss by aging and the deformation of the elderly speech signal is investigated in the frequency domain relying on the concept of the speech chain [Danes & Pinson 1993].

HEARING LOSS BY AGING

It is well known that a hearing ability deteriorates by aging. Pure tone audiometry is a traditional manner to measure static hearing sensitivity. The threshold of the auditory acuity over 8 kHz begins to rise in the thirties. In the sixties, the threshold rises across the whole frequency, but a wide variety among individuals is observed. In the seventies, the threshold is significantly boosted with less individual variation. As the result of a large-scale medical test with 15,000 elderly participants in Kanazawa, Japan, 40 % and 67 % of the elderly examinees have been diagnosed as sensorineural hearing loss, respectively [Yasuda 2009]. International surveys have been also carried out using the Hearing Handicap Scale (HHS) [Tannahil 1979] and the Hearing Handicap Inventory for the Elderly (HHIE) [Vwntry & Weinstein 1982].

The hearing threshold is numerically modelled using a quadratic form of age in the range from the thirties to the seventies [ISO 2000]. In Japan, incompatibility between measured and calculated data is reported for elderly people over the sixties. Tsuiki and Ichinose have revised the ISO model with an exponential function of age based on the hearing measurements of 1,087 elderly adults [Tsuiki and Ichinose 2003]. Figure 1 shows the hearing thresholds, which are calculated by using the Tsuiki model, as a function of age.

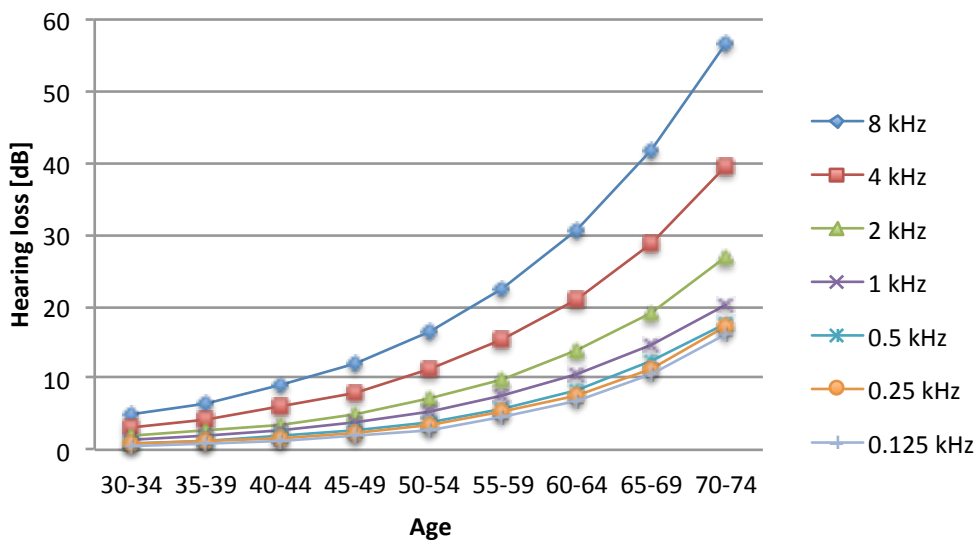

Figure 1: Hearing loss calculated by Tsuiki model [Tsuiki and Ichinose 2003].

PHONETICS WITH AGING

It is not difficult to roughly estimate speaker' age. A voice of an elderly speaker in the seventies differs from a voice of a non-elderly speaker. There must be some important factors, which subjectively characterize the utterance by elderly speakers. Subjective impressions for Japanese words uttered by 112 elderly speakers, whose ages ranged from the sixties to the eighties, were summarized by a questionnaire and a listening test [Miyazaki et al 2010]. As the result, ten adjectives were extracted to characterize elderly voice from the prepared 300 Japanese adjective phrases. Hoarseness and breathiness are the most suitable characteristics of the elderly voice. Those factors can be quantified by using GRBAS scale, which is originally proposed to diagnose pathological voice [De Bodt et al 1997]. Physiological variations in articulatory organs have been also examined in medical science.

Acoustical characteristics of elderly voice are analyzed in detail based on non-parametric power spectra [Miyazaki et al 2010]. Japanese 543 phonetically balanced word utterances are prepared with the corporation of 153 speakers, who are at the age of the twenties to the eighties. First of all, the speakers are divided into two groups: non-elderly adults and elderlies. The elderly speakers are labeled in the subjective breathiness. Each stationary part of each vowel is extracted from the word utterances, and is used for calculating its power spectrum. Figure 2 indicates power spectra of Japanese /a/, which are averaged over in each speaker group: elderly speakers with breathy voice, moderately breathy voice, ambiguously breathy voice, and non-elderly adults, respectively. Comparing the power spectrum of the breathy elderly voice (thick solid line) with that of the non-elderly adults (dotted line), a lift of power in high frequency over 4 kHz is the most significant feature for the breathy elderly voice. Concerning other Japanese vowels /e/, /i/, /o/, and /u/, it is also confirmed that the similar energy lift is observed for the breathy elderly voice.

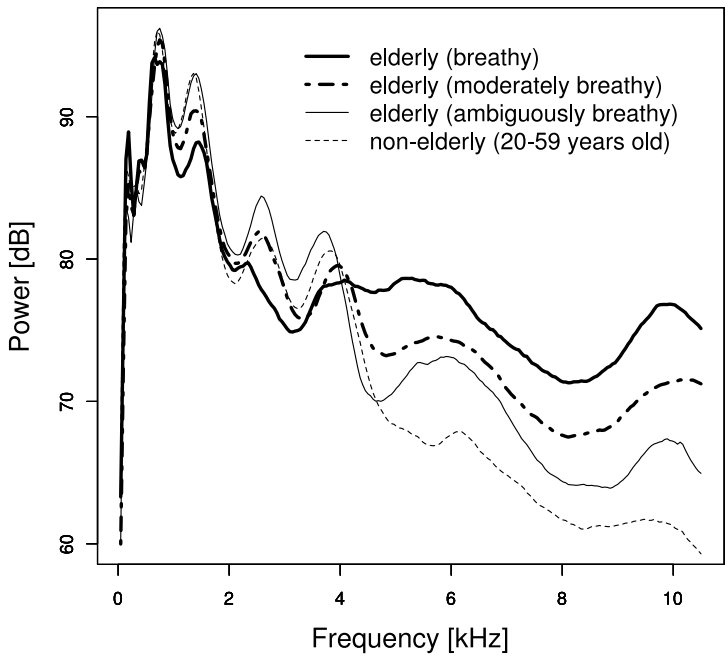

Figure 2: Power spectra of Japanese vowel /a/ for elderly speakers with breathy voices (thick solid line), moderately breathy voices (broken line), ambiguously breathy voices (thin solid line), and non-elderly adults (dotted line), respectively.

INTERACTION BETWEEN HEARING AND SPEAKING

In this paper, hearing loss due to aging is overviewed, and acoustical characteristics are introduced in the viewpoint of aging. Most of related works focus on either hearing or speaking. It is, however, important to simultaneously consider the both sides in speech communication. The hearing threshold of elderly people is seriously on the rise in the frequency range over 4 kHz as shown in Fig. 1. On the other hands, the energy lift is confirmed with the breathy elderly voice in Fig. 2. There is a complementary relationship between hearing and speaking in the viewpoint of aging. The degree of the rise of the hearing threshold is considerably compatible with the amount of the energy lift in the elderly breathy voice.

This paper proposes a hypothesis about the interaction between hearing and speaking by aging. In the concept of speech chain [Danes & Pinson 1993], long-term hearing loss due to aging might affect articulation unconsciously. To equalize their hearing loss, elderly speakers might force themselves to unreasonably articulate. This hypothesis of the interaction in speech communication is established based on the general characteristics of the age-dependent hearing loss given by the Tsuiki model and the static characteristics of the word utterances by elderly speakers. It is necessary to individually investigate the interaction between hearing and speaking through the cooperation of a large number of elderly speakers. It is also important to consider the dynamic interaction in a long period by using a sentence utterance. Furthermore, it is supposed that use of a hearing aid provides the possibility of reducing subjective breathiness for elderly speakers.

CONCLUSIONS

Aging is appeared in speech communication. A hearing threshold in high frequency rises in proportion to age. Speaking is also affected by aging, as we can estimate speaker's age from an utterance by an elderly speaker. Most of the related works deal with the problem on either side of hearing or speaking. In the concept of speech chain, however, the both sides must be mutually considered concerning the effect of aging. In this paper, the interaction between hearing and speaking is hypothesized for Japanese elderly people. Future works include investigating individual interaction between hearing and speaking by aging.

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