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Abstract: Although temples are important buildings in the Buddhist community, the acoustic qualities have not been examined in detail. Buddhist monks change the way of voice production according to the ceremony, and associated acoustical changes have not yet been examined scientifically. In this study, three kinds of chanting voices were recorded in Japanese Buddhist temples and analyzed. The difference in voice production between chanting and normal speech was reflected in the loudness, fundamental frequency, pitch strength, and spectral centroid, which is characterized by autocorrelation function. Voice production in each stage of Nembutsu-Wasan singing was characterized by the loudness, fundamental frequency, and pitch strength.

Characteristics of Buddhist chanting in Japanese temples

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Running title: Characteristics of Buddhist chanting

Abstract

Although temples are important buildings in the Buddhist community, the acoustic qualities have not been examined in detail. Buddhist monks change the way of voice production according to the ceremony, and associated acoustical changes have not yet been examined scientifically. In this study, three kinds of chanting voices were recorded in Japanese Buddhist temples and analyzed. The difference in voice production between chanting and normal speech was reflected in the loudness, fundamental frequency, pitch strength, and spectral centroid, which is characterized by autocorrelation function. Voice production in each stage of Nembutsu-Wasan singing was characterized by the loudness, fundamental frequency, and pitch strength.

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1. Introduction

A temple can be a place of worship used for prayers, preaching, or chanting a Buddhist sutra. Although temples are important buildings in the Buddhist community, the acoustic quality of temples has not received adequate attention in the literature.

The effects of aspects of the style of liturgy, such as source location and direction, in Japanese churches and temples on acoustic characteristics have recently been considered [1, 2]. Since the Second Vatican Council, the style of the Catholic liturgy has changed. In the case of the old style of Catholic liturgy with the sound source facing the altar, much of the direct sound energy does not arrive at the receiver and the sound strength is therefore low. Acoustic parameters related to the spatial impression represent effects of lateral reflection relative to direct sound. For the new style of Catholic liturgy with the sound source facing the congregation, more energy in direct sound relative to that in reflections and reverberation results in higher sound strength (G) and a higher speech transmission index. This suggests that the change in style led to improved speech intelligibility and a smaller apparent source width in Japanese churches. The location and orientation of Buddhist monks in ceremonies held in Japanese temples have similar acoustic effects. The large and coupled-like structure of the altar of a Buddhist temple may reinforce reverberation components and the table in the altar, the syumidan, may decrease the binaural coherence.

Most activities performed in temples are related to speech and similar to singing. Extensive research has revealed the acoustic characteristics of the singing voice to be the fluctuation component of vibrato, which is a quasi-periodic fluctuation component of the fundamental frequency [3-5], and a salient frequency component around 3 kHz, which is called the singer's formant [5-7]. The characteristics have also been identified in Western classic and Japanese traditional singing [8-9].

Buddhist monks control their voices according to the ceremony and sutra, but the acoustic changes in this regard have not yet been examined scientifically. To clarify the acoustic change, we recorded and analyzed Buddhist chanting for different sutra and way of voice production.

2. Methods

2.1. Investigated temples and monks

Temples A and B investigated belongs to the Hongan-ji and Otani denominations of True Pure Land Buddhism (Jodo Shinsyu), respectively. They were built of wood and mortar in 1661 and 1895, respectively. The altar of the Buddhist temple has two side chapels, one on either side of the altar. The congregation sits on the floor in the central aisle. The floor is covered by straw mats (tatami) except for the wooden board in the altar. Figure 1 shows the ground plans of the temples investigated. The volumes of the temples estimated from the floor areas and average ceiling heights A and B were 554 and 637 m^3, respectively, which are considered typical of Japanese temples [10].

Two males participated in the investigation of temple A. One is a practical Buddhist monk and the other is a monk who has received limited training. Four males and one female, all practical Buddhist monks, participated in the temple B.

2.2. Chants

Three Buddhist sutra were chanted. One was the Hyobyaku message, which is chanted in one of the most important Buddhist memorial services, Houonkou. To compare the acoustic characteristics of the basic way of reading the sutra and speech, Hyobyaku messages were chanted in the manner of a usual ceremony (H1) and in the manner of ordinary speech (H2) only in temple A. The second sutra was Nenbutsu-Wasan singing, which has “crescendo” and “allargando” features, if we use the terms of western music, in three stages. Pitch rises when Nenbutsu-Wasan is sung from the first to third stages. In Nenbutsu-Wasan singing, Nenbutsu and Wasan are sung alternately in three consecutive stages, e.g., Shojyu Nenbutsu (N1) might be followed by Shojyu Wasan (W1), Nijyu Nenbutsu (N2), Nijyu Wasan (W2), Sanjyu Nenbutsu (N3), and Sanjyu Wasan (W3). In Nenbutsu singing, Chinese holy phrases called Nenbutsu are sung. Nenbutsu consists of only six syllables –“NA-M[U]-A-M[I]:-DA-BU-[TSU]” – and is repeated. In Wasan singing, Japanese hymns are sung. The third sutra was Hakkotsu no Ofumi (Of), which was selected by Rennyo, the eighth chief priest of Jodo Shinshu. The term “Ofumi” is used only by the Otani denomination of Jodo Shinshu, and the term “Gobunsyo” is used only by the Hongan-ji denomination of Jodo Shinshu.

2.3. Monk and receiver locations

Monk locations were considered to be the actual monk position during ceremonies in each temple. Monk 1 (M1) was placed in front of the altar and directed towards the altar. This is the most common location for Buddhist monks to chant a Buddhist sutra toward the altar. Monk 2 (M2) was placed slightly on the left at the front of the temple and directed towards the right lateral wall, matching the location where Buddhist monks recite Hakkotsu no Ofumi. The receiver (R) was placed in front of M1 as shown in Fig. 1. The receiver was a dummy head with binaural microphones (KU-100, Neumann). The dummy head microphone was located at the head height of a person sitting on their heels, 0.9 m from the floor. The dummy head always faced forward towards the center of the altar. The chanting sounds were recorded by a laptop computer at a sampling rate of 48 kHz and a sampling resolution of 24 bits through the microphone and an AD/DA converter (AudioFire8, Echo Digital Audio). All measurements were taken while the temples were unoccupied.

2.4. Method of analysis

To characterize chanting sounds in the temples, we analyzed spectra, the A-weighted equivalent continuous sound pressure level (L_{Aeq}), and parameters extracted from the autocorrelation (ACF) and inter-aural cross-correlation function (IACF) [11]. The ACF parameters, τ_1 and ϕ_1, are the time delay and amplitude of the first maximum peak and are related to the fundamental frequency and pitch strength of the complex sounds [12, 13]. The third ACF parameter, $W_{\Phi(0)}$, is the width of the first decay and corresponds to the spectral centroid [11, 14]. The IACF parameter, the interaural cross-correlation coefficient (IACC) is related to the subjective diffuseness and apparent source width [13, 14]. When the IACC is 1, people can clearly perceive the direction of the sound source. As the IACC approaches zero, people can hear the sound, but the sound is diffuse [13, 14]. We calculated the spectra, L_{Aeq}, τ_1, ϕ_1, $W_{\Phi(0)}$, and IACC as functions of time. The window size or integration interval was 20 ms and the running step was 5 ms in all calculations.

3. Results and discussion

Figure 2 shows the spectra of (a) Hyobyaku (H1 and H2) and Ofumi (Of) at S2 in temple A, and (b) Nenbutsu singing (N1, N2, and N3), and (c) Wasan singing (W1, W2, and W3) at S1 in temples A and B averaged across all monks. When we compare H1, H2, and Of, we find that H1 and Of have similar frequency characteristics and components between 3000 and 4000 Hz that are approximately 3 dB larger than those of H2, these components correspond to the singer's formant [5-7], see Fig. 2 (a). This suggests chanting in manner of a usual ceremony and Ofumi produces stronger high-frequency components that are similar to singer's formant. Chanting in the manner of having an ordinary speech (H2) also generated high-frequency components, although they were weaker, because of the difficulty for the monks to read the sutra in that way. The second and third stage of Nenbutsu-Wasan singing (N2, N3, W2, and W3) had larger components between 3000 and 4000 Hz than the first stage of Nenbutsu-Wasan singing (N1 and W1), as shown in Fig. 2 (b).

Figure 3 shows (a) L_{Aeq}, (b) $1/\tau_1$, (c) ϕ_1, (d) $W_{\Phi(0)}$, and (e) IACC values of H1, H2, and Of at S2 in temple A averaged across two monks. Of had the largest L_{Aeq}, $1/\tau_1$, ϕ_1, and IACC values, suggesting Ofumi chanting had the greatest loudness, highest pitch, clearest pitch strength, and smallest diffuseness. It is because monks are trained to tune up in a considerable way when they read Ofumi aloud to people in front of them. H1 had larger L_{Aeq}, $1/\tau_1$, and ϕ_1 values than H2. This means H1 had greater loudness, higher pitch, clearer pitch strength, and higher spectral centroid. It may arise from a sense of tension in the ceremony. Fluctuations of L_{Aeq} and $1/\tau_1$ for Of and H1 were respectively larger and smaller than those for H2, suggesting fluctuations of amplitude and fundamental frequency are larger and smaller in chanting. The fluctuations in amplitude is similar to the difference between speech and a singing voice [5-7]. H2 had the largest $W_{\Phi(0)}$, suggesting ordinary speech had lower frequency components because of weaker singer's formant. Analysis of variance (ANOVA) showed significant effects of chanting way of sutra on L_{Aeq}, $1/\tau_1$, ϕ_1, $W_{\Phi(0)}$, and IACC.

Figure 4 shows (a) L_{Aeq}, (b) $1/\tau_1$, (c) ϕ_1, (d) $W_{\Phi(0)}$, and (e) IACC values for the three stages of Nenbutsu (N1, N2, and N3) -Wasan (W1, W2, and W3) singing at S1 in the temples A and B averaged across all monks. From the first to third stages, L_{Aeq}, the fluctuation of L_{Aeq}, $1/\tau_1$, and ϕ_1 (except for Wasan siging in temple A) increased, suggesting increases in loudness, fluctuation of loudness, fundamental frequency, and pitch strength. This reflects the way of Nenbutsu-Wasan singing. The results of $W_{\Phi(0)}$ and IACC had different tendencies in temples A and B. This may reflect the different methods of voice production in Hongan-ji and Otani denomination. ANOVA showed significant effects of chanting way of sutra on L_{Aeq}, $1/\tau_1$, ϕ_1, $W_{\Phi(0)}$, and IACC.

4. Conclusions

Characteristics of Buddhist chanting for different sutra and ways of voice production in Japanese Buddhist temples were analyzed. The chanting voice had greater loudness, a higher fundamental frequency, and stronger pitch strength than a normal voice, suggesting the Buddhist sutra is chanted louder and with higher and stronger pitch. The stage of a typical Buddhist sutra, Nenbutsu-Wasan singing, was characterized by the loudness, fundamental frequency, and pitch strength. The different ways of voice production employed in the different denominations of Jodo Shinsyu may be reflected in the spectral centroid and binaural coherence.

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Figure Captions

Fig. 1. Ground plans of temples (a) A and (b) B with monk (M1 and M2) and receiver locations (R) (same scale for the two temples).

Fig. 2. Averaged spectrum for (a) Hyobyaku messages chanted in the manner of a usual ceremony (H1), and ordinary speech (H2), and Hakkotsu no Ofumi (Of), in temple A and (b) Nenbutsu-Wasan singing in Shojyu Nenbutsu (N1), Shojyu Wasan (W1), Nijyu Nenbutsu (N2), Nijyu Wasan (W2), Sanjyu Nenbutsu (N3), and Sanjyu Wasan (W3), in temple B.

Fig. 3. Averaged (a) L_{Aeq}, (b) $1/\tau_1$, (c) ϕ_1, (d) $W_{\Phi(0)}$, and (e) IACC values of H1, H2, and Of at M2 in temple A. Error bar indicates standard error.

Fig. 4 Averaged (a) L_{Aeq}, (b) $1/\tau_1$, (c) ϕ_1, (d) $W_{\Phi(0)}$, and (e) IACC values of three stages of Nenbutsu (N1, N2, and N3) -Wasan (W1, W2, and W3) singing at M1 in temples A and B. Error bar indicates standard error.

Figure1

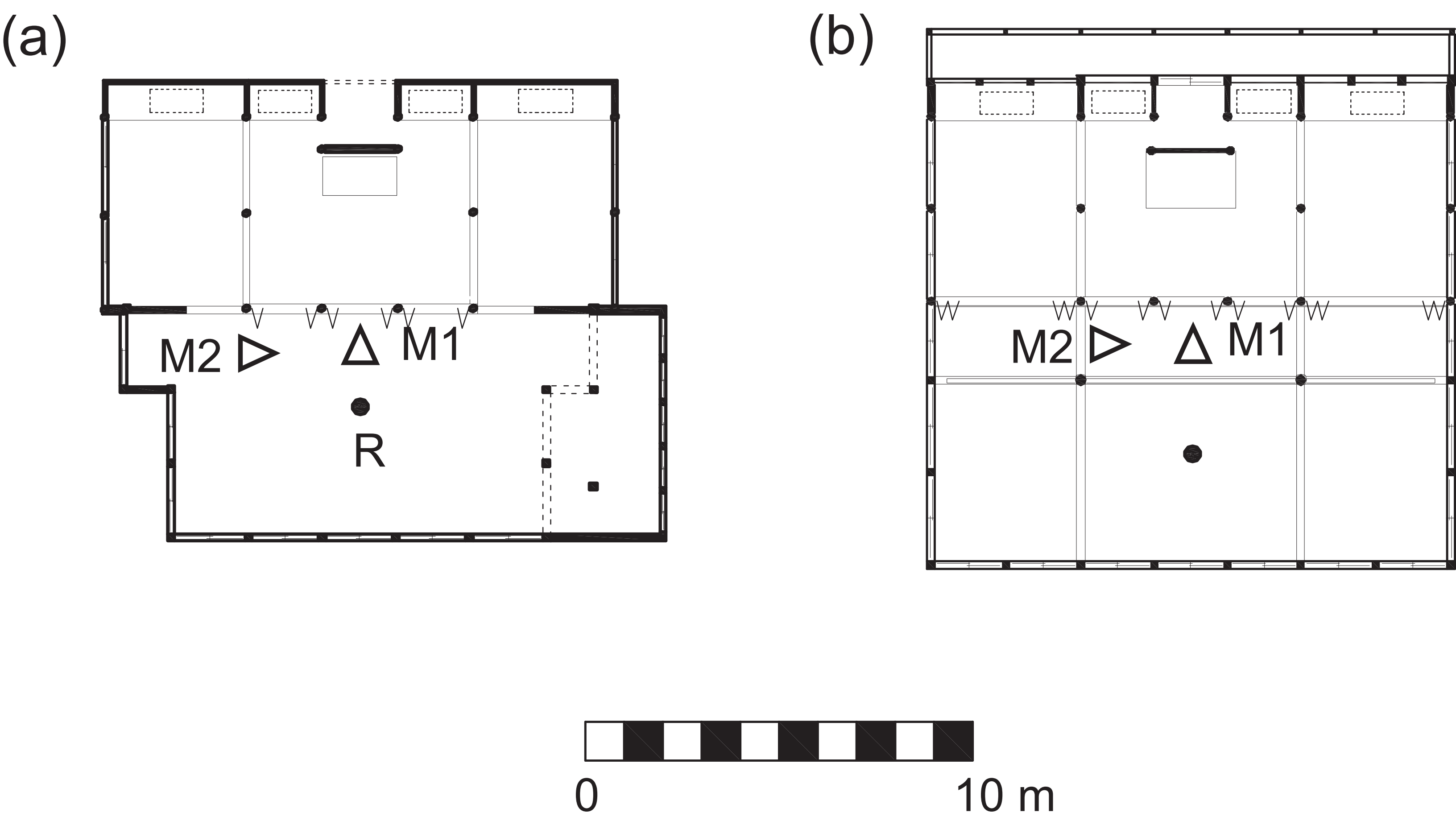

Fig. 1 Soeta et al.

Figure2

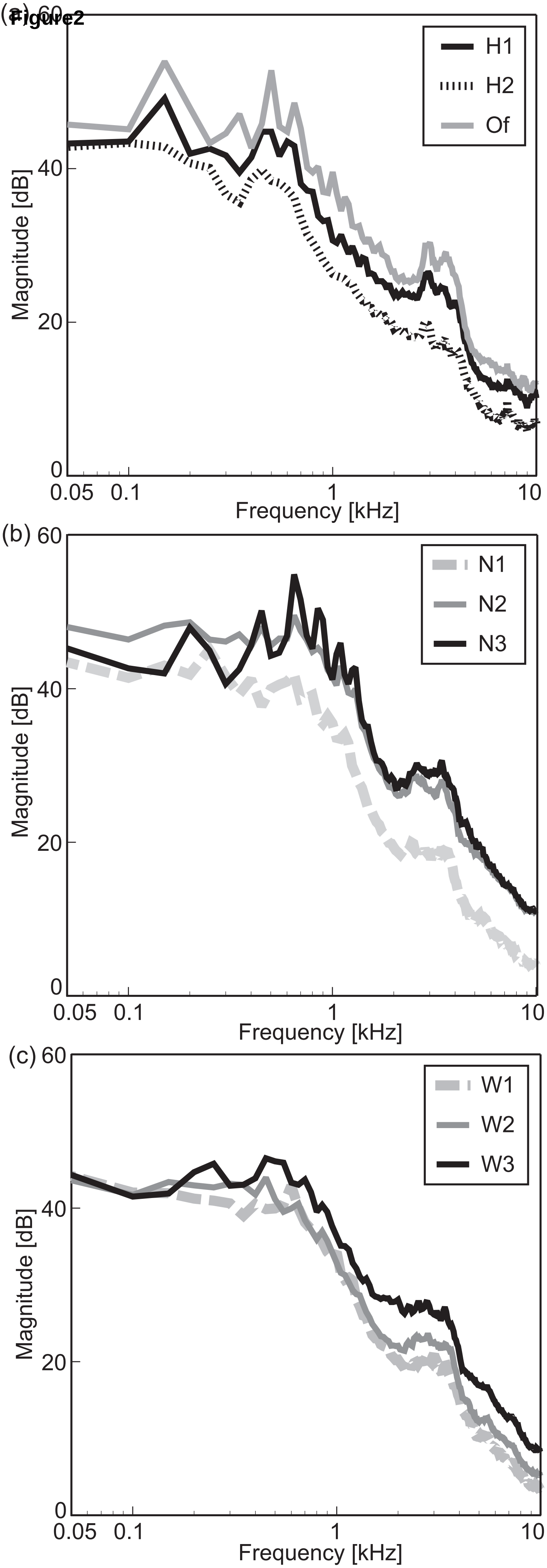

Fig. 2 Soeta et al

Figure3

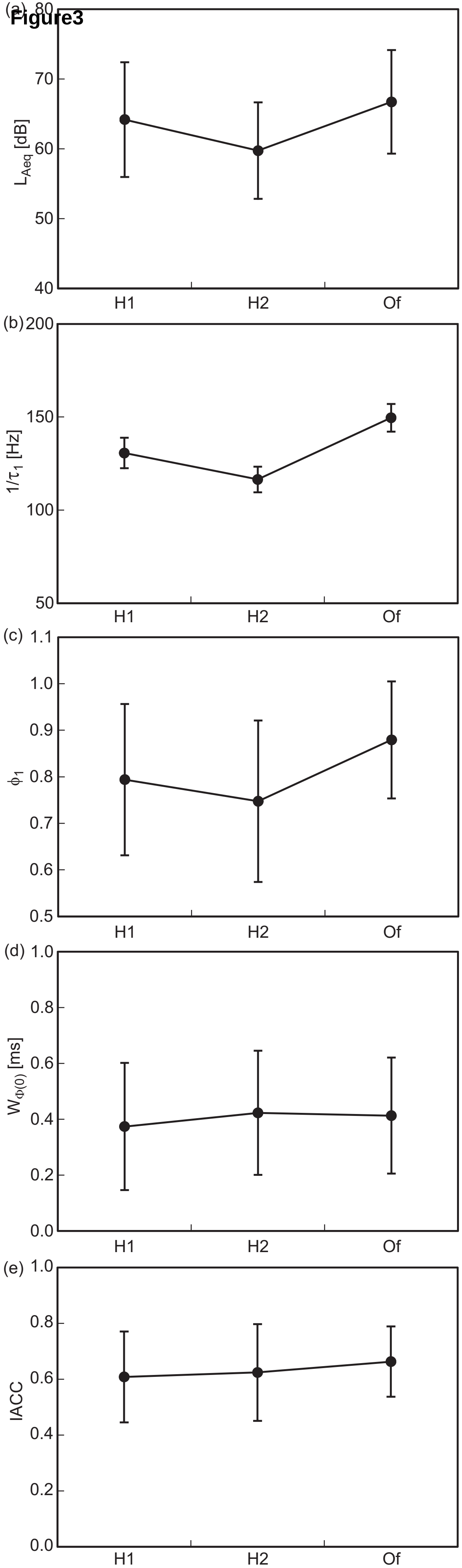

Fig. 3 Soeta et al

Figure4

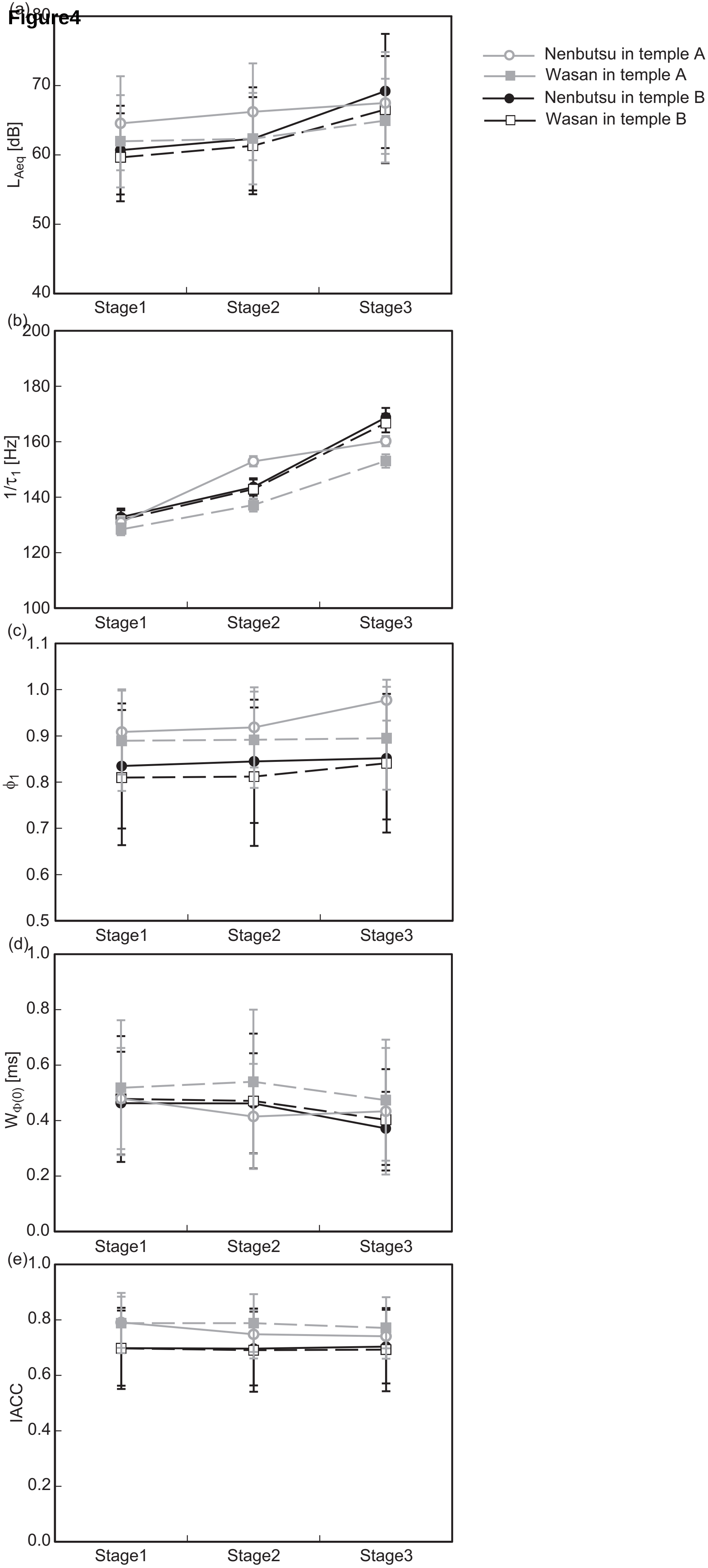

Fig. 4 Soeta et al