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Sounds and sound preferences in Han Buddhist temples

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Highlights

- Objective parameters of various sounds related to their functions in temples.
- Age and religion factors affected the bell sound preference in temples.
- Among parameters, sound preference in temples was correlated only with sharpness.

Sounds and sound preferences in Han Buddhist temples

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Abstract: This study recorded various sounds heard in Han Buddhist temples and analysed their acoustic parameters. Subsequently, it investigated the factors that influence sound preferences in these temples using a questionnaire survey. The results indicate that the physical acoustic and psychoacoustic parameters of various sounds correspond to the roles they play at the temple. Buddhism-related man-made sounds dominate the sound environment in temples. In addition, signal and soundmark are prevalent. In the case of sound preferences, natural sounds are preferred, and age and religious beliefs have a significant effect on the respondents' preference for the sound of a temple bell. Signal and Buddhism-related man-made sounds are affected by a variety of respondent demographic characteristics, while Buddhism-unrelated man-made sounds and keynote sounds are rarely affected by these characteristics. The education level of the respondents affects their preferences for various types of sound, and the respondents' evaluations of Buddhism and acoustic environment are related to their preferences for Buddhism-related man-made sounds, soundmarks, and keynote sounds. Among the assessed physical acoustic and psychoacoustic parameters, only sharpness is closely correlated with sound preference in Han Buddhist temples.

Keywords: Han Buddhist temple; sound; sound preference; acoustic parameters; influencing factor.

1. Introduction

Buddhism is one of the world's three major religions, and it has been an important part of Chinese culture for the past 2,000 years. Among the three major sects of Chinese Buddhism, Han Buddhism has the largest number of adherents. According to a 2012 survey, in the Han Chinese population, the proportion of Buddhists was the highest (6.7%), and the number of Buddhists was approximately twice that of the adherents of other religions [1]. Over Buddhism's long history, the various sounds that are heard in Buddhist temples have played a key role in creating the religious environment for Buddhist followers.

Studies on sound in Han Buddhist temples have primarily focused on the sound of temple bells and Buddhist music. The distinctive sound of the temple bell has been noted by observers since antiquity. "The Records of Qielan at Luoyang", a Buddhist classic of the Northern Wei Dynasty, states that as early as 1,500 years ago the characteristic sound of a bell was regarded as the soundmark of the temple [2]. In recent years, investigators have used modern methods to study temple bell sounds. For example, Chen studied the acoustic characteristics of the Yongle Bell of Juesheng Temple, and the results showed that the lowest of frequency of Yongle Bell is 16 Hz [3], and Zhang et al. suggested that as a part of traditional Chinese Buddhist culture, the bell soundscape has played an irreplaceable role in the temple sounds environment since ancient times [4]. Regarding music in Han Buddhist temples, Yang Yinliu investigated the folk Buddhist music of Beijing's Zhihua Temple and of Hunan Province [5]. Yuan conducted an in-depth study on the origin and development of Han Buddhist music, and recorded a large number of music scores and other materials of Buddhist music [6]. Although these studies were conducted from the point of view of musicology, many of them provided a way to understand the sound and cultural characteristics of Chinese Buddhism. Scholars have also studied the Church acoustic environment [7]. In addition to traditional acoustic research methods, in recent years, investigators have analysed the relationship between human perception and the internal and external acoustic environments of churches from the perspective of soundscapes. Soundscape research examines the relationships among human hearing, the acoustic environment, and society. A soundscape can be defined as the sound environment of a given location as perceived by an individual, group or community [8]. It was first proposed by Schafer and is still under development today [9, 10], and thus includes a relatively broad scope of study [11-14]. Kang measured reverberation time and conducted questionnaire surveys to analyse how several churches in Sheffield create a comfortable acoustic environment [15]. Kiser and Lubman analysed the important role played by the sound of traditional church bells in community identification in London [16]. Garrioch studied the effect of church bells on the soundscapes of early modern European towns [17]. Brink et al. conducted a study to analyse church bell noises and sleep disturbances of nearby residents [18]. Soeta et al. researched the effects of sound source location and direction on the acoustic fields of Japanese Buddhist temples [19], and Westermeyer's studies focused on the soundscape of churches from the perspective of the typical sounds from inside a church [20]. Burgess and Wathe worked on ancient English church music and soundscape maps [21]. Zhang et al. analysed the acoustic environment of Han Buddhist temples from the perspective of soundscape evaluation [22, 23]. Jeon et al. adopted social surveys and soundwalks to compare the soundscape around a Catholic church with that of a Buddhist temple in South Korea [24]. The above research provided a comprehensive baseline for understanding the acoustic environment of religious sites from the perspective of sound and soundscape.

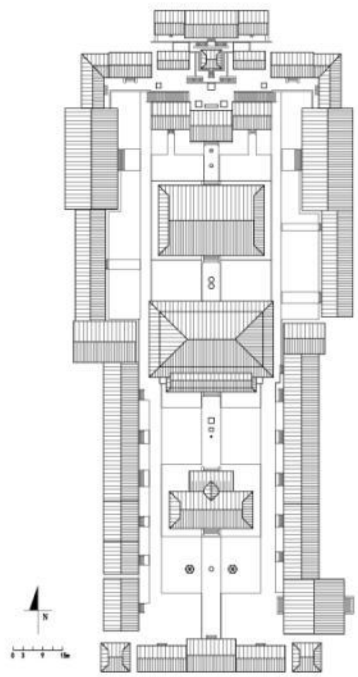
In terms of sound preferences, the literature has primarily focused on the sounds of public buildings, residential buildings, and the rural environment [25-28]. Researchers have argued that the human preference for natural sounds and aversion to mechanical sounds indicates that natural sounds can improve human mental health [29-31]. Several have analysed the sonic features and acoustic environments of religious sites. However, research on the sounds and sound preferences of visitors to Han Buddhist temples is rare.

In this study, we analysed the acoustic parameters of various sounds heard in Han Buddhist temples, and the sound preferences of visitors to these temples. First, we selected a group of Han Buddhist temples that could be considered representative. We then determined which sounds were typical at these temples and made recordings. Next, we analysed the physical acoustic and psychoacoustic parameters of the recordings. We subsequently administered a survey questionnaire regarding visitor sound preferences and the temple acoustic environment. This approach was used so that we could combine the objective acoustic parameters and the subjective questionnaire survey results to analyse the various factors that affect sound preferences in the temples. Specifically, we conducted correlation analyses between the sequence of objective parameters of various sounds and the evaluation of subjective sound preferences.

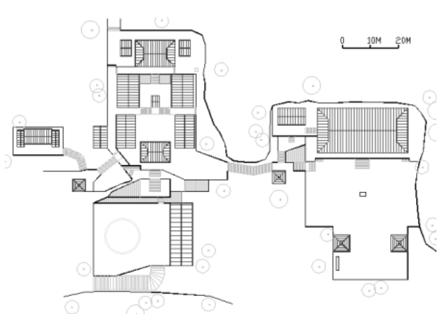
2. Methods

2.1 Selection of research temples

In a preliminary study, we investigated the temple acoustic environment and distributed the questionnaires in Puji Temple. The Puji Temple is the largest Buddhist temple on Mount Putuo, one of China’s four best-known Buddhist shrines. The subsequent formal investigation included four representative Han Buddhist temples:



（a）



(b)
Fig. 1. Site plan of Chinese traditional temples
（a） Xiantong temple in Wutai Mountain
(b) Longquan temple in Qian Mountain

Xiantong Temple on Wutai Mountain (Shanxi Province), Longquan Temple on Qianshan Mountain (Liaoning Province), Ci'en Temple in Shenyang (Liaoning Province), and Xiangguo Temple in Kaifeng (Henan Province). These temples are located in three different regions in China (the north, centre, and south), and each has substantially influenced the history of Chinese Buddhism.

The selected temples generally adopt a traditional Chinese courtyard-style layout, with main halls on an axis that are flanked by side halls and corridors. Fig. 1 (a) shows the layout of Xiantong Temple, an urban temple, with the Grand Hall as the tallest structure on the central axis. Fig. 1 (b) shows the plan of Longquan Temple on Qianshan Mountain, a mountain temple that has a dispersed layout to accommodate the mountainous terrain.

2.2 Sound classification

Field surveys revealed that there were various kinds of sounds encountered in Han Buddhist temples. These sounds were divided into natural and man-made sounds, based on their source. Natural sounds can create a religious atmosphere in a temple by masking unwanted noise, and a previous study showed that natural sounds such as the sound of rustling leaves could be masking sounds [32], and that water sounds with relatively greater energy in low-frequency ranges were effective for masking noise caused by road traffic [14]. Therefore, it is expected that natural sounds could make visitors feel comfortable in the temple. Such sounds primarily include the sounds of birds, cicadas, and frogs as well as the sounds of wind, rain, flowing water, and rustling leaves. Man-made sounds were categorised as Buddhism-related or Buddhism-unrelated sounds. The former category generally refers to sounds characteristic of religious sites, including the sounds of religious implements, bells, drums, chanting, prayer, and background music. The latter primarily includes the sounds of footsteps, tour-guide voices, tourist conversation, traffic sounds, and construction site noise.

According to soundscape classification [10], sounds can be categorised as keynote sound, signal, and soundmark. The keynote sound is the most important background sound of a place. At a temple, keynote sounds include man-made sounds, such as prayer, chanting, footsteps, guide voices, tourist conversation, and background music; they also include natural sounds, such as water flowing in a brook, wind, rustling leaves, and birds. Signal refers to a sound that audibly informs people of an event or other activity. Usually it is the one-off, unexpected, unpredictable, or intermittent sound that stands out against the backdrop of the keynote sound of the area [33]. The temple sounds that play the most important signal function are the sounds of various Buddhist implements, including the Yunban (cloud clappers), Yubang (fisher bang), Zaoban (morning plank), Linggu (tambourine), Daqing (brass qing), Hazi (cymbals), Dangzi, Yingqing, Shougu (small drum), Xiaomuyu (small wooden fish temple block), and Damuyu (large wooden fish temple block) (Fig. 2). These implements help summon worshippers for a mass or inform monks of the sequence of various religious rituals. Soundmark refers to the most representative sound of a place, and it makes the acoustic life of the community unique [10]. The distinctive and recognisable sounds of bells and drums represent the soundmark of Han Buddhist temples. From ancient times until today, whenever the matins bell and the vespers drum are heard or mentioned in China, the image of a temple or chanting monks comes to mind.

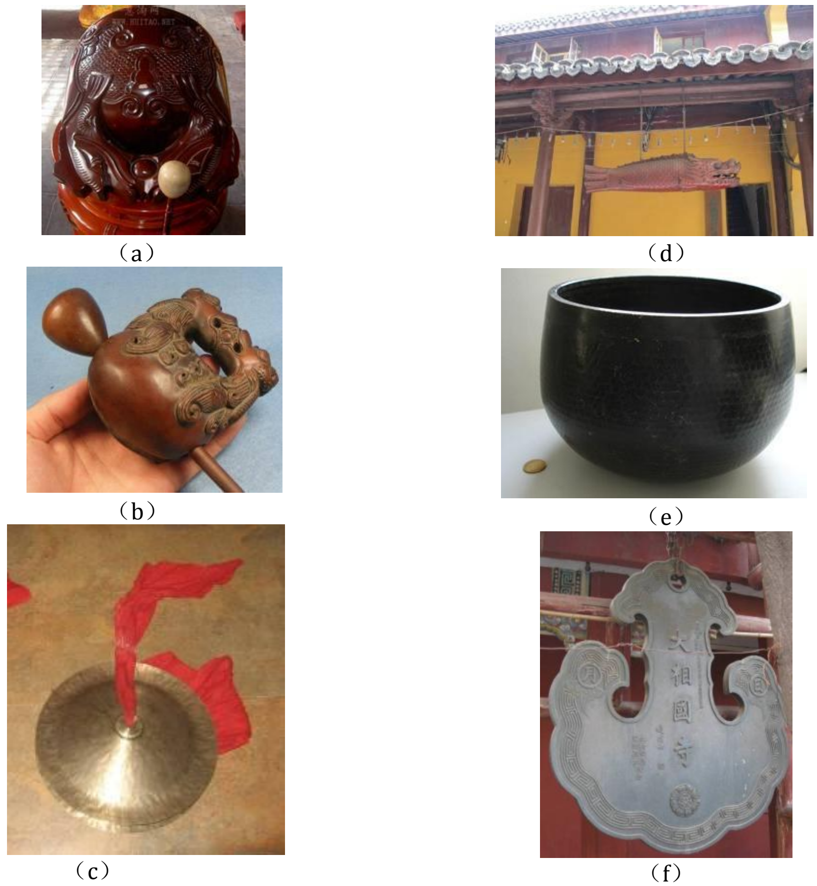


Fig. 2. Buddhist implements
(a) Damuyu (b) Xiaomuyu (c) Hazi d) Yubang (e) Daqing (f) Yunban

2.3 Sound recording and analysis

Various sounds that are heard in typical Han Buddhist temples were recorded using Fostex high-fidelity voice recorders (model FR-2LE) with a dedicated microphone, and A-weighted equivalent sound pressure level was chosen to calculate the average and maximum sound level. To avoid noise interference, the recordings were made in the morning before the temple opened or in the evening after it closed. Each sound was recorded for 10-60 seconds; for the Buddhist implements, more than one complete sequence of use was recorded. Appropriate microphone locations and distances were determined according to the sound modes and the acoustic characteristics of the recorded object [34]. When recording the sound of a Buddhist implement, the recorder was placed 0.5 – 1.0 m from the source of the sound. When recording other sounds, the recorder was placed as close as possible to the sound source. Since it is difficult to move certain large Buddhist implements, their sounds were recorded inside the temple rather than in an anechoic chamber. The advantage of this approach was a realistic recording, although the accompanying ambient sounds could not be entirely eliminated. Considering that we wished to compare only the parameters of the sounds heard at a temple, we consider that this imprecision caused by testing error was acceptable.

Each sound file was exported to the ARTEMIS acoustics software program, and the physical acoustic and psychoacoustic parameters were analysed. The physical acoustic parameters included the average and maximum sound level, and the psychoacoustic parameters included loudness, sharpness, roughness, and fluctuation strength [35]. Here, loudness refers to the intensity of sounds with various sound pressure levels and frequencies as perceived by the human ear. Sharpness measures the proportion of high-frequency components in a sound, and it was calculated using an Aures model. Roughness describes the auditory perception of chaotic, sharp, and piercing sound. Roughness and fluctuation strength are auditory effects caused by rapid changes in sound, of which the perception of sound with varying volumes is termed fluctuation strength when the change is slow (i.e., a modulating frequency less than 20 Hz) and roughness when the change is fast (i.e., a modulating frequency greater than 20 Hz). In the ARTEMIS software, roughness and fluctuation strength are calculated based on a hearing model presented by Sottek [36].

2.4 Questionnaire statistics

Questionnaires were distributed to tourists and temple members at the five Han Buddhist temples to investigate the sound preferences of temple-goers. First, 70 pilot questionnaires were distributed at Puji Temple, and the questionnaire was subsequently revised before distribution at the remaining four temples. The temple sounds included in the final questionnaire were based on the pilot questionnaire study, and were comprised of the 15 sound types which appeared most frequently in the respondents' answers. All sounds may not occur in every temple, so in the final questionnaire we asked respondents to evaluate the sound preference in the case that they imagined themselves to hear these sounds in this temple. The survey measured preferences for each temple sound and included questions on respondent's demographic characteristics, religious beliefs, and evaluation of the acoustic environment. The questions were designed as single-choice, with a scale of five levels: Level 1 represented "like the sound" (also meaning that prefer or enjoy the sound in Chinese), Level 2 "somewhat like the sound", Level 3 "neither like nor dislike the sound", Level 4 "somewhat dislike the sound", and Level 5 "dislike the sound".

A total of 720 final questionnaires were distributed at 4 temples, and 685 valid questionnaires were recovered: 177 from Xiantong Temple, 170 from Longquan Temple, 160 from Xiangguo Temple, and 178 from Ci'en Temple. The number of distributed questionnaires in a single temple was based on previous studies that found that 100 to 150 questionnaires could be considered representative in an urban environment soundscape survey [37]. The maximum number of total questionnaires required was based on empirical formula below [38].

$$n = \left(\frac{u_{a/2} S}{d}\right)^2 \quad (1)$$

where n is the maximum sample size, $u_{a/2}$ is a constant based on the confidence level, S is the estimate of standard deviation, and d is the absolute limit of error.

In the pilot investigation the standard deviation "S" of 15 sound types in the test questionnaire was between 0.5 and 1.2. Accordingly, if the maximum value was 1.2, the absolute limit of error "d" was set to 0.1 and the confidence level was set to 95%, then $u_{a/2}$=1.96, and the maximum sample size "n" was 553. In this research we completed a total of 685 samples in the final questionnaire, which met the sample size requirements. The maximum standard deviation of 15 sound preferences evaluation in the result of the final questionnaire survey was 1.23, the corresponding maximum sample size required was 581, and these again showed the sample size of this research could meet the requirements.

The target subjects of the questionnaire survey were randomly selected tourists or temple members encountered at the temples. We adopted this approach because the proportions of these two groups were the highest, and because the monks' perceptions of the acoustic environment were distinctly different from those of tourists.

The demographic characteristics of all surveyed subjects were statistically analysed. Men and women comprised 47.5% and 52.5%, respectively, of the total respondents. The subjects were divided into 3 groups based on age: under 18 years, 19-45 years, and over 45 years. These groups accounted for 9.4%, 71.9%, and 18.7%, respectively, of the respondents. The age composition of the respondents in the questionnaire was not only because more tourists and Buddhists in the temple were between 19-45 years old, but also because people in this age group were more likely to respond to the survey. In terms of education level, 4% of the respondents had an elementary school education or less; 39.4% had attended junior high or high school; 51.6% had attended vocational school or college; and 5% had completed a graduate degree. In terms of occupation, survey respondents were divided as follows: students 27.9% of the respondents, teachers 8.6%, workers 7.2%, self-employed individuals 7.2%, management personnel 6.3%, technical personnel 5.6%, retirees 5.6%, and service personnel 5.3%. Those with other occupations accounted for less than 5% of the respondents. In terms of temple visiting frequency, 57.8% of respondents were visiting the temple for the first time, 10.3% for the second time, 5.2% for the third time, and 26.7% for the fourth time (or more). Members of the last group were likely devout believers and/or residents of the surrounding communities. In terms of the purpose of the temple visit, tourism accounted for 53.3%, worship for 31.7%, physical exercise for 5.2%, and other purposes for 9.8%.

In terms of their attitude toward Buddhist teachings, 35.5% of the respondents were firm believers, 54% were believers to a limited extent, and 10.5% had little belief or were non-believers. Regarding monastic chanting, 38.3% of the respondents could fully or partially understand the words of chants, 11.7% did not express an opinion on their understanding, 28.2% largely did not understand and 21.8% did not understand at all. Thus, approximately one-half of the visitors or temple members did not understand the chants. This finding can be attributed to the language used in such chants (Sanskrit) and to the fact that the monks chanted too quickly. A total of 42% of the respondents reported that when they heard monastic chanting, they felt a strong sense of sacredness. Another 43.3% of the respondents felt some sense of sacredness when listening to chanting, and 14.7% either had no opinion or did not feel a sense of sacredness.

We divided the temple's acoustic environment evaluation into of acoustic quietness, comfort, and harmony. Level 1 in the questionnaire represented "quiet/comfortable/harmonious", Level 2 "somewhat quiet/somewhat comfortable/ somewhat harmonious", Level 3 "neither quiet nor noisy/no feeling/no feeling", Level 4 "somewhat noisy/somewhat uncomfortable/somewhat inharmonious", Level 5 "noisy/uncomfortable/inharmonious". The results show that a total of 70.1% of the respondents considered the temple's acoustic environment quiet or somewhat quiet, and 80.8% found it comfortable or somewhat comfortable. Regarding harmoniousness, 70.0% of the respondents thought that the acoustic environment and religious atmosphere of the temple was harmonious or somewhat harmonious.

2.5 Questionnaire validity and reliability tests

Reliability and validity tests are important methods for verifying a questionnaire's credibility and validity. In this study, we used SPSS software-based reliability analysis to test our instrument's validity. For the questions regarding sound preferences, the test found a Cronbach's α coefficient of 0.708, which is within the acceptable range [39]. SPSS software-based factor analysis was used to test the structure validity of the questionnaire results. Several studies have shown that factor analysis can be performed when the Kaiser-Meyer-Olkin (KMO) test value is larger than 0.7 and the p-value is less than 0.05 [38]. In the social sciences, if the cumulative contribution rate of the extracted common factors is over 50%, the factor analysis result is acceptable [39]. This study's factor analysis of the questions on sound preferences found a KMO of 0.741. The cumulative contribution rate of four factors (extracted based on the fact that their respective characteristic root was greater than 1) for all 15 variables was 51.6%. The Bartlett's test of sphericity found a value of $p<0.001$. Therefore, the structural validity requirements were met.

The questionnaire results at each temple were used to perform a non-parametric test on the multiple related samples for each of the demographic characteristics. The Friedman test p-values for gender, age, frequency of visiting a temple, education level, purpose, and religious belief were 0.896, 0.782, 0.392, 0.943, 0.589, and 0.801, respectively. All outcomes were higher than the critical value of 0.05. The ANOVA results for the numbers of different characteristics' visitors in the four temples showed that the differences of variances for age, gender, education, purpose, and belief fluctuated between 0.1 and 0.4 except for the variance of the frequency of visiting (close to 0.7). These results indicate that there was no significant difference between the respondents groups of four temples, suggesting that all the questionnaires might be pooled and analysed together.

To evaluate correlations among questionnaire answers, the dependent variable was the subjective evaluation of sound preference, structured as an ordinal variable. Independent variables included continuous variables (e.g., the sound level measurements), ordinal categorical variables (e.g., age, frequency of visiting, the attitude toward Buddhist teachings), non-ordinal categorical variables (e.g., purpose, occupation, different temples), and a binary variable (i.e., gender). Different types of correlation coefficients or indicators were chosen for calculation based on the variable type (Table 1).

Table 1. The calculation method of independent and dependent variables

Independent and dependent variables	Spss calculation approach	Index	Variables type
Respondents' characteristics in the four temples	Test for several related samples (nonparametric test)	Friedman	Continuous related variable
Gender vs preference evaluation	Independent-samples T test	Mean difference	Dichotomic (nominal) variable /ordinal variable
Sound levels by synchronous measurement with questionnaire vs preference evaluation	Bivariate correlation	Pearson	Continuous variable/Ordinal variable
Purpose, occupation, different temples vs preference evaluation	Crosstabs	Phi and Cramer's V	Nominal variable/Ordinal variable
Age, frequency of visiting a temple, attitude toward Buddhism teachings, education level, other sounds preference evaluation, the evaluation of comfort (quietness and harmony), the understanding of monks chanting, the feeling of hearing monastic chanting vs preference evaluation	Crosstabs	Gamma	Ordinal variable/Ordinal variable
Preference evaluation standard deviations, physical acoustics and psychoacoustics parameters vs the average value of sound preference	Bivariate correlation(nonparametric test)	Spearman	Continuous variable/Continuous variable

3 Results and analysis

3.1 Objective parameters of temple sounds

3.1.1 Acoustic parameters of single sounds

Physical acoustics and psychoacoustic parameters were obtained through an analysis of 15 sounds recorded in the temples (Table 2), those sounds were divided into natural sounds, Buddhism-related man-made sounds, and Buddhism-unrelated man-made sounds. The results of the spectrum analysis of each sound type are shown in Fig. 3.

The analyses of the parameters and spectra of the 15 sounds revealed the following insights. (1) The bell sound was the highest in average sound level and maximum sound level of the 15 temple sounds. The sound of birds and insects was the lowest; the difference between this sound and the bell sound was approximately 40 dBA. (2) Construction site noise was the highest in loudness and sharpness, and the bell sound was the second highest in loudness. The sound of birds and insects was the lowest in loudness, and the bell sound was the lowest in sharpness. These outcomes indicate that the bell sound contained the fewest high-frequency components. (3) The sound of drums was the highest in fluctuation strength and roughness, the sound of birds and insects was the lowest in roughness, and the sound of rustling leaves and flowing water were the lowest in fluctuation strength. These outcomes indicate that the two natural sounds were low in fluctuation and produced little irritation to the human ear. Of all 15 sounds, the fluctuation strength of the bell sound was only less than the drum and instrumental sounds, which confirmed previous research showing that the bell sound could produce a strong shaking feeling [3]. (4) As shown on the Fig. 3, among the natural sounds, the sound level of wind exhibited a linear decline trend from low frequency to high frequency. Moreover, the sound level of birds was the lowest in the mid-frequency range. Among the man-made sounds, the sound level of drums was the highest in the low-frequency range. The sound level of construction site noise was the highest in the high-frequency range. The sound level of the bell was relatively high at the frequency of 250 Hz and exhibited a downward trend below or above that frequency.

Table 2. The physical acoustics and psychoacoustics parameters of sounds in the temples

Category	Loudness (sone)	Sharpness (acum)	Roughness (asper)	Fluctuation strength (vacil)	The average sound level (dBA)	The maximum sound level (dBA)	The means of preference evaluations	The standard deviations of preference evaluations
Rustling leaves	8.53	2.12	2.94	0.00665	54.6	60.6	1.62	0.88
Bird	3.52	1.28	0.58	0.0266	44.6	52.5	1.36	0.77
Flowing water	26.4	3.16	2.80	0.0159	70.1	71.9	1.37	0.75
Wind	11.0	1.61	1.46	0.031	61.3	74.1	1.68	0.96
The average of natural sounds	12.36	2.04	1.95	0.02	57.65	64.78	1.51	0.84
Chanting	12.58	1.27	0.99	0.126	65.5	72.9	1.52	0.84
Implements	13.74	1.12	2.08	0.38167	71.5	81	1.60	0.87
Drum	24.6	1.60	4.62	0.509	70.8	78.2	1.92	1.14
Prayer	25.4	2.82	2.70	0.0488	71.2	78.5	2.13	1.11
Bell	29.8	1.11	2.14	0.121	82.1	91.2	1.24	0.56
Background music	21	1.85	2.13	0.0776	70.2	76.5	2.38	1.23
The average of Buddhism-related man-made sounds	21.19	1.63	2.44	0.21	71.88	79.72	1.90	0.96
Footstep	5.3	1.53	1.49	0.0409	47.8	53.1	2.75	1.09
tour-guide voice	10.6	1.93	1.41	0.094	62.3	73.3	2.80	1.23
Tourist conversation	21	1.85	2.13	0.0776	70.2	76.5	3.51	1.06
Traffic sound	21.4	1.94	2.39	0.0175	68.2	79.3	4.18	1.00
Construction site noise	35.9	4.7	2.79	0.0164	77.6	80.1	4.38	0.87
The average of Buddhism-unrelated man-made sounds	18.84	2.39	2.04	0.05	65.22	72.46	3.52	1.05

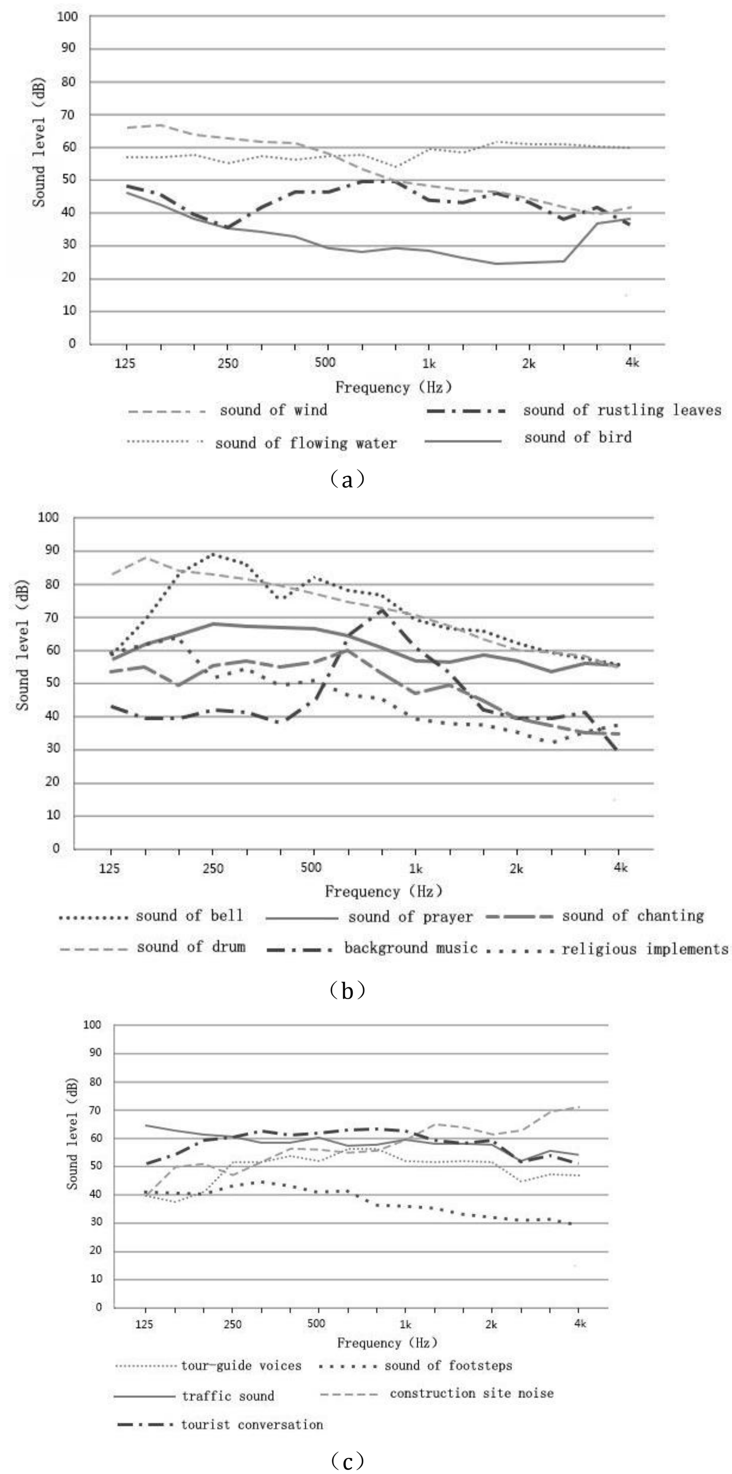


Fig.3. Spectrum of 15 kinds of sounds in temple
(a) Natural sounds (b) Buddhism-related man-made sounds (c) Buddhism-unrelated man-made sounds

3.1.2 Acoustic parameters of the different sound types

The mean values of the physical acoustic and psychological acoustic parameters for the various sound types are categorised by sound source in Table 2. The results are as follows: (1) In the temples, Buddhism-related man-made sounds were the highest in sound level and loudness, and natural sounds were the lowest. The sound level difference between the two was approximately 15 dBA, and the loudness difference was approximately 9 sone, which is 70% of the natural sounds' loudness. The values for the Buddhism-unrelated man-made sounds were between the two preceding sound groups, with sound level differences of 6 to 8 dBA. These outcomes indicate that, in the temple sound environment, man-made sounds are louder than natural ones, and that the Buddhism-related man-made sounds dominated. (2) Overall, the sharpness values for the man-made sounds and the natural sounds were similar. The Buddhism-related man-made sounds were the lowest in sharpness (1.63), which indicates that they contained the fewest high-frequency components. The Buddhism-unrelated man-made sounds were the highest in sharpness (2.39), and the sharpness of natural sounds was between the preceding two sound types (2.04). The natural sounds had lower fluctuation strength than the man-made sounds; i.e., they were soft and delicate. (3) Fig. 3 shows that the frequencies of natural sounds changed gradually. In addition, with the exception of background music, the sound levels of the Buddhism-related man-made sounds gradually declined from a low-frequency to high-frequency range. With the exception of footsteps, the sound levels of the Buddhism-unrelated man-made sounds did not exhibit a declining trend.

Table 3 shows the mean values of the physical acoustic and psychoacoustic parameters for each of the sound types according to soundscape classification. A non-parametric test on multiple related samples for the three groups of data in Table 3 was performed, and the result showed that the Friedman test p-values was 0.042, which was less than the critical value of 0.05, and it indicated that there were statistically significant differences between the elements of soundscape. The results in Table 3 reveal the following. (1) The differences in average sound level and maximum sound level between the signal and soundmark were less than 1 dBA. However, these sounds were louder than the keynote sound by more than 11 dBA. In addition, their fluctuation strength and roughness were significantly higher than those of the keynote sound, which indicates that the signal and soundmark occupied a prominent position in the temple acoustic environment. (2) Comparisons between the sharpness values revealed the following order: signal > keynote sound > soundmark. This outcome indicates that the signal contained more high-frequency components and was thus suited to signalling changes in temple activities. Comparisons between the loudness values showed the following order: soundmark > keynote sound > signal. The soundmark, with the highest loudness and the fewest high-frequency components, was softer and less irritating to the human ear than the keynote sound and signal, and could thus create the peaceful atmosphere of Buddhist temples. These results echoed the results of previous research of bell sounds that demonstrated that the sound of bells was harmonious as the temple's symbol [3].

Table 3. The mean values of physical acoustic and psychoacoustic parameters of the sound types according to soundscape classification in the temples

Category	Loudness(sone)	Sharpness(acum)	Roughness(asper)	Fluctuation strength (vacil)	The average sound levels(dBA)	The maximum sound level(dBA)
keynote sound	15.98	1.875	1.808	0.0775	64.533	71.8
Signal	18.761	2.303	2.446	0.3893	76.208	85.32
soundmark	27.2	1.355	3.38	0.315	76.45	84.7

3.2. Analyses of the factors that influence temple sound preferences

3.2.1 Sound preference evaluation features

The evaluation results for sound preferences at the temples are shown in Fig. 4, and the means and standard deviations of the evaluations are shown in Table 2. The results reveal the following findings. (1) The natural sounds were the most preferred (average evaluation value: 1.51), followed by the Buddhism-related man-made sounds (average evaluation value: 1.80), and, subsequently, the Buddhism-unrelated man-made sounds (average evaluation value: 3.53). If the Buddhism-related man-made sounds were regarded as informational sounds, then the order of ranking of sound preference in this paper was consistent with the previous soundscape research in urban neighbourhood [40]. (2) The favourite sounds of temple visitors were the bell (average evaluation value: 1.24) and the sound of birds and insects (average evaluation value: 1.36). The least favourite sounds were construction site noise (average evaluation value: 4.38) and traffic sounds (average evaluation value: 4.18). The correlation coefficient between the means of the evaluation values and the standard deviations of the sound preferences was 0.662 ($p<0.01$). This outcome indicates that respondents preferred sounds with a lower amplitude.

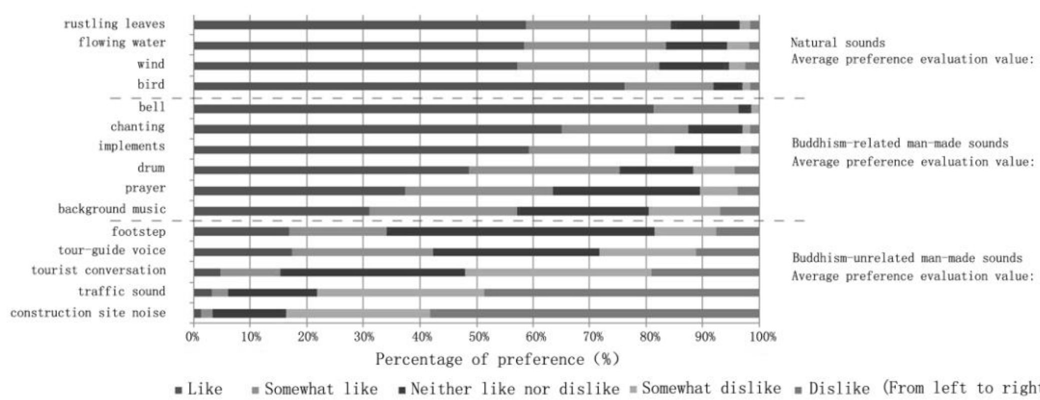


Fig.4. Evaluation of sound preference at Buddhist temples

3.2.2 Factors that influence preferences for the temple bell sound

The sound of the bell is the most representative sound of a temple, and the questionnaire survey indicated that among the 15 temple sounds, respondents favoured the bell. Therefore, we analysed the factors that affect preferences for the bell sound at temples.

(1) Respondent demographic characteristics

The mean evaluation values of the temple bell sound for young respondents (under 18 years), adults (18-45 years) and older individuals (over 45 years) were 1.49 (standard deviation: 0.809), 1.22 (standard deviation: 0.521), and 1.18 (standard deviation: 0.513), respectively. The correlation coefficient between age and sound preference evaluation value was -0.299 ($p<0.001$). This result indicates that, as the respondent's age increased, the respondent was more inclined to favour the sound of the temple bell, with little variation in the evaluation values. Fig. 5 shows the means of the evaluation values for respondents from different age groups at the four temples. At the mountain temples, (Xiantong Temple and Longquan Temple), the sound preference evaluation values of the bell sound tended to be more favourable with an increase in respondent age. However, at the urban-type temples (Ci'en Temple and Xiangguo Temple), this trend was absent. This finding likely emerged because the mountain temples have maintained the ritual of tolling the bell at matins and vespers, but the urban-type temples have dispensed with it to avoid disturbing nearby urban residents. This distinction may have affected respondents' perceptions.

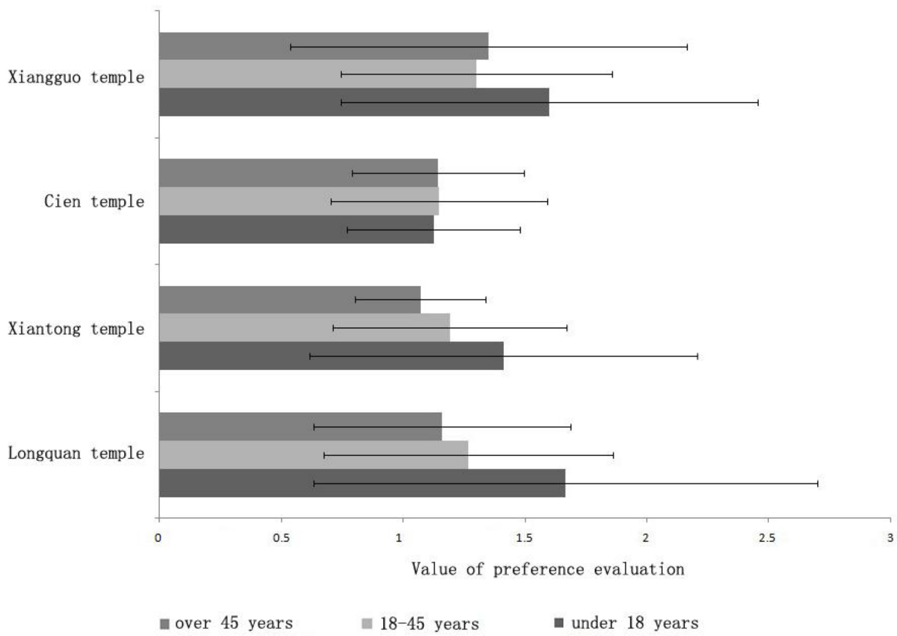


Fig.5. Bell evaluation values of different age groups at the four temples

The evaluations of preferences for the bell sound also varied according to the purpose of the respondents' visits. The correlation coefficient between these two variables was 0.121 ($p<0.01$). Worshippers liked the sound the most (average evaluation value: 1.09; standard deviation: 0.330), followed by tourists (average evaluation value: 1.32; standard deviation: 0.651), physical exercisers (average evaluation value: 1.26; standard deviation: 0.505), and visits for other purposes (average evaluation value: 1.22; standard deviation: 0.505). The survey also revealed that the most frequent visitors to the temples (likely Buddhists) liked the bell sound the most, with a correlation coefficient of -0.301 ($p<0.01$). The average evaluation values of the preference for the bell sound among men and women were 1.23 (standard deviation: 0.530) and 1.25 (standard deviation: 0.584), respectively. Overall, at each of the four temples, the p-value of gender difference in this preference was more than 0.05, which indicates that gender did not exert a significant effect on the bell evaluation.

The correlation analysis results of gender preferences in this paper are consistent with the results of previous soundscape surveys related to residential areas [41], but they are inconsistent with the research of church bell sounds in British urban squares [29], which may be related to different cultural factors of respondents in different countries [42]. At the same time, the correlation coefficient between the bell preference and occupation was 0.253 ($p=0.591$), which is not significant. This is consistent with previous research on the relationship between occupation and preference of the people in the square [42]. Similarly, the results showed the degree of education did not significantly affect the evaluation of bell sound.

The analysis of the results of the questionnaire survey shows that there is a correlation among age, purpose, and the frequency of visiting temples, therefore, it is necessary to conduct a multivariate linear regression model analysis of bell sound preference with three variables including age, purpose, and the frequency of visiting temple. Results (table 4) indicated that frequency (β =-0.042, $p=0.017$) and age (β =-0.103, $p=0.018$) were independently associated with bell preference evaluation, whereas purpose was not an independent significant factor ($p>0.05$).

Table 4. Results of multivariate linear model analysis of bell preference evaluation

Variable	β	Standardized error	Standardized β	95.0% confidence interval for β	p
Frequency of visiting temple	-0.042	0.017	-0.097	-0.076 to -0.008	0.017
Age	-0.103	0.043	-0.096	-0.188 to -0.018	0.018

Multivariate linear model analysis included frequency of visiting temple，age and purpose.

(2) Evaluation of Buddhism and the acoustic environment

The respondents' evaluation of Buddhism affected their preferences for the bell, and our analyses showed that respondents' attitudes toward Buddhist teachings were correlated with their preference for this sound. Firm believers liked the bell sound the most (average evaluation value: 1.10; standard deviation: 0.383, which represents a low fluctuation). They were followed by individuals who were believers to a limited extent (average evaluation value: 1.30; standard deviation: 0.383), and then by people with minimal Buddhist belief (average evaluation value: 1.52; standard deviation: 0.557). Non-believers had the lowest preference for the bell sound (average evaluation value: 1.52; standard deviation: 0.928). The correlation coefficient between the attitude toward Buddhist teachings and preferences for the bell sound was 0.430 ($p<0.001$). The correlation coefficient between the ability to understand monastic chanting and the preference for the bell sound was 0.278 ($p<0.001$). The correlation coefficient between the perception of the sacredness of monastic chanting and the preference for the bell sound was 0.397 ($p<0.001$). Visitors who reported that monastic chanting is sacred had an average evaluation value of 1.12 and a standard deviation of 0.330. They were followed by respondents who perceived the chanting as somewhat sacred (average evaluation value: 1.31; standard deviation: 0.593), and then by people who had no opinion on the issue or who did not feel a sense of sacredness (average evaluation value: 1.62; standard deviation: 0.865). Overall, with a decrease in the level of acceptance of Buddhist beliefs, preferences for the bell sound also decreased. In evaluations of the temple's acoustic environment, the correlation coefficient between acoustic comfort level and preference for the bell sound was 0.341 ($p<0.001$). Between harmoniousness level and the preference for the bell sound, it was 0.235 ($p<0.001$), and between the quietness level and preference for the bell sound, it was 0.199 ($p<0.01$).

Fig. 6 shows all the variables that exhibited a significant correlation with preference for the bell sound. Except for age, most of these correlations can be attributed to religious factors, including the purpose and frequency of visiting a temple, attitudes toward Buddhist teachings, the ability to understand monastic chanting and the perception of the sacredness in such chanting. Additionally, respondents' preference for nine types of natural sounds and Buddhism-related man-made sounds were correlated with preference for the bell sound, with a correlation coefficient that varied from 0.144 to 0.671. Overall, correlations with the more religiously meaningful sounds were higher, and preference for the bell sound displayed no significant correlation with the five types of Buddhism-unrelated man-made sound.

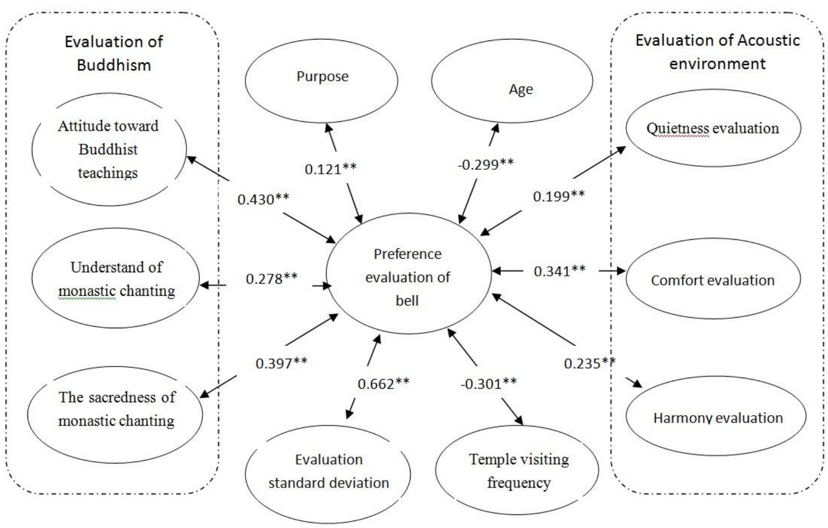


Fig.6. Correlation diagram between the variables and the preference evaluation of the bell

3.2.3 Factors that affected the preference for different sound types

(1) Respondent demographic characteristics

The relationships between preferences for different types of sound and respondent demographic characteristics are shown in Fig. 7 (a) (b). The results indicate the following findings. (1) In terms of sound source, the preference for Buddhism-related man-made sounds was significantly related to all demographic characteristics except occupation, with a correlation coefficient (absolute value) that varied between 0.11 and 0.27. Preference for natural sounds was affected by factors such as occupation, purpose of the temple visit, and education level. Preferences for Buddhism-unrelated man-made sounds were only affected by purpose of the visit and education level. (2) In terms of soundscape categories, the signal was affected by all the demographic characteristics except occupation, with a correlation coefficient absolute value that varied between 0.14 and 0.35. Preferences for the soundmark were affected by age, frequency of visits, and education level, while preferences for the keynote sound were only affected by education level. (3) In terms of demographic characteristics, education level affected the preference for each of the sound types, with a correlation coefficient absolute value that varied between 0.10 and 0.18. This outcome indicates that education level influenced the respondents' perceptions of sound, whereas occupation only affected preferences for natural sound. In contrast, our analysis of the impact of gender on sound preference revealed that gender did not exert a significant influence on preferences for each type of sound.

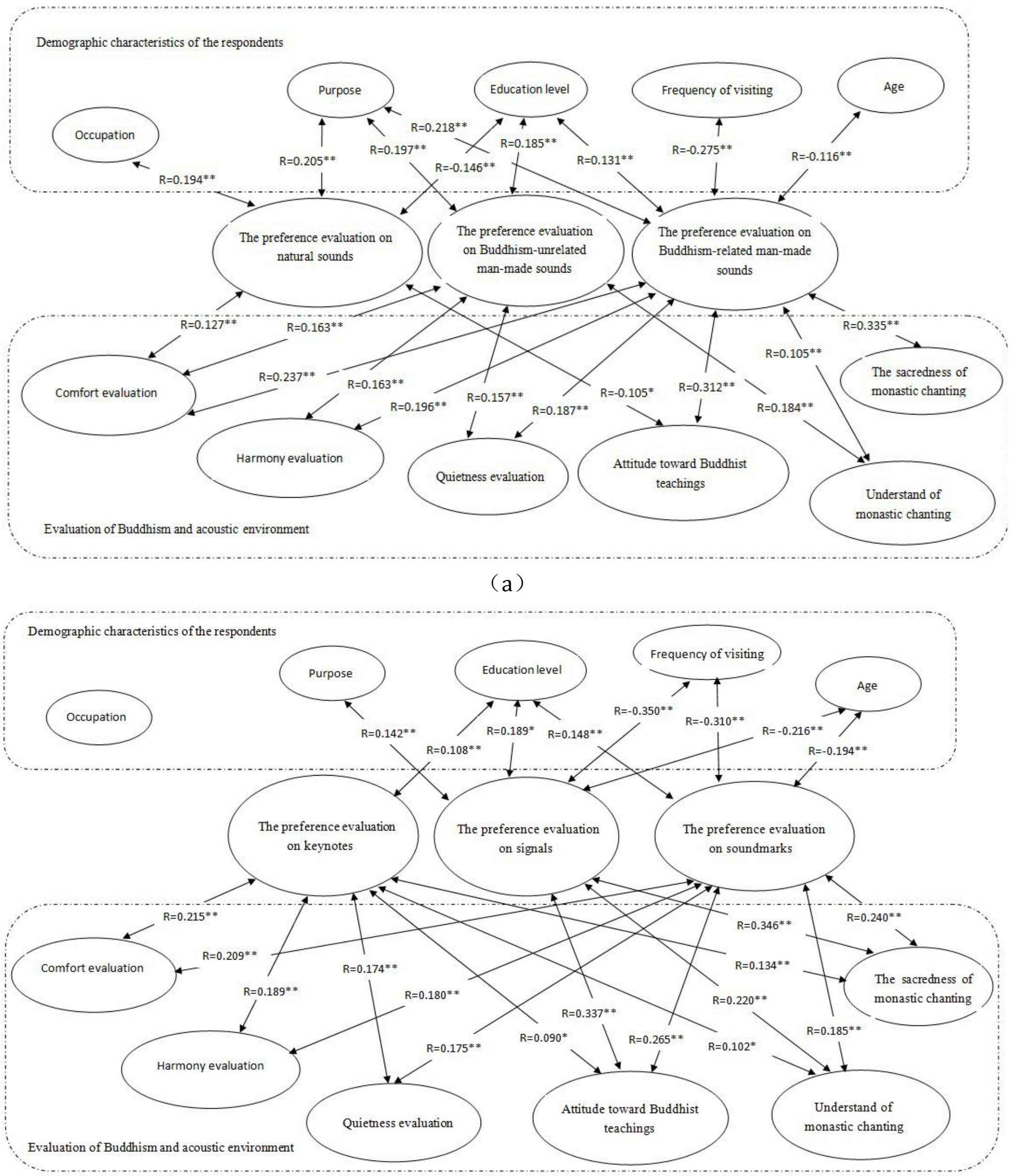
(2) Evaluation of Buddhism and the acoustic environment

The impact of the respondents' evaluation of Buddhism and the acoustic environment of the temples on the preference for different sound types are shown in Fig. 7 (a) (b). In terms of sound source, the respondents' evaluations had a significant impact on the Buddhism-related man-made sounds, with a correlation coefficient that varied between 0.19 and 0.34. However, they had no significant effect or little effect (the absolute value of the correlation coefficient was below 0.13) on preferences for natural sounds. The respondents' evaluations of the temple's acoustic environment had a significant impact on preferences for Buddhism-unrelated man-made sounds, with a correlation coefficient of 0.16. In terms of soundscape categories, the respondents' evaluations had a significant impact on their preferences for the soundmark and keynote sounds. For the soundmark, the correlation coefficient varied between 0.18 and 0.27. For the keynote sound, it varied between 0.10 and 0.21.

The primary factor that affected the preference for the signal was the respondent's evaluation of Buddhism, with a correlation coefficient that varied between 0.22 and 0.35. The signal exhibited no correlation with the respondents' evaluation of the temple acoustic environment. In terms of the evaluation of the temple acoustic environment, the evaluation of acoustic comfort had the highest correlation with preferences for each type of sound, followed by the evaluation of acoustic harmoniousness. The evaluation of quietness had the lowest correlation with preferences for each sound type.

3.2.4 Objective factors that affected temple sound preferences

Previous studies have shown that the preference for a certain sound is associated with the sound's parameters. For example, people prefer water sounds that have low fluctuation strength values, because in this situation the overall fluctuation strength of background sound is reduced [43]. The physical acoustic and psychoacoustic parameters of the various temple sounds are shown in Table 2. After matching the parameters with the means of the preference evaluation values, we calculated correlation coefficients (Table 5). The correlation coefficient between the average sound preference evaluation value and sharpness was 0.531 ($p<0.05$). With the exception of sharpness, correlations between the average sound preference evaluation values and other physical acoustic and psychoacoustic parameters were insignificant. These outcomes agree with the finding reported in a previous study that showed sound preference may primarily depend on sharpness [44]. However, other research indicates that although sounds with low sharpness are preferred on average, no acoustical or psychoacoustical parameter is absolutely correlated with individual sound preferences [45], so further research is still needed.



（b）

Fig.7. Correlation diagram between influencing factors and sound preference evaluation
(a) In terms of sound source categories (b) In terms of soundscape categories

Table 5. The correlation coefficients between acoustic parameters and preference means in the temples

Acoustic parameters	Correlation coefficients/Significance level						
	Loud ness	Sharpness	Roughness	Fluctuation strength	The average sound levels	The maximum sound level	The means of the preference
Loudness	1	0.34/0.22	0.639/0.01(*)	0.05/0.86	0.86/0.0(**)	0.73/0.01(**)	0.12/0.67
Sharpness	—	1	0.55/0.03(*)	-0.68/0.01(**)	0.03/0.90	-0.05/0.87	0.531/0.04(*)
Roughness	—	—	1	-0.26/0.34	0.47/0.08	0.34/0.22	0.15/0.59
Fluctuation strength	—	—	—	1	0.39/0.15	0.38/0.17	-0.15/0.60
The average sound levels	—	—	—	—	1	0.90/0.00(**)	0.07/0.80
The maximum sound level	—	—	—	—	—	1	0.21/0.46
The means of the preference	—	—	—	—	—	—	1

Our analyses of the relationships among factors (such as the measured sound level in the different temples and the survey evaluations of various temple sounds) revealed that the measured sound level was only correlated with the evaluation value for natural sounds, with a correlation coefficient of 0.165 ($p<0.001$). This outcome indicates that changes in sound level at a temple only affected the respondents' evaluation of natural sounds. Specific temples also affected the respondents' evaluation of sounds. With the exception of the Buddhism-unrelated man-made sounds, the evaluation of each sound type was correlated with a specific temple, with a correlation coefficient that varied between 0.13 and 0.27. These findings may have resulted from the different religious atmosphere of each temple.

4. Conclusion

This study investigated the acoustic parameters of various sounds at Han Buddhist temples and human preferences for these sounds through measurement and a questionnaire survey. The results showed that in terms of sound parameters, the bell sound exhibited the highest average sound level and the highest maximum sound level, while the sound of drums had the highest values in fluctuation strength and roughness. According to sound source, the Buddhism-related man-made sounds had the highest values for sound level and loudness, and they dominated the temple acoustic environment. Natural sounds had lower values for these parameters; the difference in the sound level between the two sources was approximately 15 dBA, and the difference in loudness was approximately 9 sone. The measured physical acoustic and psychoacoustic parameters of the various sounds were consistent with the roles they played at the temples. In terms of soundscape category, the average and maximum sound levels of the signal and the soundmark were both higher than those of the keynote sound by over 11 dBA. The signal contained more high-frequency components, as required by its purpose of signalling events or changes in activity. The soundmark was characterised by high loudness and low sharpness and thus was well suited to the typical soundscape of a Buddhist temple, with its high regard for quiet and tranquillity during meditation.

In terms of sound preferences, respondents preferred both natural sounds and the bell sound. This finding was similar to previous research which proposed that religious and natural sounds were treated as essential components in the temple precinct [24]. Factors such as age and religion significantly affected the respondents' preference for the bell sound, with a correlation coefficient (absolute value) that varied between 0.12 and 0.43. Preferences for Buddhism-related man-made sounds and signal were significantly affected by multiple demographic characteristics, and preferences for Buddhism-unrelated man-made sounds and keynote sounds were less affected. The respondents' evaluations of Buddhism and the acoustic environment had a significant impact on their preferences for Buddhism-related man-made sound, soundmark, and keynote sounds. The preference evaluation values for sounds at Buddhist temples were only significantly correlated with sharpness, with a correlation coefficient of 0.531 ($p<0.05$).

Acknowledgements
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6. References

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