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Effects of typical dining styles on conversation behaviours and acoustic perception in restaurants in China

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ABSTRACT

The acoustic environment of restaurants is important for diners. Based on acoustic measurements and a questionnaire survey of typical restaurants, differences in diners' conversation behaviour and acoustic perception were analysed. Three dining styles were compared (centralized, separate, and dispersed), and crowd density and background music were considered. Several interesting findings were gained. First, dining styles affected conversation behaviour. When there were four or more diners per table, conversation increased compared to when there were three or fewer; and background music did not reduce conversation. With the centralized style, the proportion of speech diners heard was greater than for the other two dining styles, even as crowd density increased. Second, dining styles affected sound pressure level. With background music, the separate style decreased sound pressure level more effectively than the other two styles when crowd density was low, and without background music, the separate style decreased sound pressure level more effectively than the other two dining styles irrespective of crowd density. Dining styles also affected acoustic comfort: with the centralized and separate styles, acoustic comfort took on a parabolic shape, first increasing and then decreasing as crowd density increased, while with the dispersed style, as crowd density increased, the acoustic comfort of diners decreased.

Keywords: Restaurants, Dining styles, Conversation behaviour, Acoustic perception

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1. Introduction

Restaurants have expanded their significance beyond dining alone and become places of emotional communication, family gatherings, and commercial negotiations. Field research by Heung and Gu [1] found that customers' choice of restaurants is not limited to the consideration of food factors any longer; the restaurant environment, particularly the sound environment, considerably affects diners' evaluation of their comfort and the overall dining experience.

The sound environment and users' acoustic perception in restaurants are a common focus of research, since the evaluation of meals and the income of restaurants can be affected strongly by sound factors [2]. Various studies have examined acoustic problems in dining spaces, including those related to noise control, speech intelligibility, and acoustic comfort [3-5]. Regarding noise control, Kang and Lok [6] found that the background noise level in restaurants is generally 80–90 dBA, while the ideal noise level is 70–75 dBA [7]. The acoustic environment in restaurants can be substantially affected by equipment noise, including lampblack machines and fans, and using any type of stone material for sound absorption in restaurants is not optimal [8, 9]. To examine speech intelligibility in restaurants, Kang [10] used a radiosity-based computer model to establish a mathematical model which revealed that increasing boundary absorption typically increases the speech transmission index (STI) by 0.2–0.4. With certain reverberation times, unintelligible speech sounds are expected to act as masking sounds, so that communication among diners around the same table will not be disturbed by the noise of diners at neighbouring tables. While the sound level, threshold of background noise that sheltered the noise interference of diners at neighbouring tables and guaranteed their speech articulation was found to be relatively narrow, at 69–71 dBA [11-13]. In terms of acoustic comfort, Leccese et al. [14] proposed a simplified analytical model to evaluate the acoustic conditions required to ensure the intelligibility of conversations in restaurant dining rooms, and found that the 'cocktail party effect' significantly affected the level of comfortable acoustic conditions. Another study, on two typical large dining spaces, found that background music, other diners' speech sounds, and impact sound from tableware had the dominant impacts on acoustic comfort evaluations by diners [7].

The conversation of diners is one of the main behaviours influencing the sound environment and diners' acoustic perceptions in restaurants. Ariffin et al. [15] studied the influence of environmental factors including colour, lighting, design, and layout on the conversation behaviour of diners. The Lombard effect or Lombard reflex is the involuntary tendency of speakers to increase their vocal effort when speaking amid loud noise, to enhance the audibility of their voice [16]. Field research has found that the listener may follow conversation of interest despite many concurrent sources of sound [17].

The indoor and outdoor sound environment and users' acoustic perception can also be affected by crowd density [18, 19], since a crowd is a special sound source in that it gives rise to certain sound absorption effects [20-22]. Studies have found that the sound environment in commercial pedestrian streets and underground shopping streets has undergone many changes, and acoustic comfort—as a key evaluation index of acoustic perception—varies substantially with crowd density [23]. Meng and Kang put forward a crowd acoustic model applicable to large spaces and applied a method of equivalent sound source calculation along with a simplified method for crowd sound sources [24]; in a separate study, Nie and Kang also analysed the relationship between crowd density and sound pressure level and between the number of persons present and the number of persons conversing [25]. However, few studies have considered the influence of the crowd factor on conversation behaviours and acoustic perception in restaurants.

Background music, which is a common sound source in restaurants, may also affect the sound environment and users' acoustic perceptions. Previous studies have indicated that the acoustic comfort of customers in commercial spaces is higher with than without background music [26]. In restaurants, previous studies have been confined to the influence of background music on eating behaviour, dining rate, meal volume, and sensitivity to food, without taking the influence of background music on conversation behaviour into account [27-30].

Thus, the aim of this study is to find out the effects of typical dining styles on conversation behaviours and acoustic perception in restaurants in China. First, this study examined the influence of dining styles on conversation behaviours, such as diners' frequency of conversation and frequency of speech sound. Second, the influence of dining styles on sound pressure level in restaurants was studied. Third, the influence of dining styles on acoustic comfort of diners was investigated. Three typical dining styles, including centralized, separate, and dispersed styles, were compared. Crowd density and restaurants with and without background music were considered in this study, as two factors which may affect conversation behaviours and acoustic perception in restaurants.

Some key terms used in this paper are defined/explained below: (1) Dining styles. Based on the analysis of relevant studies [31-34], this study divides dining styles into three categories: centralised, separate, and dispersed, as shown in Fig.1. The centralised style refers to diners sharing a dish, such as a hot pot; the separate style means that diners do not share dishes with others but eat their own food; while in the dispersed style, diners share many dishes, which is common in family gatherings (see Fig. 1). Previous studies have shown that these three dining styles are common not only in China but also in other countries in Europe and Asia [35]. (2) Conversion behaviours. This study considers two kinds conversion behaviour, namely the frequency of conversation and the frequency of speech sound. The former indicates the proportion of the time of a diner having conversation with any diner at the same table. The latter indicates the proportion of the time of a diner heard surrounding speech. (3) Sound pressure level. It is a logarithmic measure of the effective pressure of a sound relative to a reference value, and the unit of sound pressure level is dB [11]. (4) Acoustic comfort. It is the subjective evaluation of a diner on the dining environment, with a five-point scale in this study: 1, very uncomfortable; 2, uncomfortable; 3, neither comfortable nor uncomfortable; 4, comfortable; 5, very comfortable [26].

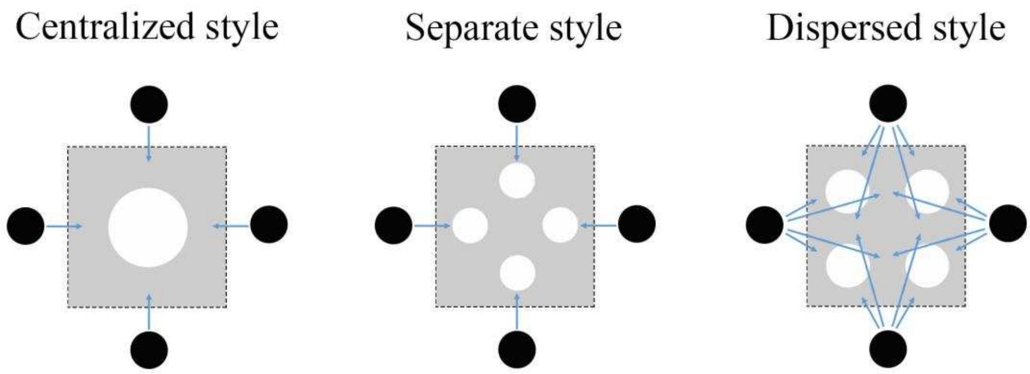


Fig. 1. Three dining styles: centralized, separate and dispersed.

2. Methodology

2.1. Survey site

The selection of case restaurants for acoustic studies is important, since many factors may affect sound environment and acoustic perception in restaurants [7, 10, 36, 37]. A study has indicated that compared with general restaurants, fast-food restaurant may be less noisy, since dining periods of less than half an hour will involve less conversation than those of more than 1 hour [36]. Kang pointed out that the different geometry of restaurants may change their reverberation time (RT) [10] Previous studies have also pointed out that sound environment can change with the interior layout of the restaurant; for instance, a restaurant with the kitchen inside usually has higher sound level than one with the kitchen adjacent [7]. Some recent studies have indicated that table shape can also affect users' acoustic perceptions in indoor spaces; for example, when the length of the table is 5 times the width [37].

Thus, based on a preliminary study, 523 Chinese restaurants were surveyed to find out their typical features, considering dining style, geometry, and layout and the social and behaviours characteristics of diners [38]. Each of the above mentioned three dining styles in this study was investigated, with and without background music. Consequently, six restaurants were chosen to cover all these situations.

The restaurants with music were Hongming Hot Pot (HHP), with a centralized style, Alpine Buffet (AB), with a separate style, and Bee Kitchen (BK), with a dispersed style. The restaurants without music were Si Chuan Ren (SCR), with a centralized style, Hawaiian Pizza (HWP), with a separate style, and Chuan Ren Bai Wei (CRBW), with a dispersed style. To avoid unusual influences of space and scale on sound distribution [39], the proportions of these six restaurants (length, width, and height) were within a ratio of 1:3, in order to avoid extremely non-diffuse sound fields [40]. Some details of the case sites, such as restaurant style, capacity, geometry, and indoor photographs, are shown in Table 1. As previous studies have indicated that the evaluation of acoustic environment can be influenced by reverberation time [41], the measured unoccupied RT for each of the six restaurants is also given in Table 1. It can be seen that the difference in RT T30 is less than 0.1s; therefore, the influence of reverberation time was not taken into account in this study [42-44]. Rindel [45] found that the typical number of persons at a table was 2–6, which was so in the cases of the restaurants listed above. To avoid the influence of the signal-to-noise ratio of the restaurant's public-address (PA) system on behaviour patterns and acoustic perception [45], the same acoustic system and background music were used in all the selected restaurants (that had background music). The type and tempo of music used [27, 46] are shown in Table 1.

Table 1. The basic information about six typical restaurants.

	HHP	SCR	AB	HWP	BK	CRBW
Dining style	Centralized	Centralized	Separate	Separate	Dispersed	Dispersed
Volume	910 m3	910 m3	1208 m3	1190 m3	942 m3	1173 m3
Geometry (length/width)	Rectangle 13 m/20 m	Rectangle 14 m/19 m	Rectangle 18 m/19 m	Rectangle 17 m/20 m	Rectangle 14 m/ 19 m	Rectangle 17 m/18 m
Shape of table (length/width)	Rectangle 1.5 m/1 m	Rectangle 1.5 m/1 m	Quadrate 1 m/1 m	Rectangle 1.2 m/1 m	Rectangle 1.5 m/1 m	Quadrate 1 m/1 m

Photograph							
Interior materials and sound absorption coefficient	Ceilings	Gypsum α=0.3	Gypsum α=0.3	Gypsum α=0.3	Gypsum α=0.3	Gypsum α=0.3	Gypsum α=0.3
	Walls	Ceramic α=0.02	Plaster α=0.01	Wood α=0.03	Marble α=0.01	Ceramic α=0.02	Plaster α=0.01
	Floors	Marble α=0.01	Ceramic α=0.02	Ceramic α=0.02	Marble α=0.01	Ceramic α=0.02	Marble α=0.01
Reverberation time		1.57 s	1.58 s	1.61 s	1.57 s	1.58 s	1.58 s
Music		With music	Without music	With music	Without music	With music	Without music
Music style		pop		pop		pop	
Music tempo		95-100 bpm		95-100 bpm		95-100 bpm	
Price level CNY/USD*		62 yuan 8.9 dollars	80 yuan 10.1 dollars	63 yuan 9.1 dollars	63 yuan 9.1 dollars	56 yuan 8.1 dollars	54 yuan 7.8 dollars
Age segment of diners		17–44	22–40	18–42	18–43	20–40	15–46

*According to Bank of China, the average exchange rate between China yuan and the US dollar in 2016 is 6.9125.

2.2. Crowd density measurement

Previous studies have shown that crowd density was a key influence on the acoustic environment and acoustic perception in open and indoor urban spaces [21]. Given this, we might expect conversation behaviour in restaurants as well to be influenced by crowd density; thus, this study also measured crowd density with each of the dining styles. Measurements were performed every half hour between the hours of 10:00 and 22:00 to cover variations in occupancy rate over time, as shown in Fig. 2 [47]. In order to reduce measurement error, volunteers were asked to measure the number of diners at the same time, each covering 2–3 tables. Further, cameras recorded the scene, and numbers were confirmed through video playback in the laboratory [21]. At the end of each measurement, the numbers collected by the volunteers were weighted to get the total number of diners. Finally, crowd density was calculated as the total number of diners divided by the area of the restaurant [48].

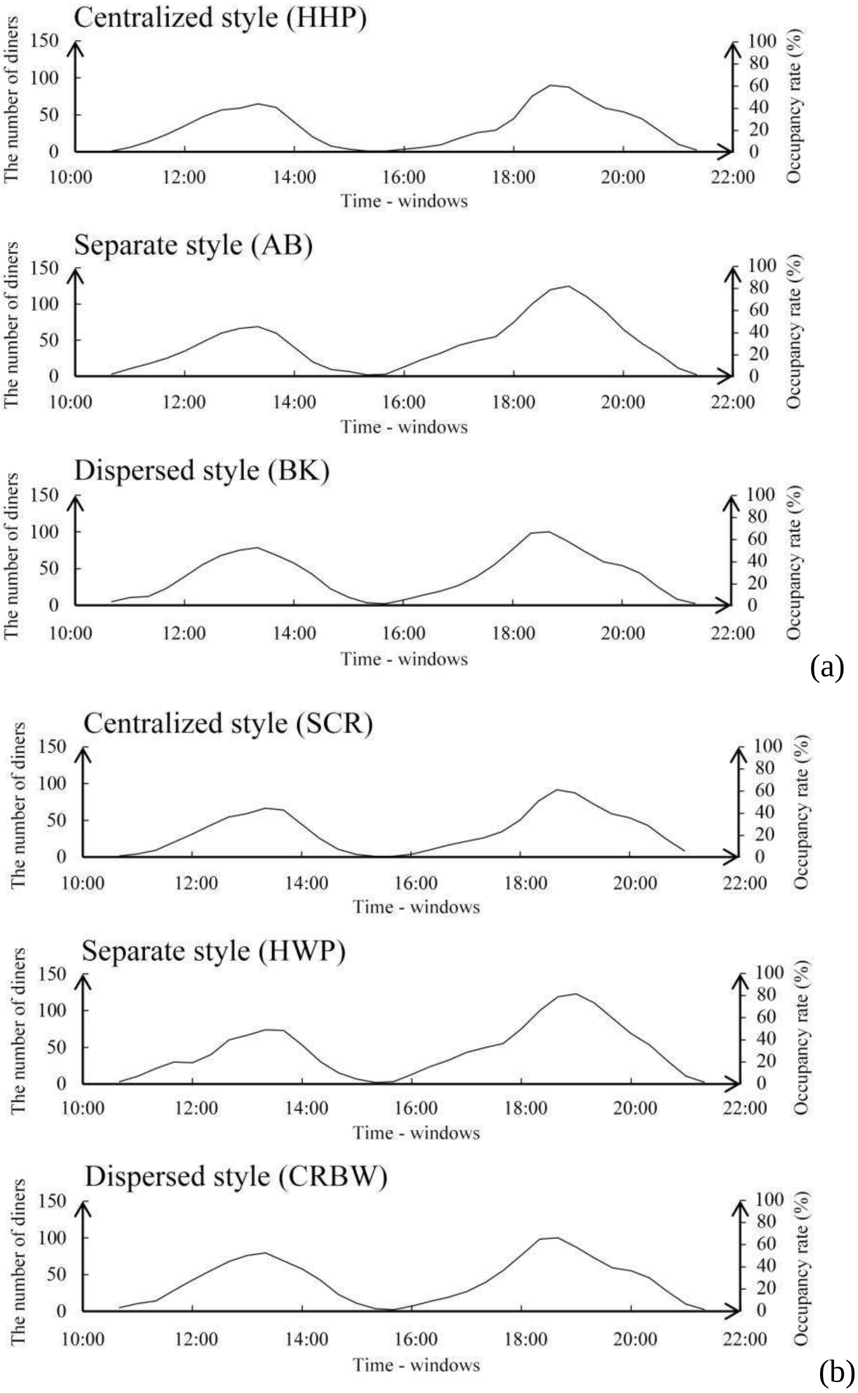


Fig. 2. Trend and variation in number of diners and occupancy rate with time-windows: (a) with music; (b) without music.

2.3. Conversation behaviour measurement

Some previous studies have shown the patterns of persons who talk and are talked to at table, are shown in Fig. 3 [49, 50]. Given that previous studies had indicated that demographic and social characteristics, including gender, age, education background, income, dining out, and occupation [7, 38], may influence acoustic perception in indoor spaces, a pilot study was carried out, and it was confirmed that the influences of these factors on conversation behaviours and acoustic perception were not significant, with $p > 0.1$ [50]. Therefore, these factors were not taken into account in this study. Only diners at the same table who knew each other were investigated. The above-mentioned preliminary study showed that when two diners sit at a table, one is the speaker and the other the listener at a given moment, while when three persons are at a table, one is the speaker and the other two are listeners. With four persons at a table, there may be two kinds of conversation behaviours: one speaker and three listeners, or two speakers talking at the same time while the other two persons are listening (one to each of them). Similarly, with five diners, one may see a speaker and four listeners, or two speakers talking at the same time while three persons are listening (one to one of them and two to the other), while with six diners, there are four kinds of conversation behaviour: one to three diners may be talking at the same while the others listen.

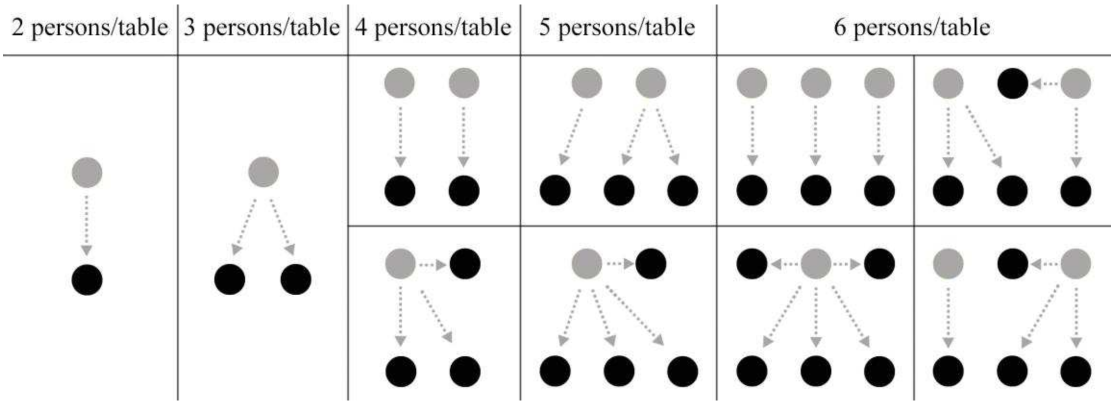


Fig. 3. Conversation patterns: grey circle indicates persons who talk, black circle indicates persons who listen.

Both frequency of conversation and frequency of speech sound were measured in this study. Frequency of conversation was measured across three periods into which the dining process was divided: waiting, eating, and after-eating. The waiting period begins when diners are seated and ends when they start eating, the eating period lasts from when they start eating to when 75% or more of them have stopped eating, and the after-eating period starts at the end of the meal and ends when the diners leave their seats. For measurements, an HD video camera was used to record the dining process. The video recorded the total time of each period, and the speaking time of each diner in each dining period was measured using a stopwatch. Speaking time was estimated from when one diner started speaking to when s/he stopped. When two or more diners spoke at the same time, speaking time was only measured once. The duration of each diner's speech was weighted and divided by the total time to obtain the frequency of conversation. In every restaurant, after each measurement of crowd density 10–15 tables were randomly chosen and the diners were asked to sit for an interview. These interviewees were asked to describe the 1–3 most salient sounds [32] that they had heard and to categorize them as speech, background music (if there was any), or other sounds [51, 52]; then, the frequency of different sounds was calculated and divided by the total frequency of all sounds to get proportions for each.

2.4. Sound pressure level measurement

Previous studies have suggested that different crowd aggregation states and behaviour patterns influence the sound environment and acoustic perception of users in open and indoor spaces, and the sound environment can in turn influence their acoustic perception [38]. Therefore, the level of sound pressure in every restaurant was measured, with the following methods, immediately after each measurement of crowd density. The sound pressure level meter was set to slow-mode and A-weight, and a reading for instantaneous data was taken every 10 s. The probe of the sound level meter was positioned 1 m away from walls and other main reflectors and 1.2–1.5 m off the ground [53, 54]. A total of 5 minutes of data were obtained at each measurement position, and the corresponding A-weight equivalent sound pressure level was derived. In order to avoid measurement error, each measurement in each restaurant was taken from at least five random points, with a distance between each point of at least 3 m [55]. In order to avoid the impact of persons speaking on the measurement, there were no persons talking within 3 m of the scope [55]. The A-weight sound pressure levels measured at each point were averaged [56].

2.5. Acoustic comfort survey

Acoustic comfort is a key evaluation index for the soundscape of open and indoor spaces [7, 21]. Thus, this study examined the influence of different dining styles on the evaluation of diners' acoustic comfort. After the measurement of crowd density and sound pressure level, some diners were immediately extracted and invited to take a questionnaire survey (questions and scales are in Table 2). The questions covered diners' social characteristics, and acoustic comfort [57]. The interviewers were instructed to explain questions and ensure that interviewees understood them. The interviewees, who were diners chosen randomly from the case sites, were asked to assess the acoustic comfort of the restaurant. On acoustic comfort, interviewees answered on the following five-point Likert-type scale: 1, very uncomfortable; 2, uncomfortable; 3, neither comfortable nor uncomfortable; 4, comfortable; 5, very comfortable [57]. Before the formal investigation, the validity and reliability of the questionnaire were tested [58-60]. As previous studies indicated that users may not able to evaluate an acoustic environment accurately until around 15 min after they have entered it [61], the interviews were carried out about 20–30 min after diners entered the restaurant. Previous studies have also indicated that an interview of more than 5 minutes may decrease the reliability of investigation [61-62], so the questionnaires in this study were all delivered and finished within 2–3 minutes.

To ensure the representativeness of the results, a survey on the social characteristics of diners, including age, gender, income, and education, was also done in all six restaurants before the formal investigation [38]; there was no significant difference found between these social characteristics of dinners in the preliminary survey and in the formal investigation (mean difference 0.01–0.04 with p>0.1). It was shown that the results obtained from the six restaurants are typical.

Table 2. Questionnaire questions and scales

Questions	Scale
Gender	1, male; 2, female
Age	1, <18; 2, 18–24; 3, 25–34; 4, 35–44; 5, 45–54; 6, 55–64; 7, >64
Income	1, <1000; 2, 1000–2000; 3, 2001–3000; 4, 3001–4000; 5, 4001–5000; 6 >5000 RMB
Education level	1, primary; 2, secondary; 3, higher education
Occupation	1, farmer; 2, industrial worker; 3, soldier; 4, teacher; 5, student; 6, unemployed person
Visit time	1, morning (9:00 to 11:59); 2, midday (12:00 to 14:59); 3, afternoon (15:00 to 18:00)
Stay time	1, less than an hour; 2, 1–2 hours; 3, more than 2 hours
Acoustic comfort	scale 1 to 5, with 1 as very uncomfortable and 5 as very comfortable

2.7. Statistics and analysis

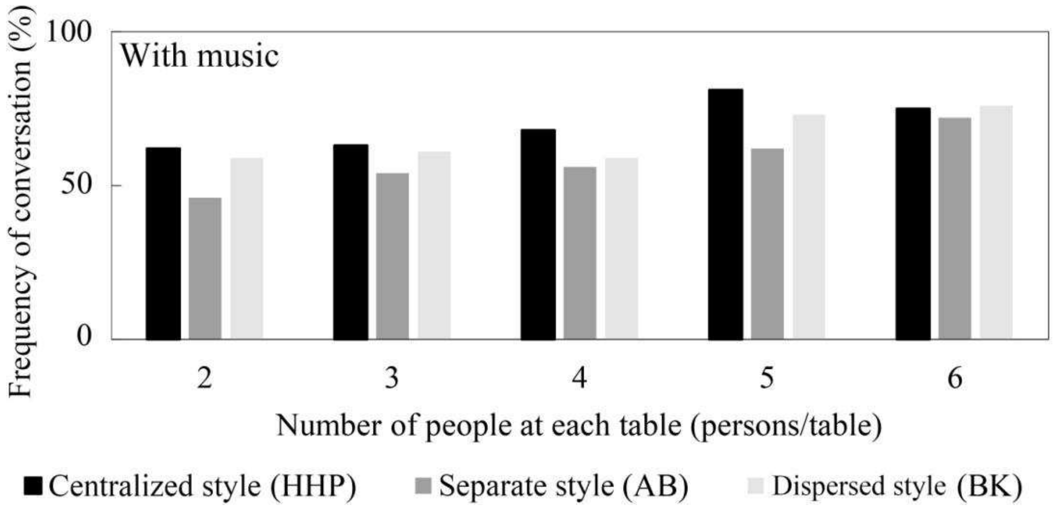
SPSS 15.0 [63] was used to establish a database for all the subjective and objective measurements. The Pearson correlation was used to calculate the relationships between crowd density and sound pressure level and between crowd density and diners' comfort evaluation. The linear and nonlinear regression analyses were used to establish the regression equations of crowd density and sound pressure level, and crowd density and diners' comfort evaluation. The t-test at $p<0.01$ and $p<0.05$ was used to test sound perception with and without background music.

3. Results

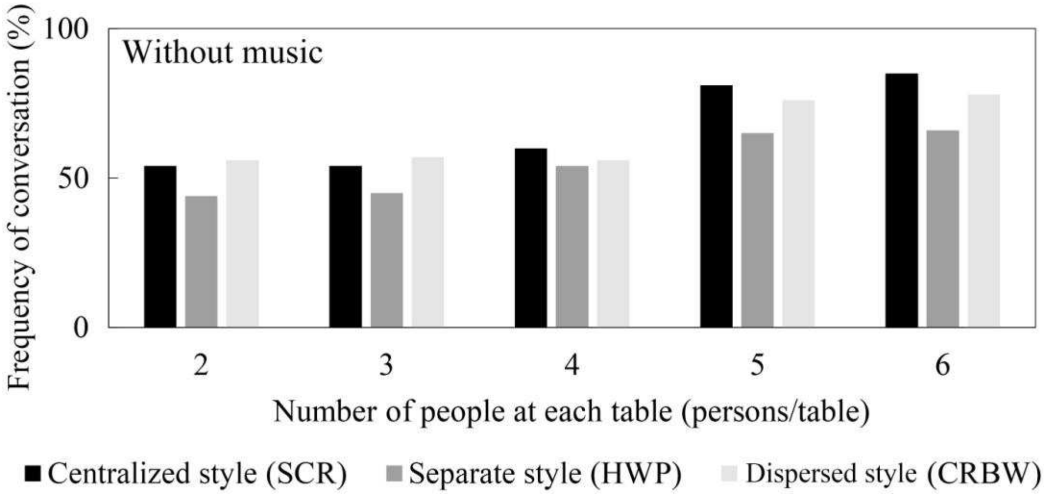
3.1. Influence of dining styles on conversation behaviour

3.1.1. Frequency of conversation

The frequency of conversation of diners in the waiting, eating, and after-eating periods is analysed first. The maximum difference in frequency of conversation between the three dining periods was 6.8%, which is not significant; therefore, the periods were merged to analyse the influence of dining styles on frequency of conversation, frequency of speech sound, and subjective experience of diners. Fig. 4 shows the influence of increasing the number of diners at each table on frequency of conversation. Restaurants with and without background music were considered.



(a)



(b)

Fig. 4. Influence of increasing number of diners at each table on frequency of conversation in three typical dining styles: (a) with music; (b) without music.

a. With background music. As Fig. 4a shows, in restaurants of a centralized style, frequency of conversation of diners was the highest when five persons were at each table, reaching a value of 81.5%. In the separate and dispersed styles, it was highest with six persons, with values of 72.2% and 76.0%, respectively. Average frequency of conversation was 69.8% with centralized, 65.6% with dispersed, and 58.0% with separate style. This might emerge from the characteristics of each dining style: in the centralized style, diners are seated around a brazier to share a dish, which would plausibly account for the increased frequency of conversation. In contrast, there were many dishes in the dispersed style, so that frequency of conversation was relatively moderate. Finally, in the separate style, diners use tableware individually and communications between diners are less frequent, resulting in the lowest frequency of conversation.

b. Without background music. As Fig. 4b shows, in the centralized, dispersed, and separate styles respectively, when six persons were at each table the frequency of conversation was 85.1%, 77.8%, and 66.7%. Similarly, the average frequency of conversation of diners in centralized dining was the highest, with a value of 66.8%, while the average frequency of conversation of diners with separate and dispersed styles was 64.6% and 54.8%, respectively.

In conclusion, four persons or more per table reduced the frequency of conversation of diners effectively, as did the separate and dispersed styles. It is also interesting to note that the average frequency of conversation of diners in restaurants with background music was higher than that in restaurants without background music, with mean differences of 3.2% in separate, 3.0% in centralized, and 1.0% in dispersed dining ($p<0.01$). A possible reason is that when playing background music, the diners felt that their privacy improved; thus, an acoustic environment with music is more suitable to help diners chat. Another reason may be that the comfort of diners improved, so that they wanted to talk more when background music played.

3.1.2. Frequency of speech sound

In the three typical dining styles, the relationship between crowd density and the frequency of sound heard is shown in Fig. 5; restaurants with and without background music were considered.

a. With background music. As Fig. 5a shows, the percentage of diners who heard speech increased with increasing crowd density, which corresponds to previous results for studies in urban open spaces [21]. When the crowd density was between 0 and 0.1 persons/m^2, the Frequency of speech sound in the centralized style was 30.9%, which was 16.4% higher than that in separate and 8.4% higher than that in dispersed style. When crowd density ranged from 0.25 to 0.35 persons/m^2, the frequency of speech sound in the centralized style was 80.4%, which was 13.7% higher than with separate and 9.2% higher than with dispersed style. With different dining styles, crowd density increased by 0.05 persons/m^2, and the average frequency of speech sound increased by 11.3% with the centralized, 9.8% with the separate, and 9.3% with dispersed style.

b. Without background music. As Fig. 5b shows, when crowd density ranged from 0 to 0.1 persons/m^2, the frequency of speech sound in the centralized style was 30.4%, which was equivalent to that in the dispersed style and 8.9% higher than in the separate style. When crowd density ranged from 0.25 to 0.35 persons/m^2, the frequency of speech sound in the centralized style reached 73.1%, which was 19.6% higher than in the separate and 3.8 % higher than in the dispersed style. With different dining styles, crowd density increased by 0.05 persons/m^2, and the average frequency of speech sound increased by 9.3% with the centralized, 7.5% with the dispersed, and 7.0% with the separate style.

These results indicate not only that the frequency of speech sound in the centralized style was higher than that in the other two styles, but that it also had a greater increment of the frequency of speech sound with increasing crowd density than the other two dining styles. When crowd density was lower than 0.15 persons/m^2 in all three dining styles, as crowd density increased the increment of the frequency of speech sound was higher than for 0.15 persons/m^2 and higher crowd density ranges, where privacy derived from distance disappeared and so frequency of speech sound increased only slowly with density. In addition, the average frequency of speech sound in restaurants with background music was higher than in restaurants without background music, with a difference of 5.2% in the separate, 4.3% in the centralized, and 1.2% in the dispersed style ($p<0.01$), which matches the results on frequency of conversation, which showed it higher with background music than without.

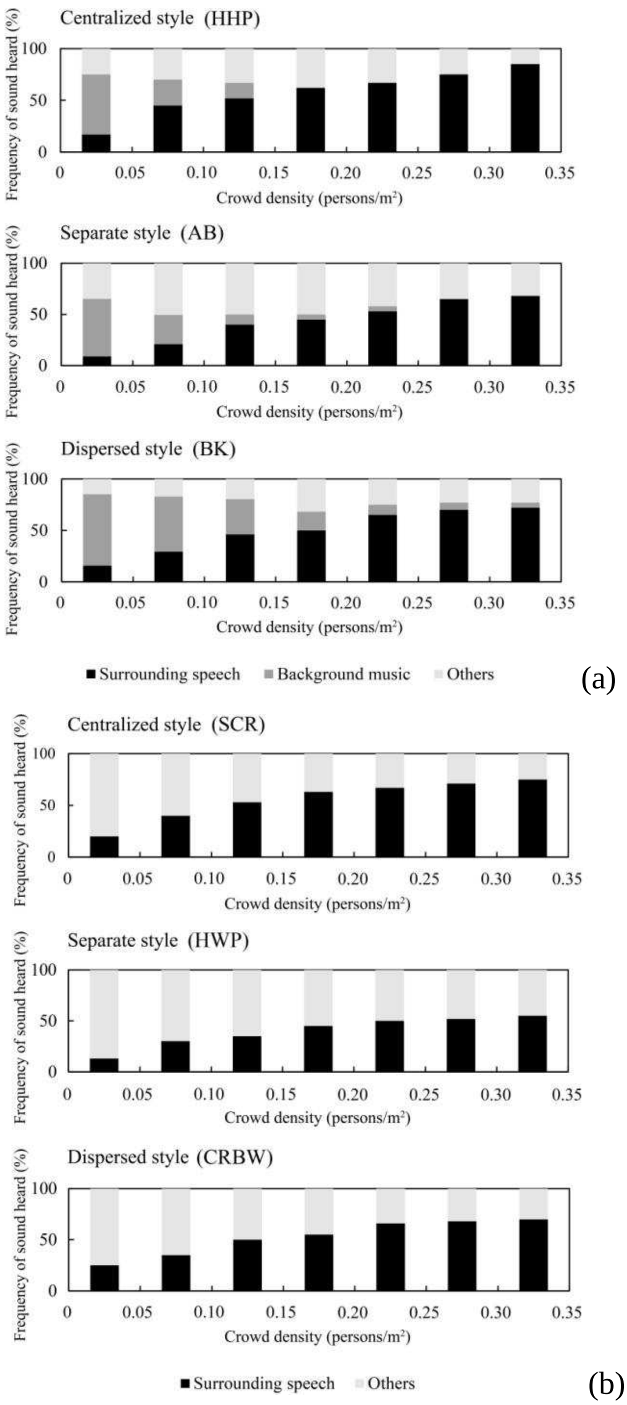
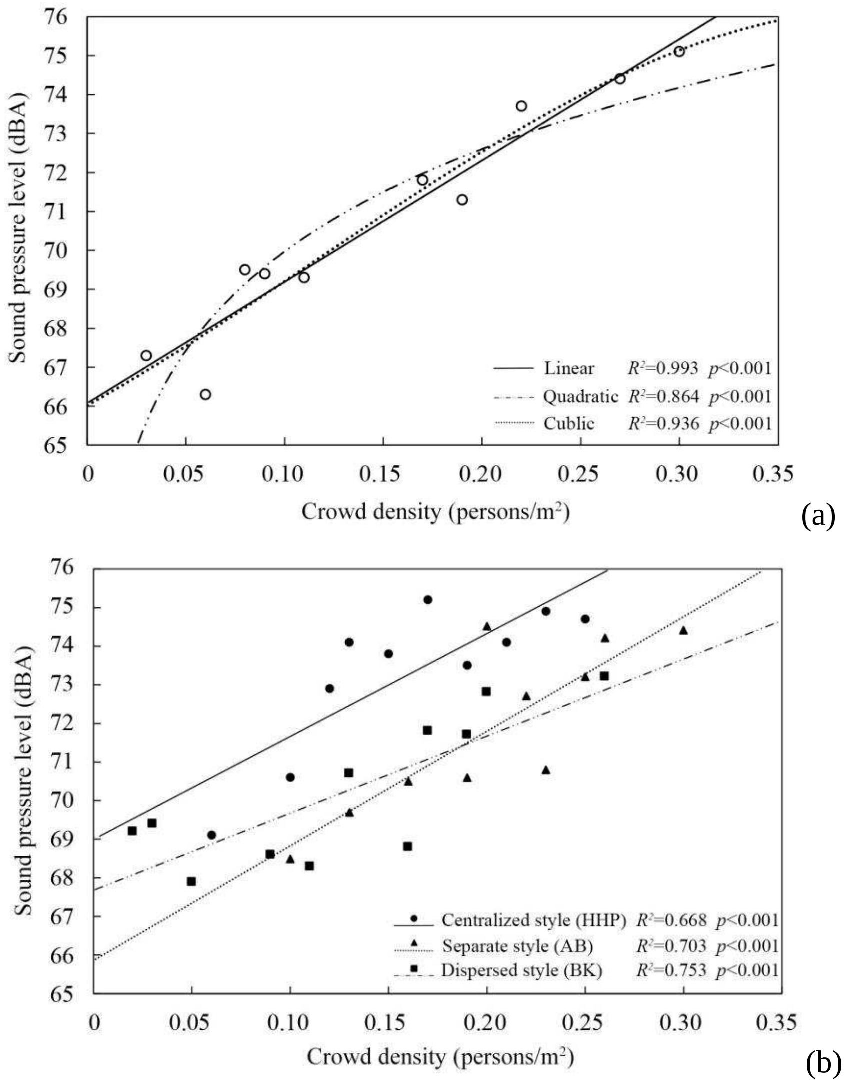
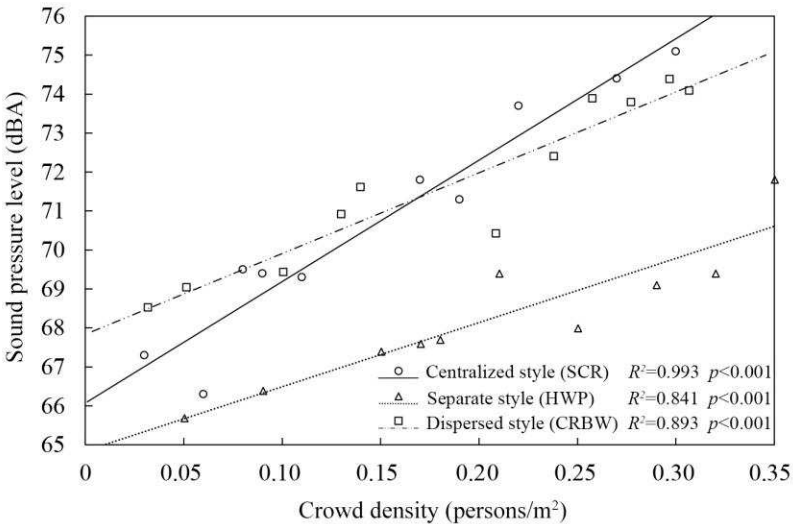


Fig. 5. Relationship between crowd density and frequency of sound heard in the three typical dining styles: (a) with music; (b) without music.

3.2. Influence of dining styles on sound pressure level

As seen, diners' conversation behaviours differed between dining styles. This section discusses the influence of different dining styles on sound pressure in restaurants, considering cases with and without background music. Fig. 6 shows the relationship between crowd density and measured sound pressure level in these six restaurants, with the corresponding linear trend curves and coefficient of determination R^2 and with $p<0.001$. Various regressions, including linear, quadratic, and cubic, were used to find out the best fit to show relationships between crowd density and measured sound pressure level; Fig. 6a shows a centralized style without music as an example. It can be seen from the figure that the linear regression for this restaurant is better than the others, with $R^2=0.993$. Therefore, in the following analysis, this linear regression is used to explain the relationships between crowd density and measured sound pressure level.





(c)

Fig. 6. Relationship between crowd density and measured sound pressure level in six restaurants with the corresponding linear trend curves and coefficient of determination R^2, at p<0.001: (a) 3 trends (linear, quadratic, and cubic) between crowd density and the measured sound pressure level in centralized style without music; (b) with music; (c) without music.

3.2.1. With background music

As Fig. 6b shows, when crowd density increased from 0.05 to 0.25 persons/m^2, the level of sound pressure inside the restaurant increased accordingly, by 5.9 dBA in the separate, 5.3 dBA in the centralized, and 4.1 dBA in the dispersed dining style. For the same crowd density, the sound pressure level in the centralized style was higher than in the separate and dispersed styles, with values of 2.5 dBA and 2.0 dBA, respectively. One reason for this may be the fact that in the case with background music, frequency of conversation in the centralized style was higher than in the separate, with a difference of 11.8%, and the dispersed, with a difference of 4.2%. In the separate and dispersed styles, conversely, under the same crowd density, in the range of 0 to 0.18 persons/m^2, mean sound pressure in the dispersed style was higher than in the separate style, while from 0.18 to 0.35 persons/m^2, it was higher in the separate style. This seems to show that when background music is played, the separate style can reduce sound pressure effectively when crowd density is less than 0.18 persons/m^2, while when crowd density exceeds 0.18 persons/m^2, the dispersed style can reduce the level of sound pressure more effectively.

3.2.2. Without background music

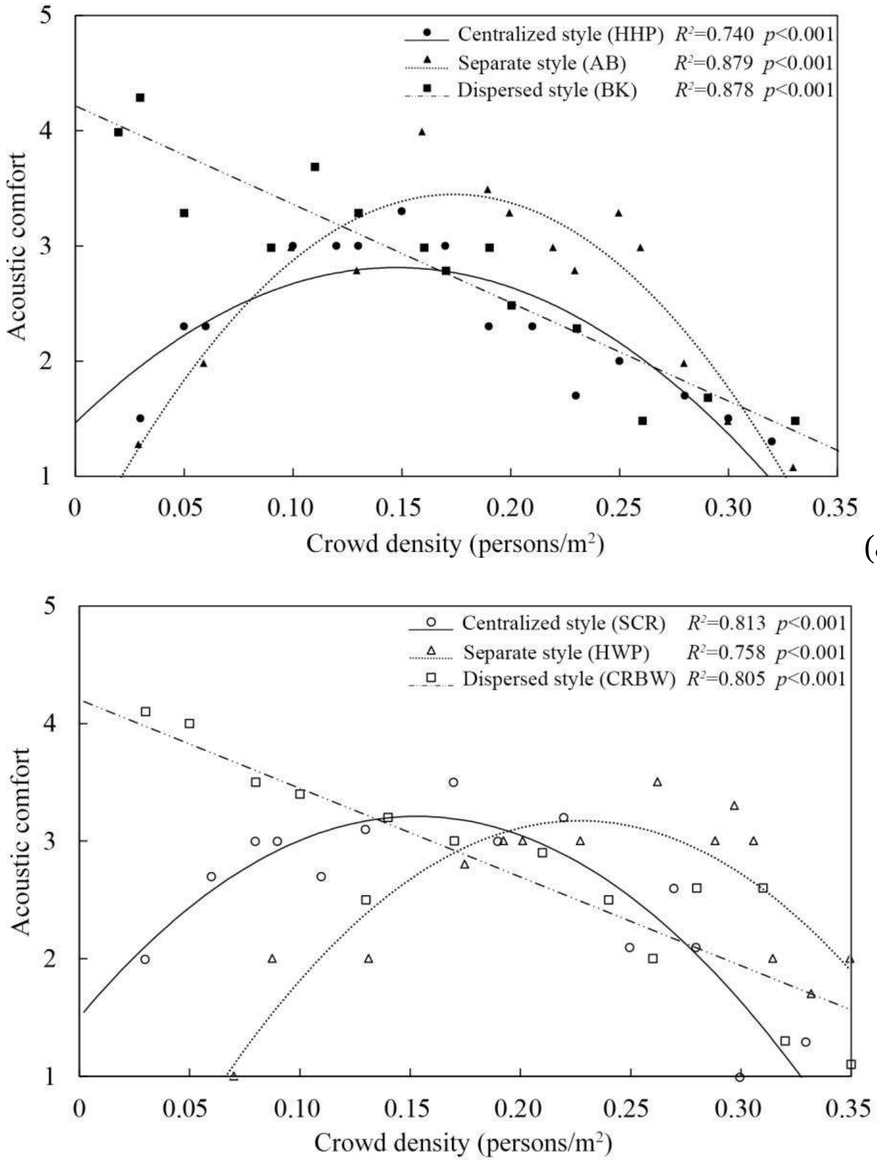
As Fig. 6c shows, when crowd density increased from 0.05 to 0.25 persons/m^2, sound level inside the restaurant increased by 6.2 dBA in the centralized, 4.2 dBA in the dispersed, and 3.3 dBA in the separate dining style. At this crowd density, sound pressure levels of the centralized and dispersed styles were higher than that of the separate style, with difference of 4.4 dBA and 3.8 dBA, respectively. One reason for this may be the fact that in the absence of background music, frequency of conversation in the centralized and dispersed styles was higher than in the separate style, with a difference of 12.0% and 9.8%, respectively. In the centralized and dispersed styles, at the same crowd density, in the range from 0 to 0.17 persons/m^2, average sound pressure in the dispersed style was 0.8 dBA higher than that in the centralized style. In contrast, when crowd density ranged from 0.17 to 0.35 persons/m^2 the average sound pressure level in the centralized style was 1.0 dBA higher than in the dispersed style. These results indicate that in the absence of background music, the separate style can more effectively reduce sound pressure in restaurants than the other two dining styles.

3.3. Influence of dining styles on acoustic comfort

Fig. 7 shows the relationship between crowd density and acoustic comfort across the three dining styles, with the corresponding linear trend curves and coefficient of determination R^2 and significance $p<0.001$.

3.3.1. With background music

As Fig. 7a shows, in the centralized and separate styles, the value of acoustic comfort takes a parabolic shape as a function of crowd density, with an initial increase and subsequent decrease, similar to the study by Meng and Kang [24] on underground shopping streets. Comparing these two dining styles demonstrated that when crowd density exceeded 0.08 persons/m^2, acoustic comfort in the separate dining style was higher than that in the centralized style. Interestingly, the linear trend of acoustic comfort with varying crowd density in the dispersed dining style was significantly different from the other two dining styles: with increasing crowd density, the acoustic comfort of diners decreased. It was higher than that in the other two dining styles when crowd density ranged from 0 to 0.12 persons/m^2, and lower at higher densities. The reasons for these different trends may be that the centralized and separate styles are mainly used for family gatherings, and diners dining in these two styles prefer these busy establishments. In such a case, a sound environment with lower crowd density could make customers feel less cheerful. On the other hand, the dispersed style is generally used for commercial dining, and these diners prefer a relatively quiet dining environment with lower crowd density that may be more suitable for conversation (as when crowd density exceeds a given range, normal exchange is affected). These results indicate that in the case of background music, the dispersed style is suitable to achieve better acoustic comfort when crowd density is less than 0.12 persons/m^2, while when it exceeds that level, the separate style is better suited to achieving acoustic comfort.



(a) (b)

Fig. 7. Relationship between crowd density and acoustic comfort in the three dining styles, with the corresponding linear trend curves and coefficient of determination R^2, at $p<0.001$: (a) with music; (b) without music.

3.3.2. Without background music

As Fig. 7b shows, in the centralized and separate styles, acoustic comfort also took a parabolic shape that first increased and then decreased as a function of crowd density. The value of acoustic comfort in centralized dining was higher than that in the separate style when crowd density was less than 0.2 persons/m^2, but when crowd density was more than 0.2 persons/m^2, the reverse was true. Also as before, acoustic comfort in the dispersed dining style was significantly different from that in the other two dining styles, taking a downward linear trend. Overall, when crowd density was less than 0.12 persons/m^2, acoustic comfort in the dispersed style was higher than in the centralized style, showing that in the absence of background music, the dispersed styles was best suited to ensure acoustic comfort at this density. Conversely, when crowd density ranged from 0.12 to 0.2 persons/m^2, the centralized style yielded the best acoustic comfort, and when crowd density exceeded 0.2 persons/m^2, the separate style was best suited to achieving acoustic comfort.

Comparing cases with and without background music indicated that the mean difference in acoustic comfort in restaurants with background music was higher by 0.6 compared to that in restaurants without background music ($p<0.01$) when crowd density ranged from 0 to 0.23 persons/m^2, whereas when crowd density ranged from 0.23 to 0.35 persons/m^2, the reverse was true ($p<0.01$). Consequently, when crowd density is less than 0.23 persons/m^2, background music can be played to achieve better acoustic comfort; but when crowd density is greater than 0.23 persons/m^2, background music is not conducive to acoustic comfort.

4. Conclusions

Based on objective measurements and a subjective survey of six typical Chinese restaurants, this study examined the differences between conversation behaviour and acoustic perception of diners in three styles of restaurant, respectively featuring centralized, separate, and dispersed dining. The following conclusions can be drawn from the results:

First, regarding the influence of dining styles on conversation behaviour, centralized dining will increase frequency of conversation. The presence of four or more persons at each table can also increase frequency of conversation effectively. It is interesting to note that, with the same crowd density, the frequency of conversation of diners in restaurants with background music was higher than that in restaurants without background music.

Second, as crowd density increased, sound pressure inside the restaurant increased as well. In restaurants with background music, the separate style reduced sound pressure most effectively when crowd density was less than 0.18 persons/m^2. In the absence of background music, the separate style reduced sound level most effectively across the board.

Third, regarding the influence of dining styles on acoustic comfort, in the centralized and separate styles, acoustic comfort took on a parabolic shape, while in the dispersed style it decreased linearly as crowd density increased. With background music, the dispersed style achieved better acoustic comfort when crowd density was less than 0.12 persons/m^2, while the separate style achieved better acoustic comfort when crowd density was more than 0.12 persons/m^2. In the absence of background music, when crowd density was less than 0.12 persons/m^2, the dispersed style achieved the best acoustic comfort, while when crowd density was greater than 0.2 persons/m^2, the separate style was best suited to ensure acoustic comfort.

While this study is based only on typical Chinese restaurants, a previous study has shown that the size of restaurants in Europe is usually 1/3-1/4 of that of Chinese restaurants [64]. This could lead to rather different reverberation times, which could influence the acoustic comfort of diners [10]. Moreover, another previous study pointed out that the vary price of restaurants may lead to social differences, which in turn, could influence the conversation behaviours [65]. Furthermore, some recently works have shown that the different background music styles, such as jazz, rock-and-roll, and classical music may also lead to the different speed of conversation [66], and the acoustics comfort could consequently be affected. Thus, in future studies, those could be further examined.

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