Effect of music in large activity spaces on the perceptions and behaviours of older adults in China

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Abstract

The role of soundscape quality is being increasingly recognised in human well-being. This is also true for older adults, an increasingly growing group. In this study, we investigated the influence of different sound environments on the emotions and behaviour of older adults, as well as the correlation between crowd density and sound environment. This study was conducted in large and comprehensive activity spaces in a residential aged care facility in China. The participants included older adults who utilize or reside at the centre; they were divided into a control group and an experimental group. The experimental and control groups were provided a 'with music' or 'no music' environment, respectively. By setting the music type in the experimental group, we found that positive emotional experience and satisfaction were higher with slow-rhythmed music than that with fast-rhythmed music ($p < 0.001$). Crowd density was also significantly higher when slow-rhythmed music was played compared to that during fast-rhythmed music. Under the setting of natural sounds, the pleasure associated with individual activities was significantly higher than that of group activities. With an increase in crowd density, correlation with natural sounds was also increased. Overall, these research results provide a theoretical basis for the accurate control of audio variables in residential aged care facilities.

Keywords: soundscape quality; acoustic comfort; individual response; music; older adults

1. Introduction

With rapid development in interior design, increasing attention is being given to the coordination of acoustics in the environment because this affects quality of life (QoL), as well as restricts physical behaviour. Optimising the design of urban spaces and ensuring soundscape quality have always been important components of urban landscape ecology and the cornerstones of sustainable urban development (Zhang et al.2006). An accurate understanding of the influence of the soundscape on individuals in a specific space is a prerequisite for optimising the design of urban spaces and ensuring soundscape quality (Axelsson 2012; Torresin et al. 2020). Sound perception in a given space has been shown to differ in the indoor office sound environment (Lee et al. 2016; Dokmeci

and Kang 2017). This includes physical perceptions as well as spiritual aesthetic perceptions (Aucouturier et al.2007; Torresin et al.2019). Therefore, studying the characteristics of soundscapes in specific environments and comprehensively analysing their emotional impact on human behaviour is critical for accurately assessing open spaces in urban landscapes and supporting human health. The physical conditions and design features and their use and functions are equally important when objectively and subjectively evaluating the acoustic environment in studies focusing on soundscapes, especially if they are indoors (Dokmeci and Kang 2016).

As China's economy continues to grow and people live longer and healthier lives, the population of older adults has become increasingly prominent. According to previous studies, the number of older adults in China is expected to peak in 2053(Lu and Liu 2019; Zhai et al. 2017). The aging population has different challenges, such as an increased demand for residential aged care facilities. Currently, residential care providers focus on how design and simple implementation can improve the overall QoL of the residents. Despite its environmental significance, sound is mostly overlooked as a factor that contributes to the perception of such surroundings. There are relatively few current studies on the soundscapes of care facilities for older adults, leading to a lack of specific standards for their acoustic performance (Aletta et al.2017; Aletta et al. 2018;Wang and Kang 2020). As an essential component in the life of older adults, the importance and universal significance of music culture is self-evident. However, currently in China, apart from a small number of piano and chorus courses for older adults, targeted services with content aimed at older adults in health care facilities for music therapy, entertainment activities, music media, and other aspects are lacking. Regardless of the operational mode or musical content, there are limited musical materials specially designed, created, and compiled for older adults.

A recently published systematic review indicated that, although there is some evidence (Gill and Englert 2013; Gök et al. 2017) suggesting that the wrong volume or type of music could inflict negative emotions, most studies indicate that music in a nursing home setting affects the physical and mental health of older adults positively (Mileski et al. 2019). Music can also have a positive effect on human behaviour, owing to its impact on mood and arousal, which in turn appears to be determined by the tempo (fast vs. slow) (Bottiroli et al.2014). Despite many studies on the positive effects of music on the well-being of older adults, the effect of music on the daily routines and activities of residents in residential aged care facilities remains unclear (Dahms et al. 2017).

Based on this limited background, creating an experimental sound environment to explore the responses of older adults to different sound environments should have great significance in improving their QoL by enhancing their living environment. Thus, the purpose of this study was to explore the effect of environmental sounds in a specific space on individual responses. In particular, the effects of different types of music on satisfaction, emotion, and behavioural responses were explored. The research objectives were as follows: (1) to determine the psychological impact of different environmental sounds on older adults; (2) to determine the association between demographic and social backgrounds of older adults and their assessment of different environmental sounds; (3) to investigate how the acoustic environment affects the activities of older adults; and (4) to determine the effect of environmental sounds on crowd density, that is, the number of people per area, in an activity space. To achieve these objectives, a research experiment was conducted in a large-scale activity space. The behaviours of older adults were recorded after playing different musical clips in the space. The older adults were invited to participate in a questionnaire regarding approach-avoidance behaviour and determining what type of entertainment they preferred, as well as to measure the influence of acoustic environmental factors on their perception and activity.

2. Methods

This study used a combination of quantitative and qualitative methods to explore the effects of environmental sound in the large-scale, comprehensive activity spaces of a residential aged care facility and its impact on the behaviours, psychological conditions, and perceptions of older adults. First, the indoor sound pressure levels (SPLs) of the large-scale activity spaces were measured, and different musical pieces were played to change the environmental sound inside the space. A questionnaire survey was then conducted to explore the impact of different music pieces on the

individual activities of older adults in different environments. Second, to explore the relationship between environmental sound and crowd density, the influence of sound from different sound-related activities, evaluation of acoustic comfort of the older people participating in sound-related activities, and the influence of different sound backgrounds were determined. Further, the impacts of different musical backgrounds on the behaviours and psychological conditions of older adults in the activity spaces were analysed and discussed.

2.1 Process of the study

This study was conducted in a large residential aged care facility with the dimensions and characteristics described above. The objective parameter SPL was measured to analyse the parametric acoustic environment while different types of music were played, as described in section 2.4 (Sound Settings). Simultaneously, crowd density was captured using a photographic method during different times and sound environments, and image recording was performed to observe behaviour. As merely analysing objective parameters lacks coherence, subjective data were collected using questionnaires comprising demographic data and an evaluation of the sound environment.

Descriptive statistics were generated for the questionnaire data, and analysis of variance (ANOVA) was performed to analyse the relationships between the psychological state of older adults and different sound environments, as well as the music types. To learn more about the preferences of older adults, two-way ANOVA was used to analyse the impact of music or no music, different rhythms, and different music types on the psychological states of different subsets of older adults, categorised by education level, activity type, age, and area where the activity took place. Furthermore, ANOVA was also used to clarify the relationships between behaviour and SPL, as well as their evaluation of the sound environment and the activities they conducted. Lastly, to further study the preference of older adults for music and its loudness, Pearson's correlation coefficient was applied to measure the association between the satisfaction of older adults, as expressed in the questionnaire and the SPL of different decibels, and between satisfaction for different types of music and crowd density.

2.2 Survey location

Harbin, located in Heilongjiang Province, is a typical city in China with an extensive cultural and historical background. The cold winter climate affects a number of activities enjoyed by older adults, making indoor activities the mainstay in winter. Therefore, the quality of indoor activity spaces in residential aged care facilities in Harbin has a dual impact on the daily activities of older adults, impacting both their psychological and physical health. Previous studies have shown that differences in the environment or space may lead to different assessments of soundscapes (Kang and Zhang 2010; Lercher and Schulte-Fortkamp 2003). Thus, research on the impact of sound-related activities should be conducted in the same environment. Runfu Activity Hall, where this study was conducted, is composed of two major parts and has been designed for large-scale comprehensive activities. The entire interior space of the building was divided into three parts for this study: a fan-shaped sunshine hall (covering an area of 1,560 m^2, with a height of 14 m), corridor (covering an area of 720 m^2, length of 72 m, width of 10 m, and height of 4.5 m), and small activity rooms (including the painting room and lecture room). Pictures of the hall are shown in Fig. 1. These three activity spaces are comprehensive in terms of their size, shape, and building material, as listed in Tables 1 and 2.

(a) (b)

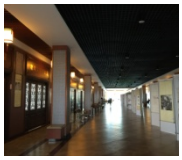
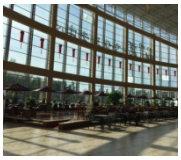
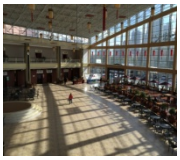
(c)

Figure 1. Pictures of the hall.

Table 1. Characteristics of the research locations

	Hall	Corridor	Activity room
Shape	Fan-shaped	Rectangle	Rectangle
Area	1,560 m^2	720 m^2	84 m^2
Material	Concrete，Glass	Concrete	Concrete

Table 2. Detailed characteristics of the research locations

		Classroom	Corridor	Hall Rest area	Hall Centre area	Stage area
Space type		Small space	Large space	Atrium space	Atrium space	Atrium space
Volume		84	720	240	960	360
Geometry (length/width)		10.5/8	72/10	40/6	48/20	30/12
Average customers		20	15	8	30	6
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
	Walls	Brick with lime α = 0.02	Wood α = 0.06	Glass α = 0.18	Glass α = 0.18	Wood α = 0.06
	Floors	Ceramic α = 0.02	Marble α = 0.01	Marble α = 0.01	Marble α = 0.01	Marble α = 0.01
Sound absorber/reflector		Desk，Seat，Blackboard	Table，Seat，Billboard	Table，Seat，Sunshade	Table，Seat，Sunshade	Table，Seat，Stage
Background music		With background music	With background music	With background music	With background music	With background music

2.3 Sound-related activities and behaviour measurements

Image recording is a promising research method for collecting behavioural observations of older adults (Österholm and Larsson 2020; Meng and Kang 2015; Asan and Montague 2014). The data for each of the comprehensive activity spaces were collected at survey sites situated between 0 and 10 m outside the activity area, as previous studies have shown that the behaviour of older adults is usually not affected by activities or sound sources more than 10 m away (Akeroyd et al. 2007). For the corridor on the first floor of the activity hall, the experiment was performed by taking a photograph every 30 s for five consecutive minutes (Meng and Kang 2015).

By observing the activities in the activity hall, the noise generated by the older adults could be divided into three categories. The first category covered silent activities including resting, reading books, and using the Internet. The second category included low-decibel activities comprising activities that produce some small sounds or include light conversation such as meeting guests, chatting, walking, and playing chess. The third category covered activities that produced high-decibel sounds such as loud music and dancing. The indoor activities and behaviour patterns of the older adults were recorded while different music pieces were played in the activity hall (see section 2.3). The activities of older adults in the activity hall were not confined by activity type, and the activity area changed accordingly. Further, depending on their daily customs, some older adults participated in more than one activity. Therefore, the observation time for each activity type was set to 15 min.

2.4 Sound settings

Two music settings were designed, i.e., settings 'without music' and settings 'with music.' For the 'with music' settings, the experiment was divided into two groups. In the first group, three different pieces of music were played: instrumental music, musical instruments with lyrics, and natural sounds. In the second group, two pieces of music with different melodies were selected: fast-rhythmed instrumental music and soothing slow-rhythmed instrumental music.

Before the experiment, we monitored and recorded the A-weighted equivalent continuous sound level (LAeq) of each sound signal collected on-site. All music pieces were set within 100–110 beats per minute (bpm), apart from the fast-rhythmed instrumental music, which was used as a contrast. For this experiment, musical pieces that older adults were familiar with were selected. The 'musical instruments with lyrics' setting was the song called Qia Si Ni De Wen Rou (Just Like Your Tenderness) by the famous female Chinese singer Cai Qin, which is popular among older adults, with Chinese lyrics and 109 bpm. The selected 'instrumental music' piece was the famous song, Yu Zhou Chang Wan (Fisher Boat at Nightfall), played on a guzheng (a classic Chinese instrument) with 107 bpm. The natural sounds were a combination of bird calls and flowing water, taken from the Silver Mountain sound installation at the Contemporary Music Museum, with 106 bpm.

In the control experiment using instrumental music, different musical rhythms, fast and slow, were compared to reduce the impact of lyrics and instrument differences on the advanced evaluation. In this control experiment, two musical pieces played on the same instrument, a traditional Chinese musical instrument called the pipa, were selected: Chun Jiang Hua Yue Ye (A Spring Night on the Riverside where Flower Blooms), with a slow soothing rhythm at 103 bpm, and Shi Mian Mai Fu (Total Ambush), with a fast rhythm at 142 bpm.

2.5 Questionnaire survey

The questionnaire consisted of two parts. The first part collected basic demographic information of the participants and the second part concerned their evaluation of the sound environment using a seven-point Likert scale, which has been widely used in survey research on the effects of environmental sound for subjective evaluations (Yang 2019). The questionnaire was administered immediately after the behaviour measurements were taken (Meng and Kang 2015; Yu and Kang 2009). In general, the older adults were able to complete each questionnaire within 3 to 5 min (Litwin 1995). In total, 302 valid questionnaires were obtained from the survey site. To analyse the psychological status of the participants, the widely used pleasure-arousal-dominance (PAD) emotion status model (Mehrabian and Russell 1974) was utilised to describe and measure the emotional status with three numerical dimensions: pleasure (positive or negative feelings), arousal (degree of physiological activation), and dominance (feelings of control). In addition, we used the results of the

questionnaire and the PAD model to establish the emotional threshold (sensitivity of the emotional response) of the participating older adults.

2.6 Measurement of crowd density

Crowd density at different times and in sound environments was measured using a photographic method to investigate the impact of crowd density on the sound environment and the auditory preferences of older adults in the activity hall, without affecting their normal activities (Meng et al. 2017; Oakes and North 2008). The optimal photography locations that eliminated blind spots were selected around the fan-shaped sunshine hall and corridor on the second floor, at which point the entire activity hall could be captured from above. A photograph was taken every 30 s for five consecutive minutes (Meng and Kang 2015; Westover 1989). In the laboratory, the positions of the older adults in each photograph were marked with dots on a planar graph, and a 3 m × 4 m grid was used to calculate the standard value of the total number of older adults in the photographed area during a 5 min period. These values were then divided by the measurement area to obtain the average crowd density value in persons/m^2 (Yu and Kang 2017; Zhang et al. 2016). Figure 2 shows the experimental design.

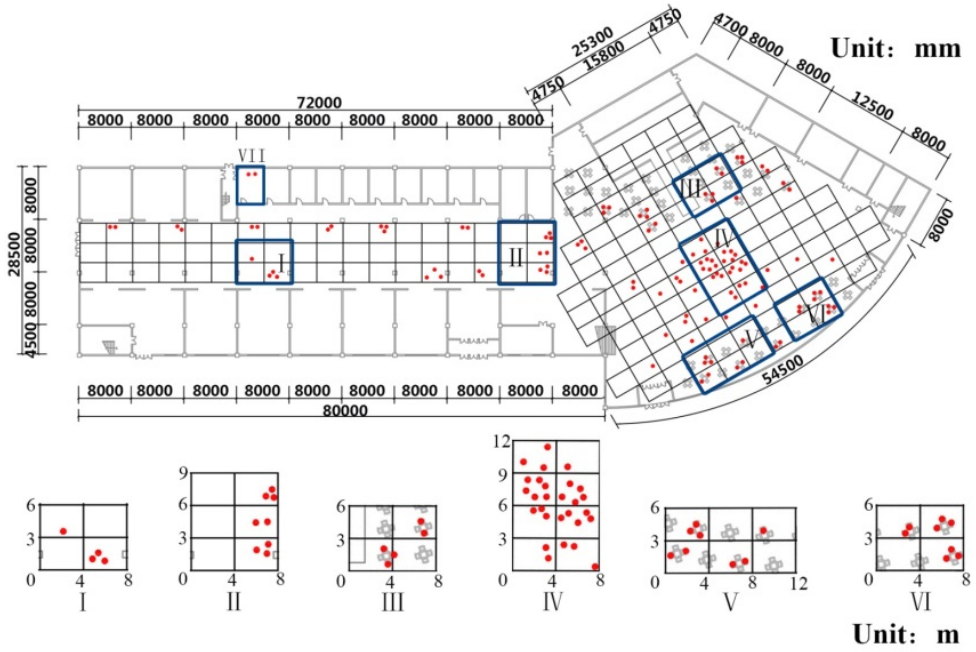


Figure 2. Photographic method used to measure crowd density

2.7 Sound level measurement

For each measurement point, sound level meters (Type 1) were set to slow mode, A-weighting, and an instantaneous reading was taken every 10 s (Tavossi 2003). To avoid changes in sound sources, each SPL was measured 10 times every hour at each measurement point, and the average value of 10 data points was obtained as the result for that measurement point. The measurement period was from 08:00 to 18:00. The equipment selection and measurement process followed the ISO3382 standard. The sound level meters were positioned 1 m from the wall and other major reflectors and at 1.2–1.5 m from the ground. A total of 5 min of data were obtained at each measurement location, and the average LAeq was calculated. To avoid measurement errors, measurements in each space were taken from at least five random points, 3 m apart. To prevent talking from influencing the measurements, speaking within 3 m of the sound level meter was prohibited.

3. Results and Discussion

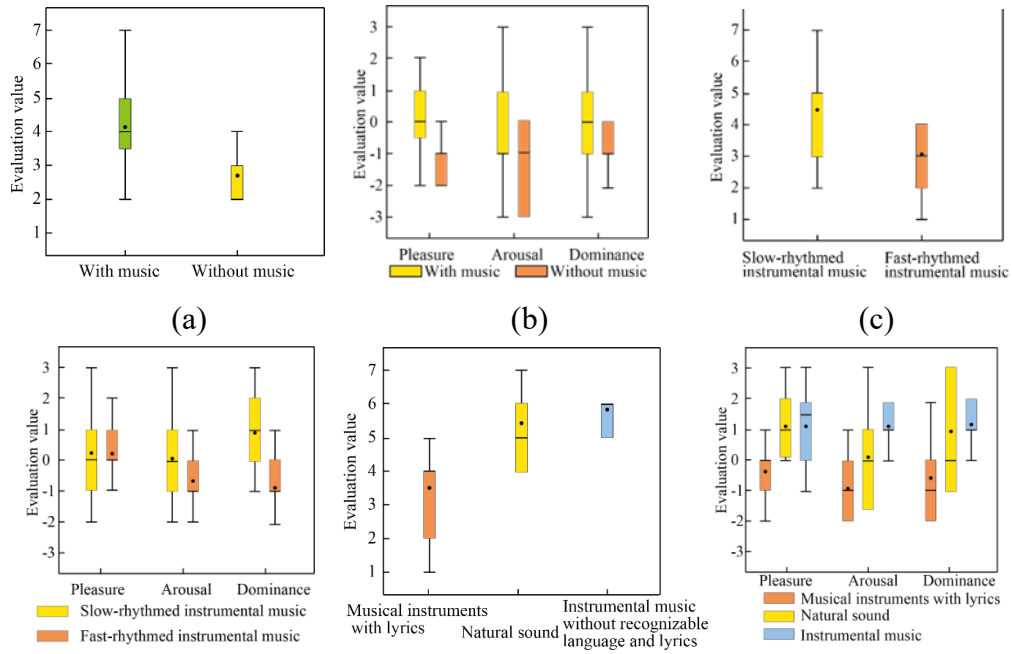
The purpose of this research was to explore the influence of specific environmental factors on the response of older adults in a specific space. The research mainly studied the impact of different

sound environments on the participants' psychology, the impact of demographic factors on the psychological aspects of older adults, the impact of the sound environment on the activities of older adults, and the impact of the sound environment on crowd density. In particular, the effects of different types of music on personal satisfaction, emotions, and behavioural responses were studied to accurately control the audio variables in a specific space.

3.1 Impact of different sound environments on participant psychology

There was a significant difference in the mean value of the emotional threshold of the older adults in the 'with music' setting ($p < 0.01$). In the 'with music' setting, the average values of pleasure, arousal, and domination for the emotional performance of the participants increased by 1, and their intervals expanded by 4-, 2-, and 3-fold, respectively (Fig. 2a–b). As reported by Schubert, dominance provides an additional dimension for distinguishing emotional responses to music, which are not covered by pleasure and arousal (Hays and Minichiello 2005). These results show that older adults think more positively with music, and that music helps them maintain positive emotions (Hays and Minichiello 2005). This is consistent with the results reported by Sweeney & Wyber (Schubert 2007), who showed that music can affect a customer's perception of service and product quality, as well as their excitement and pleasure ($p < 0.001$); the value setting range of 'with music' compared to 'no music' was much larger.

In the comparison of different music types, a significant difference was found in the mean value of the emotional threshold when the music type changed ($p < 0.01$). Under the influence of slow-rhythmed instrumental music, the average satisfaction increased by two, and the threshold range expanded by 2-fold. The dominance measure for slow-rhythmed music was significantly different from that of fast-rhythmed instrumental music. Slow-rhythmed instrumental music can help older adults meet their psychological needs and occupy a more dominant position. According to a previous study, the preference for slow-rhythmed instrumental music is related to personal characteristics and the external environment (Sweeney and Wyber 2002). These results show that when older adults are in a bad mood, they prefer slow-rhythmed instrumental music (Scherer 2004), which significantly improves their satisfaction, whereas the dominance measure has a significantly different value than that of fast-rhythmed instrumental music. Overall, the psychological needs of older adults showed a significant positive correlation with whether the music rhythm was slow ($p < 0.001$). This is consistent with the results reported by Lally(Altenmüller 2002), that is, slow-rhythmed music can improve people's satisfaction, as shown in Fig. 3(c)–(d).



(a) (b) (c)

(d) (e) (f)

Figure 3. Impact of different sound environments on the psychological aspects of a subset of older adults (a) The evaluation value for the emotional performance of the participants in the with music and without music settings; (b) The evaluation values of pleasure, arousal, and domination for the emotional performance of the participants in the with and without music settings; (c) Participant's evaluation value in the case of slow-rhythmed instrumental music and fast-rhythmed instrumental music; (d) In the slow-rhythmed and fast-rhythmed instrumental music setting, the evaluation values of pleasure, arousal, and domination for emotional performance of participants; (e) Participant's evaluation value in the case of musical instruments with lyrics, natural sounds, and instrumental music; (f) Evaluation values of pleasure, arousal, and domination for the emotional performance of the participants in the settings of musical instruments with lyrics, natural sounds, and instrumental music

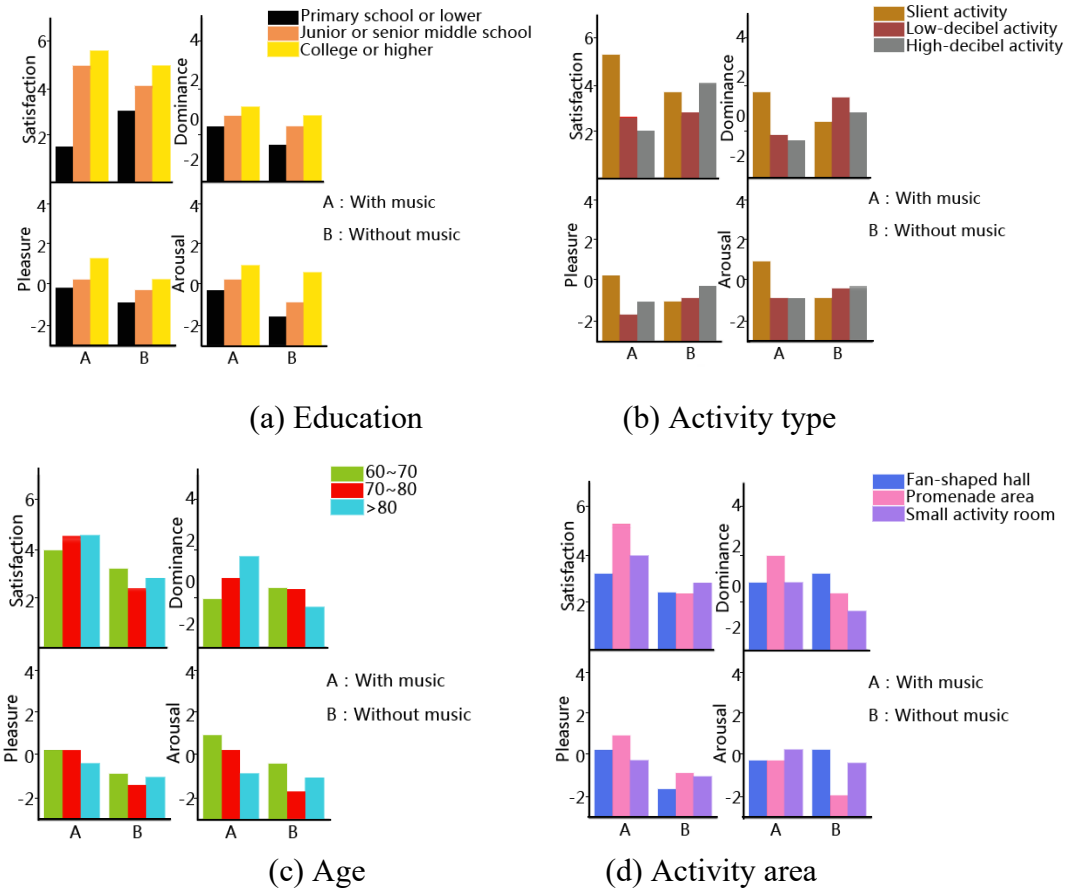
Comparing different types of music, when listening to musical instruments with lyrics, the satisfaction statistics decreased from 5 to 1, and there were significant differences in approach-avoidance behaviour as well as in pleasure, arousal, and dominance. The lowest evaluation values for music with lyrics were lower than those for the other types of music; compared with musical instruments with lyrics, the evaluation value for natural sound was higher, with a statistical mean value of 5. This is consistent with the results reported by Sataloff (Lally 2009), indicating that natural sounds and music can significantly improve people's satisfaction and arousal. Previous studies have also reported that different types of music make older adults display different personality characteristics (Sataloff 1992; Laukka 2007); Natural sounds help to reduce their stress, whereas musical instruments with lyrics can improve their logical thinking ability and instrumental music can improve their aesthetic ability (Hays and Minichiello 2005; Dhar and Chang 2009). Figure 3(e)–(f) show the statistical data.

3.2 Impact of demographic factors on the psychological aspects of older adults

3.2.1 Impact of 'with music'/'without music' surroundings on the psychological aspects of older adults

The survey results indicated that older adults' level of cultural literacy also has a profound impact on their sense of PAD. In the 'with music' environments, participants with higher cultural literacy were more likely to be affected by the music. As shown in Fig. 4a, older adults with a primary school education or lower were less sensitive to music compared to the more highly educated adults. The score of older adults with primary education increased by 1.89, with or without music. In the 'with music' environment, their values for arousal (0.21), pleasure (–0.15) and dominance (–0.31) were at the lowest. Older adults with a college degree or higher showed the highest values, both with and without music. Older adults with a medium education level had middle-level PAD values. The results showed that there was a significant correlation between the education level of older adults and whether they had musical appreciation ($p < 0.05$). For the arousal level, the perception of older adults, with the highest education background, on the existence of music was the same. As shown in Fig. 4b, satisfaction was significantly different between the different activity conditions; older adults conducting the quietest activities had the highest satisfaction with the sound environment. Kantono et al. (Zhang et al.2018) found that instrumental music can provide unique sensory enjoyment. Chebat et al. (Kantono et al. 2016) demonstrated that older adults with higher education levels focus more on the beauty of sound.

In terms of pleasure and arousal, our results show that people aged 60 to 80 years are more susceptible to music, and that arousal is positively correlated with age. However, dominance was more prominent in older adults aged 80 years and older under the influence of music, as shown in Fig. 4c. With melodious music, older adults are more likely to engage in activities with a good mood. The results in Fig. 4d indicate that the activities in the promenade area were associated with a higher level of satisfaction, dominance, pleasure, and arousal under the influence of music. Only the level of dominance and arousal in the fan-shaped hall was higher in the absence of music.



(a) Education (b) Activity type

(c) Age (d) Activity area

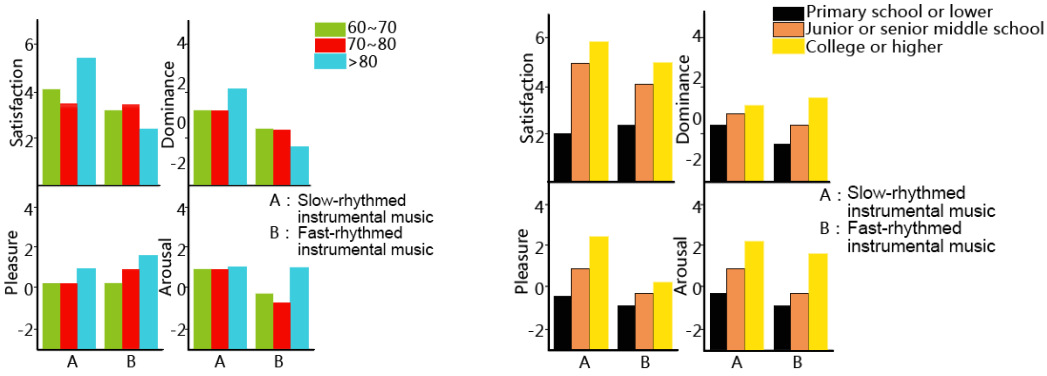
Figure 4. Impact of 'with music'/'without music' surroundings on the psychology of different subsets of older adults: (a) Education, (b) Activity type, (c) Age, and (d) Activity area

3.2.2 Impact of different music types on the psychological aspects of different subsets of older adults

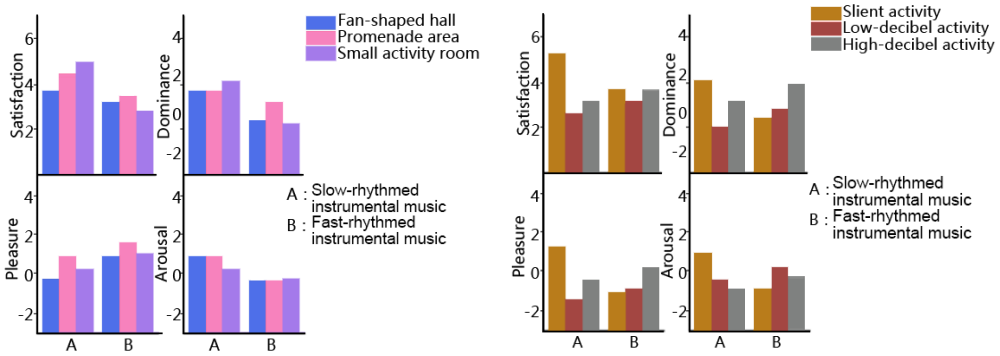
For different music types, slow- and fast-rhythmed instrumental music were regarded as two typical music types and were compared from the perspectives of age, education level, activity area, and activity type. Satisfaction and dominance were clearly higher in older adults aged > 80 years under the condition of slow-rhythmed instrumental music, which could be correlated with their personal preference for music. The level of arousal was clearly lower in older adults aged 60–80 years while listening to fast-rhythmed instrumental music, as shown in Fig. 5a. The comparison of music rhythms and education levels showed significant differences in the values of pleasure between the two music rhythms ($p < 0.05$), but there was no significant difference between the two in terms of dominance and arousal ($p > 0.05$), as shown in Fig. 5b. The satisfaction of older adults in each subgroup was improved under the influence of slow-rhythmed instrumental music. Although older adults over 80 years preferred rhythmic instruments, soothing slow-rhythmed music dominated overall. Older adults with a higher educational background preferred slow-rhythmed instrumental music. One possible reason is that older adults wanted to spend more time enjoying life in their later years (Chebat et al. 2001), and slow-rhythmed music made them feel more relaxed. A previous study found that slow-rhythmed instrumental music can improve nursing effects in older adults (Levitt 2009). In addition, a study with results similar to ours indicated that older adults with higher education levels prefer slow-rhythmed instrumental music because different aesthetics can be heard in the melody (Wang et al. 2017).

Comparing music rhythms in different activity areas revealed significant differences in pleasure and dominance ($p < 0.05$), but there was no significant difference in arousal, as shown in Fig. 5c. Figure 5d shows that older adults were more satisfied when performing silent activities. However, older adults who engaged in low- and high-decibel activities preferred fast-rhythmed instrumental music. A possible reason for this is that this type of music can stimulate and improve cortical activity

(Cohen et al. 2002; McDowell 2002). However, slow-rhythmed instrumental music still dominated overall because it was dull most of the time (McDowell 2002; Perham and Withey 2012). Different activities have various effects on different indicators (Staum and Brotons 2000), and slow-rhythmed instrumental music can significantly improve arousal. This is because it can cultivate the mental and emotional states of older adults (Schäfer et al. 2013).



(a) Age (b) Education level



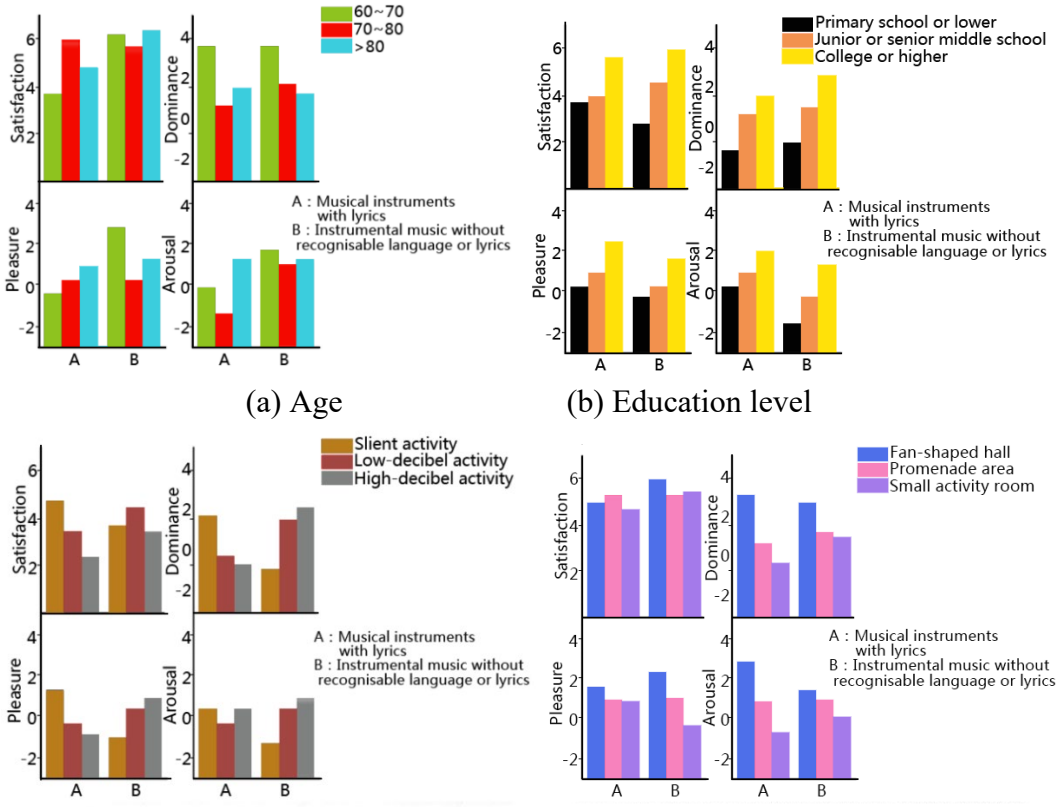
(c)Activity area (d) Activity type

Figure 5. The impact of different music types on the psychological aspects of different subsets of participants (a) Age, (b) Education, (c) Activity type, and (d) Activity area

3.2.3 Impact of different musical content on the psychological aspects of different subsets of older adults

Whether a song has lyrics directly determines the song type. Older adults have different preferences, and older adults of different ages have different feelings about music (Kumar and Jaiswal 2020). In terms of dominance and pleasure, there was no significant difference between age and preference for lyrics ($p > 0.05$). For arousal, the 60–80-year-old participants appeared to be more easily aroused, especially those aged 70–80 years, and a significant difference between the existence of lyrics ($p < 0.05$) was found, as shown in Fig. 6a. There was no significant difference between the lyrics and education levels ($p > 0.05$). Figure 6(a)–(b) show that older adults preferred natural sounds and instrumental music to unintelligible languages or lyrics; those aged between 60 and 70 years were most satisfied with instrumental music. Older adults with lower education levels had the highest satisfaction and pleasure from instrumental music, whereas those with a secondary education level had the best evaluation of natural sounds. These results are consistent with a previous study indicating that educational background is related to the satisfaction and dominance based on music content (Savage 2006).

The statistical results showed significant differences in PAD ($p < 0.05$). However, there was no significant difference between the existence of lyrics, activity types, and areas, and PAD ($p > 0.05$), as shown in Fig. 6(c)–(d).



(a) Age (b) Education level

(c)Activity type (d) Activity area

Figure 6. Impact of different music content on the psychological aspects of different subsets of older adults: (a) Age, (b) Education, (c) Activity type, and (d) Activity area

3.3 Impact of the sound environment on the activities of older adults

3.3.1 Activity patterns in different sound environments

Figure 7 shows the effects of different music environments on the three types of activities (high-decibel activity, low-decibel activity, and silent activity) in different activity areas (fan-shaped hall, promenade area (corridor), and small activity room). Figure 7 shows that with the increase in natural sounds, most older adults conducted low-decibel activities in all three activity areas, and the difference was statistically significant ($p < 0.001$). In the setting of a musical instrument with lyrics, the ratio of older adults conducting high-decibel activities in the fan-shaped hall and small activity room to older adults conducting low-decibel activities in the promenade area was increased significantly. Under the settings of music with language, lyrics, and slow-rhythmed music, no one conducted high-decibel activities in the promenade area.

In the natural sound environment, the proportion of high-decibel music activities increased by 15% in the activity space, decreased by 5% in the promenade area (corridor), and increased by 18 % in the activity room. In the experimental group with or without lyrics, the proportion was not notable, but there was a slight increase. These results suggest that music can increase the willingness of older adults to participate in sports activities. Consistent with previous studies, music can increase the willingness to perform sports activities (Magowan 2007). Compared with other music types, slow-rhythmed instrumental music was accompanied with increased activity because it can increase the release of endorphins (Barney and Prusak 2015). Under natural sound, activity decreased, possibly because of increased contemplating and planning, which has also been reported in previous studies (Tarr et al. 2014). By increasing the activities and music, the annoyance caused by noise can be reduced, and soft and slow-rhythmed music can ease the mood of older adults (Sztubecka and Skiba 2016). A previous study demonstrated that concerts with low arousal potential have a positive impact on human activities (Lesiuk 2010).

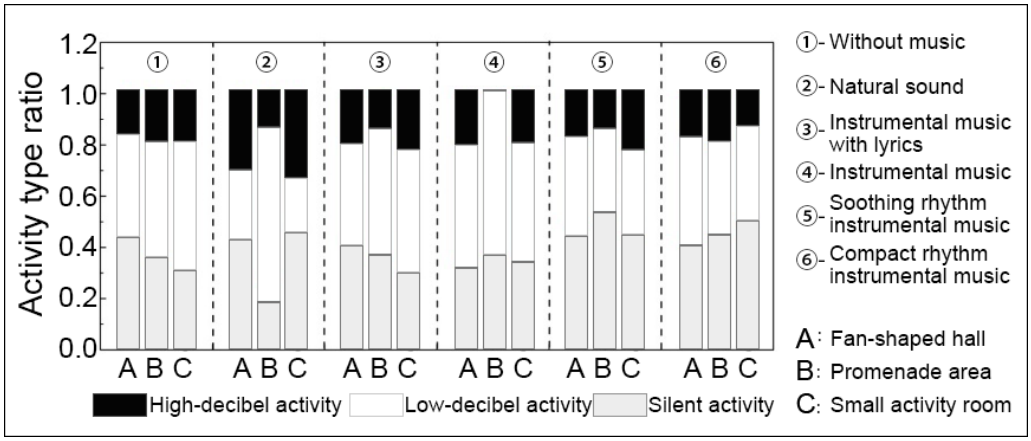
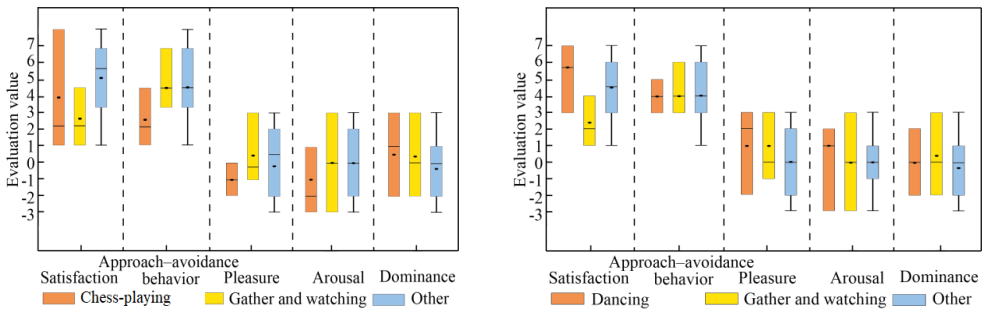


Figure 7. Proportion of various types of activities in the activity space under different acoustic environments

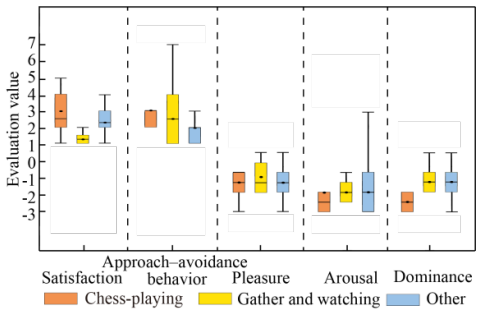
3.3.2 Impact of music on the evaluation of different activity groups

Figure 8 shows the evaluation of the following three different groups of older adults for a specific type of music: those conducting a specific activity (dancing, chess, and Tai Chi), onlookers (gathering and watching), and those conducting other activities. Figure 8 shows these five indicators: satisfaction, behaviour, pleasure, arousal, and dominance. Older adults who were dancing had high satisfaction with fast-rhythmed instrumental music (Fig. 8b), whereas chess players were satisfied with slow-rhythmed instrumental music (Fig. 8c). This is similar to a systematic review of active participation in music and dance, which showed that older adults prefer dancing to music, as it can result in improved well-being, health, and QoL. Further, chess players are more likely to prefer slow-rhythmed music as they can think more clearly in a quiet and soothing environment (Cassidy and MacDonald 2007). The average values of pleasure (i.e., –1 and 0) for older adults conducting Tai Chi and dance were the same. As shown in Fig. 8, chess, Tai Chi, and dance showed more individual activity than collective activity in terms of approach-avoidance behaviour and satisfaction ($p < 0.01$), which may indicate that older adults prefer participating in these activities rather than watching or doing something else when music is played. Overall, the average values for the satisfaction of older adults conducting individual and other activities were significantly higher than those of the onlookers, which is consistent with previous studies (Sheppard and Broughton 2020; Beidel et al. 1985), again confirming that they prefer to participate. Furthermore, the results show that older adults prefer natural sounds during simple activities such as playing chess, which may be easier to implement under natural sounds, which are perceived as vibrant or calm by most people (Axelsson 2012).

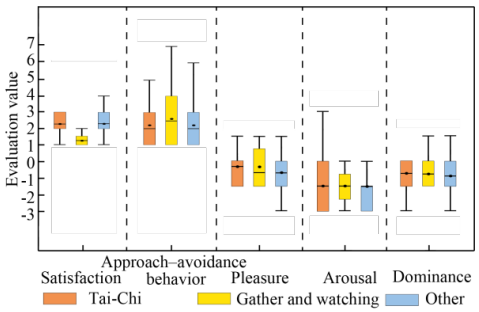


(a) Chess-playing activity under fast-rhythm instrumental music

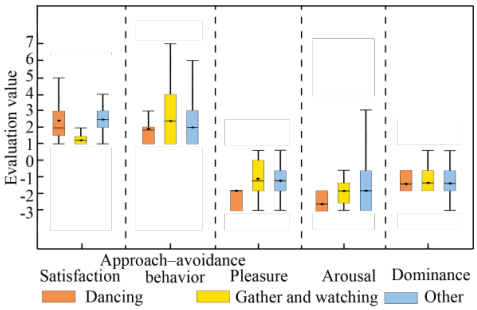
(b) Dancing activity under fast-rhythm instrumental music



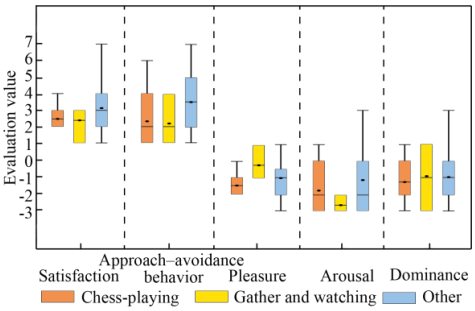
(c) Chess-playing activity under slow-rhythm instrumental music



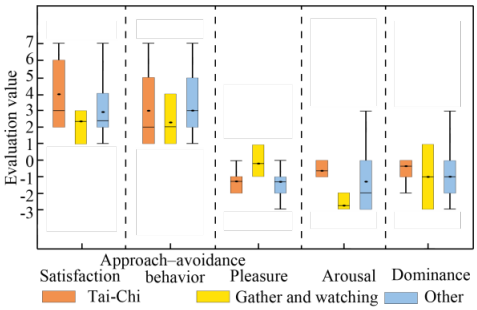
(d) Tai Chi under slow-rhythm instrumental music



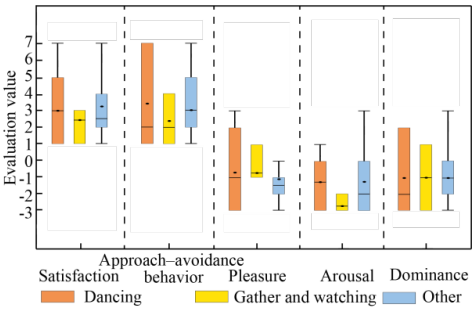
(e) Dancing activity under slow-rhythm instrumental music



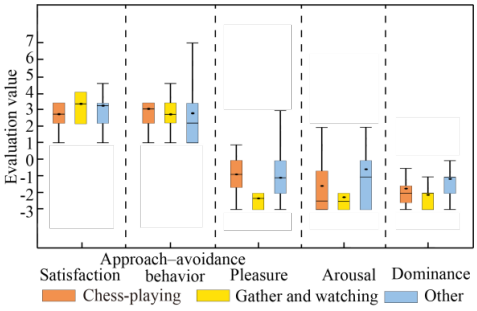
(f) Chess-playing activity under instrumental music



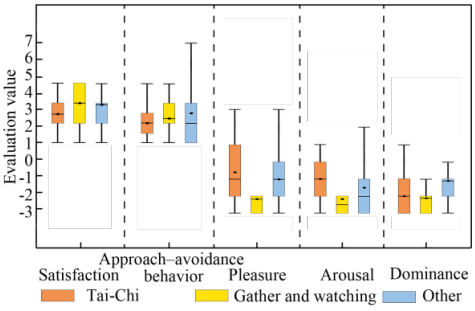
(g) Tai Chi exercise under instrumental music



(h) Dancing activity under instrumental music



(i) Chess-playing activity under natural sounds



(j) Tai Chi exercise under natural sounds

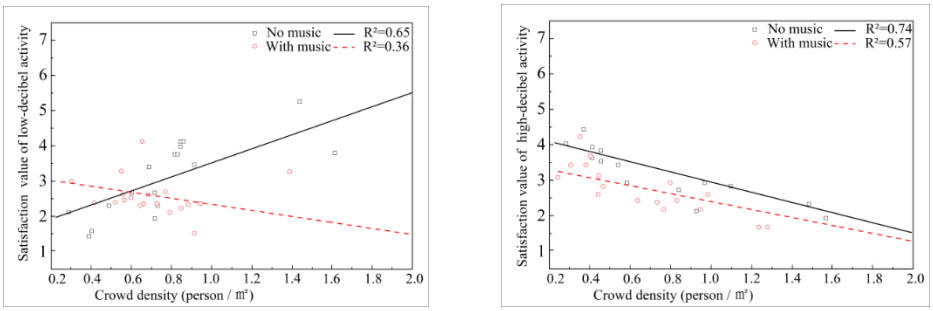
Figure 8. Impact of different sound environments on different activities performed by the participants

3.4 Impact of the sound environment on crowd density

The relationships between crowd density and sound environment perception, as well as satisfaction in different sound environments (with or without music), are represented by linear regressions and their coefficients of determination (R2), as shown in Figs. 9 and 10. With the increase in crowd density during low-decibel activities, the impact of music decreases. The relationship between the crowd density and satisfaction perception during low-decibel activities in the ‘with

music' sound environment was low (R2 = 0.36). However, when there was no music in the activity space, the R2 value was 0.65. The relationship between the crowd density and satisfaction perception of high-decibel activities in 'no music' sound environments was relatively high (R2 = 0.74), i.e., higher than that in the 'with music' environment (R2 = 0.68).

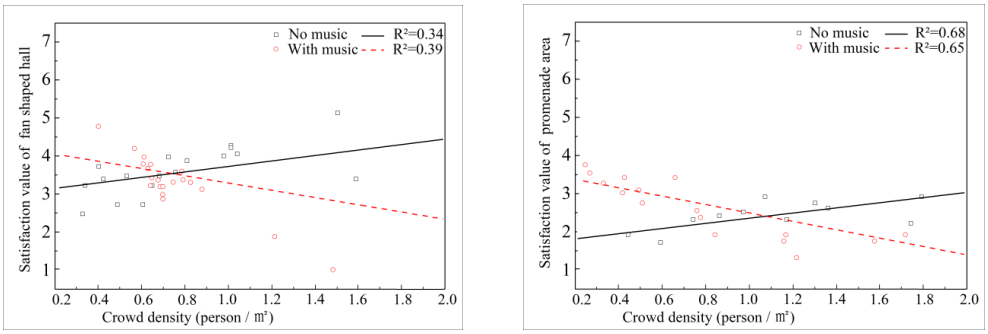
However, with an increase in crowd density, the overall trend declined, regardless of the presence of music, as shown in Fig. 9. If music is played while conducting low- or high-decibel activities, the correlation of satisfaction continues to increase with a decrease in crowd density. In the fan-shaped sunshine hall, satisfaction and boredom increased, whereas the correlation with pleasure decreased (see Fig. 10). A similar decrease in pleasure has been reported in previous studies (Ost et al. 1981). However, Lawton and Fujiwara (Layard 2002) found that satisfaction and arousal levels differ at different decibel levels; if the external environment is quiet, satisfaction is higher; whereas if the external environment is louder, satisfaction is lower. Within a reasonable range, this may occur because of the individual differences in research samples.



(a) Relationship between crowd density and sound environment satisfaction with low-decibel activity

(b)Relationship between crowd density and sound environment satisfaction with high-decibel activity.

Figure 9. Impact of music on different type of activities



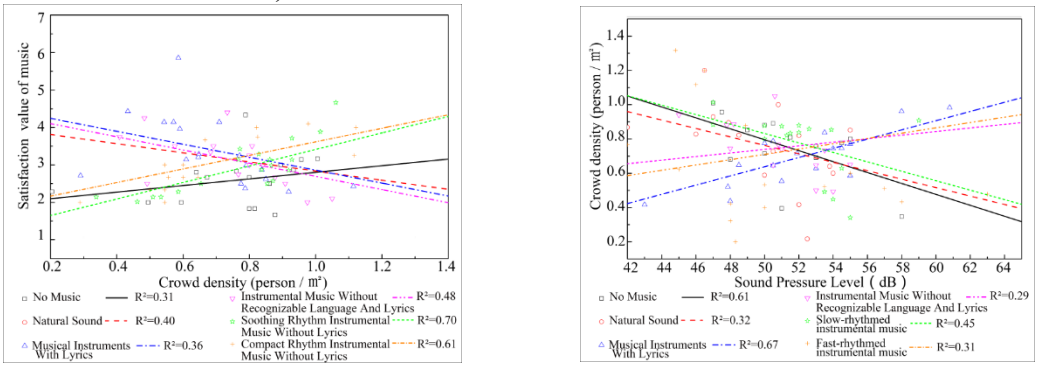
(a) Relationship between crowd density and sound environment satisfaction in the fan-shaped hall.

(b) Relationship between crowd density and sound environment satisfaction in the promenade area.

Figure 10. Impact of music in different areas on crowd density

Figure 11 shows that in the case of 'no music,' the R2 value of 0.31 indicates a low correlation between crowd density and satisfaction. Natural sound, music with lyrics, and instrumental music settings also showed low correlations, with R2 values of 0.40, 0.36, and 0.48, respectively. However, the R2 of slow-rhythmed music and instrumental music was 0.70 and that of fast-rhythmed instrumental music was 0.61. These results suggest that older adults prefer slow-rhythmed instrumental music in a large space. The SPL also showed a trend of first increasing and then decreasing (as shown in Figs. 11a and b). With an increasing crowd density, a correlation was found between instrumental music and lyrics and the crowd density. These results suggest that the SPL is positively correlated with crowd density, which is consistent with previous studies (Lawton and

Fujiwara 2016; Keith et al. 2016; Mennitt and Fristrup 2016). Further, under fast-rhythmed instrumental music, the satisfaction of these two behaviours decreased more rapidly. A previous study reported that in places with a high crowd density, slow-rhythmed instrumental music can improve the mental state of older adults and relieve their physical pain and mental pressure (Van Dyck et al. 2012; Li et al. 2019).



(a). Relationship between sound evaluation and crowd density

(b) Relationship between crowd density and SPL

Figure 11. Relationship between various music situations and sound evaluation in large activity spaces

4. Conclusions

The purpose of this study was to explore the impact of specific environmental factors on the responses of older adults in a specific space. In particular, the impact of different types of music on personal satisfaction and emotional and behavioural responses were studied to accurately control the audio variables in a specific space. The main research results are as follows.

(1) The results of comparing the behavioural effects of different sound environments on older adults show that they do not have strong preferences for environments with or without music. In terms of music rhythm, older adults preferred slow-rhythmed instrumental music; in terms of music type, they preferred natural sounds.

(2) There was a significant positive correlation between the education level of older adults and slow-rhythmed music ($p < 0.001$), indicating that highly educated older adults were most satisfied with slow-rhythmed instrumental music.

(3) The influence of sound environments on the psychological aspects of older adults was mainly reflected in the manner in which music enhances individual behaviours, demonstrating that older adults generally evaluate the acoustic environment to be better; that is, they experience more satisfaction as compared to onlookers. Under the setting of natural sounds, significantly more low-decibel activities were conducted in all three activity areas ($p < 0.001$). For fast-rhythmed instrumental music, the ratio of older adults conducting high-decibel activities was increased significantly. These results show that older adults are more willing to participate in activities with the appropriate music environments.

(4) Observations of activity spaces showed that music increases crowd density, especially in an environment with natural sounds, as older adults prefer a natural sound environment without interference from lyrics. With the increased playing time of natural sounds, the proportion of activity types was also increased. However, while conducting low- or high-decibel activities, satisfaction continued to decrease when the crowd density increased.

In this study, the comprehensive effects of multiple music types and indoor environmental quality on the psychological and physiological aspects, as well as acoustic comfort, of older adults in

large activity spaces were analysed. The results indicate that the influence of different music types on the activities and gathering of older adults in residential aged care facilities and the community should be considered. In addition, even in the conceptual design stage, it is recommended that architects and acousticians work closely when designing residential spaces for older adults that require noise reduction. In this manner, the living environment of older adults will be humane and, most importantly, the indoor acoustic environment of residential aged care facilities can be designed in a manner more suitable to improve the wellbeing of older adults.

There are a few limitations to this study that should be addressed. First, the choice of music type and piece could have impacted the evaluation as older adults have different preferences for music. Second, the results were not analysed with respect to gender, which could have shown significant results as studies have reported differences between men and women in terms of emotions and preference for music.

Future studies should incorporate validated physiological index tests, more detailed music types, and then analyse the difference in genders to increase the scientific evidence on how to improve the living environment and well-being of older adults.

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