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Interaction Effects between Mood State and Background Sound Level on Students' Sound Perceptions and Concentration Levels in Study Spaces

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Abstract: This study investigated the impacts of students' mood states and background sound levels on students' sound perceptions and academic performance in four library rooms. The background sound level was measured for five days. Meanwhile, around 300 students were invited to participate in a survey of questions about their acoustic perceptions and mood states and a concentration test. Pearson correlation, one-way ANOVA, and two-way ANOVA were applied to establish the relationships between the LAeq, students' mood states, acoustic perceptions, and concentration levels on both the individual level and the room level and to identify the interaction effect between the background sound levels and mood states on students' acoustic perception and concentration. The results indicated that LAeq in learning spaces significantly impacted students' acoustic satisfaction, but only at the room level. In contrast, mood states mainly influenced students' sound perception and concentration at the individual level. Furthermore, this study reports significant interaction effects between mood state and LAeq on students' sound perceptions and reveals different impacts of mood states due to different sound levels. These results could help improve occupants' acoustic perceptions and performance in learning spaces in the future.

Keywords: acoustic quality; sound pressure level; mood states; concentration; study space

Citation: Zhang, D.; Mui, K.-W.; Wong, L.-T. Interaction Effects between Mood State and Background Sound Level on Students' Sound Perceptions and Concentration Levels in Study Spaces. *Buildings* **2024**, *14*, 1419. https://doi.org/10.3390/buildings14051419

Academic Editors: Francesco Asdrubali, Giovanni Semprini, Simone Secchi, Aminhossein Jahanbin and Ángel Fermín Ramos Ridao

Received: 8 December 2023
Revised: 22 January 2024
Accepted: 13 May 2024
Published: 15 May 2024

1. Introduction

Background sounds usually refer to ambient sounds that are not the primary focus of occupants' attention but are still perceptible in an environment. Most background sounds are undesirable and could significantly impact people's comfort, health, and performance [1,2]. As one of the everyday environmental stressors in modern society, background sounds have three primary sources: ventilation systems, occupants' activities, and noise from outside [1,3,4]. No matter where they come from, all these sounds could cause negative effects on subjects' performance [5,6].

1.1. Background Sounds in Study Places

Background sounds play an even more crucial role in study places for the following reasons. First, the background sounds in study places were usually higher than the designed baselines [7,8]. For example, Shield and Dockrell [8] revealed that the background noise levels in 142 schools in London, UK, all exceed 35 dB(A), which is the maximum A-weighted equivalent sound pressure level (LAeq) recommended by WHO and Building Bulletin 93. Similar results were also found in schools in Canada [9], Brazil [10], and Egypt [7]. Second, the background sounds in study spaces caused considerable annoyance among students. According to a survey conducted among 1145 students in the Netherlands, 87% reported being bothered by classroom background sounds [11]. Similar disturbances were also reported by university students in non-classroom spaces (such as study places in libraries), especially when they were performing complex tasks [12,13]. Being annoyed could affect how well one can concentrate, influencing learning performance.

Additionally, background sounds could significantly impact occupants' acoustic satisfaction and performance [7,10]. Their effect on occupants' comfort is relatively straightforward; the lower the sound level, the more satisfied occupants feel [14]. Moreover, background sounds could also detriment occupants' cognition and comprehension abilities [15,16]. Previous studies have conducted many tests to determine the impact of acoustic quality in study places on students' learning performance [17–20]. Among them, semantic tasks and verbal tasks were the most commonly used ones. It is easy to understand that background sounds could degrade teachers' speech clarity and negatively affect students' reception and recognition of proper sound signals [21]. Furthermore, several studies reported that mathematical calculation and reading performance were significantly affected by background sounds as well [22–24]. The reason for these impacts on mathematics or reading performance was not as direct as those on sound-related tasks. Jafari et al. [25] first monitored brain activity patterns in their research using electroencephalography (EEG) to explore the effects of sound exposure. They found that sounds could affect the power of Alpha and Beta bands which are the brain signals correlated with people's attention. Therefore, the impact on people's attention might be the reason for the impact of background sounds on students' academic performance. Yet, the effect of background sounds on students' attentiveness or concentration was rarely tested before. Although the influence on concentration is relatively subtle compared with other academic performances, it deserves more attention since it is more fundamental in performance.

1.2. Studies on Occupants' Mood States

Apart from the influence on occupants' performance, background sounds also considerably influence occupants' mood states. A field survey conducted among 300 students in Egypt revealed that more than half of the students thought classroom background sounds disturbed their peace of mind, and 37% contended that those sounds made them angry/upset [7]. Recently, more studies have been inclined to focus on the dichotomous outcomes (i.e., positive or negative impacts) of sounds on individuals [26,27]. For example, Jiang et al. [28] conducted experiments in a controlled environment by playing audio clips that included four background sounds (i.e., none, traffic, nature, and mechanical sounds). By comparing the participants' mood changes before and after hearing different sound types, Jiang et al. identified the significant positive effect of natural sounds on people's mood changes, and this effect was more apparent when compared with traffic sounds. A similar study was conducted by Zhang and Kang [29] recently but with different sound clips (i.e., street music, traffic, and fountain sounds). This study demonstrated the variation in occupants' mood states, predominantly negative, under conditions with different background sounds. Although the impacts of background sounds on peoples' mood states were found and investigated by several studies in the past decade, most of them focus on natural sounds [30,31] and traffic sounds [32], while the learning environment and common background sound in classrooms (e.g., students' talking, typing, clicking the pen, etc.) was rarely considered in these studies. Moreover, most previous studies focused on the background sound types, and very little is currently known about the relation between the background sound levels and occupants' mood states.

Furthermore, mood states, in turn, were found to have significant impacts on occupants' acoustic satisfaction [33] and performance [34]. According to Västfjäll [33], students in negative moods were more dissatisfied with the sound than those in neutral. This impact is direct and consistent with the mood-congruent theory that people in a negative mood tend to perceive things negatively [35]. However, by contrast, the impact of mood on performance is more complex since working/studying is an integrated and dynamic process, among which memory, understanding, and causal reasoning were found to be closely related to mood states [36]. It is worth noting that both positive and negative effects of positive moods were identified on students' cognition and learning [37,38].

Additionally, some studies indicated that mood states do not affect academic performance [39,40]. Based on a comprehensive review of the impact of moods on performance, Mehta [34] found that both high-intensity positive and negative moods might impair students' performance, and the best performance occurs when students have low-intensity positive moods. Additionally, this study concluded that the impacts of moods on learning performance depend on the task types and suggested more specific studies for future research [34].

1.3. Research Hypothesis and Research Questions

Given the literature mentioned above, a conceptual model was proposed. As shown in Figure 1, this model illustrates the relationships between the acoustic environment, mood states, acoustic satisfaction, and performance. It is worth noting that the acoustic environment was evaluated by background sound level in this study since it is the most commonly studied acoustic indicator in educational buildings [41], and it is closely correlated with the occupants' auditory sensation feelings in an air-conditioned environment [42]. Previous studies demonstrated the relationships between every two of these parameters shown in Figure 1. However, the interaction effects of the sound level and mood states on acoustic comfort and performance, especially concentration performance, were rarely studied.

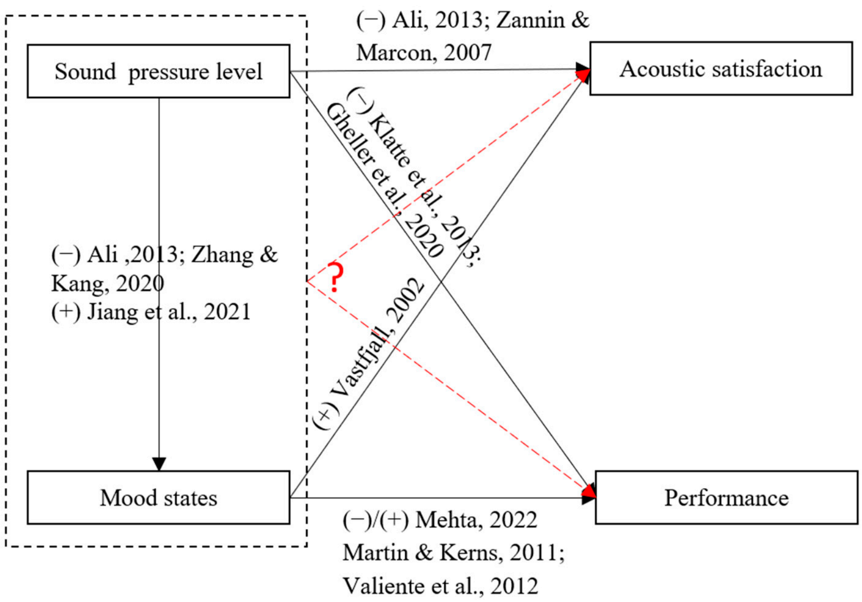


Figure 1. The conceptual model. Note: (−) and (+) represent negative and positive impacts, respectively [7,10,15,16,28,29,33,34,37,38].

Additionally, in terms of performance, most previous studies focused on classroom teaching processes. At the same time, other learning activities and environments, such as self-study and group discussion in libraries, were seldom researched. Moreover, besides listening, reading, and comprehension tests, students' concentration performance was not well-studied. Therefore, to address these research gaps, the current study was conducted. The primary goal of this study is to examine the influence of acoustic quality and mood states on students' acoustic satisfaction and concentration performance. Correspondingly, the research questions are:

(1) What are the current situations regarding the acoustic quality, students' mood states, and concentration levels in the investigated study rooms?
(2) What are the impacts of the background sound level and mood states, separately, on students' acoustic satisfaction and concentration performance?
(3) What are the interaction effects between the background sound level and mood states on students' acoustic comfort and concentration performance?

2. Methods

Figure 2 illustrates the research methods of this study. Four parameters, namely background sound level, students' mood states, acoustic satisfaction, and performance, were collected using on-site measurements and questionnaire surveys in four different learning spaces. Then, these parameters were analyzed in four steps to answer the research questions mentioned above. Detailed information is explained in the following subsections.

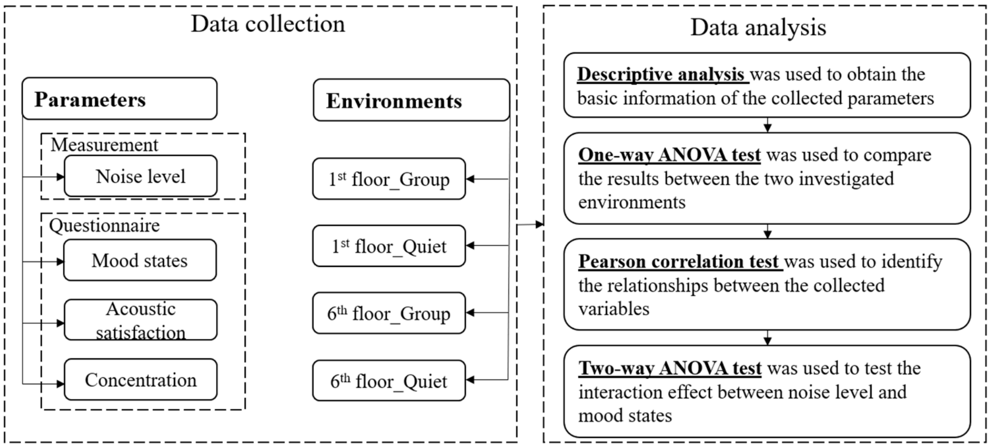


Figure 2. Research methods of the current study.

2.1. Data Collection

The investigation was conducted in a university library in Hong Kong during the weekdays from the 19 to the 25 October 2022. Both on-site measurements and questionnaire surveys were conducted simultaneously in the selected study spaces. Four study rooms on the first and sixth floors, including two group-study rooms and two self-study rooms, were appointed (hereinafter referred to as 1G, 1S, 6G, and 6S, respectively). The layouts of these study rooms are shown in Figure 3. The external façades were glass in the study rooms on the sixth floor, while they were concrete walls without any windows in the group study room on the first floor (hence no natural light), and they were concrete walls with windows in the self-study room on the first floor. The floors were carpeted in almost all the selected rooms except for part of the group study room on the sixth floor, where linoleum was used. The furniture was flexible in the group study rooms while fixed in the self-study rooms, yet the materials were the same in all the investigated rooms. Another thing worth noting is that sound absorption partitions were applied in the self-study rooms on the first floor to separate the study spaces.

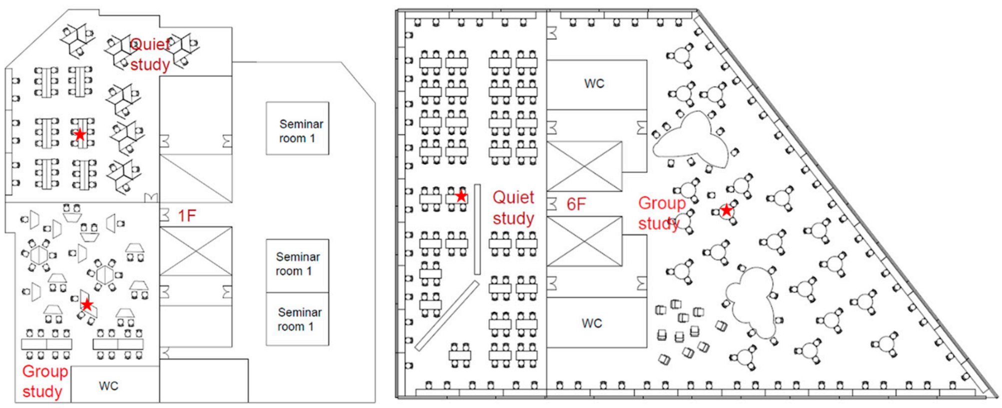


Figure 3. Layouts of the selected study rooms (the stars represent the measurement locations).

2.1.1. On-Site Measurement

Four study spaces in a university library in Hong Kong were selected for the current study. The background sound level was measured every minute using the integrated indoor environmental quality sensor from 9:00 to 18:00 every investigation day. This study was conducted in the study rooms of a library, where no sound was the primary focus of the occupants, which was unlike the classrooms. Therefore, all the sounds in the investigated rooms were considered background sounds. According to the sampling process suggested by CIBSE [43], the device "should be placed as close as possible to the most likely listening position", therefore it was placed on top of a desk, approximately 1 m in height, at the center of each investigated study room (see the stars in Figure 3). Since the investigated rooms have symmetrical layouts and similar sound sources and acoustic properties throughout the space, the background sound levels were considered relatively consistent across these rooms. Thus, measuring the sound level at one representative point could provide a reasonable estimate of the overall sound environment while imposing less influence on the library operation.

Before the measurement, the devices were calibrated by comparing the results with a reference value. The differences were within 3 dB(A), the device's measurement accuracy. Besides the measurement, the researchers completed a short checklist in the investigated rooms every day to record the main indoor and outdoor sound sources and the time when each questionnaire was completed.

2.1.2. Questionnaire

A questionnaire has been designed to evaluate students' sound perceptions and satisfaction and test students' concentration levels. The questionnaire comprised five parts, including personal information, the evaluation of acoustic quality, and a concentration assessment, which were analyzed in the present paper. The personal information part includes questions on participants' gender, age, mood, etc. The mood-related information was collected through three questions:

- How are you feeling now? (Good/Neutral/Bad)
- Have you recently experienced a positive event? (Yes/No)
- Have you recently experienced a negative event? (Yes/No)

The answers to the feeling question, Good/Neutral/Bad, were coded as $1/0/-1$ for subsequent analysis. Although there might be a slight difference between feelings and moods, the self-assessment of the question "How do you feel?" was usually used to understand the current mood [44,45]. In terms of the acoustic quality evaluation, it also includes three questions:

- How do you perceive the indoor sounds (such as the sounds of ventilation, people talking, typing. . .) in this study room?
- How do you perceive the outdoor sounds (such as the sounds from the hallway or the campus) in this study room?
- How satisfied are you with this acoustic (aural) environment?

They were all answered using the 7-point Likert scale (from "extremely noisy/totally dissatisfied" to "extremely silent/totally satisfied", coded as "-3" to "3"). The concentration assessment includes three similar dots tests (train driver concentration tests or Group Bourdon tests), often used to measure subjects' ability to maintain concentration [46]. Each test consists of an 11×6 matrix of square lattices with different numbers of dots (See Figure 4). In the first, second, and third tests, students were asked to circle all three, four, and five dots. The time limitation for each test is 15 s, which the researchers in the same room monitored. The final score of each test is the number of correct circles minus the number of wrong circles, and a higher score indicates a higher concentration level. Since the researcher in room 1G failed to count the time correctly, the concentration scores in room 1G were not considered in the current study.

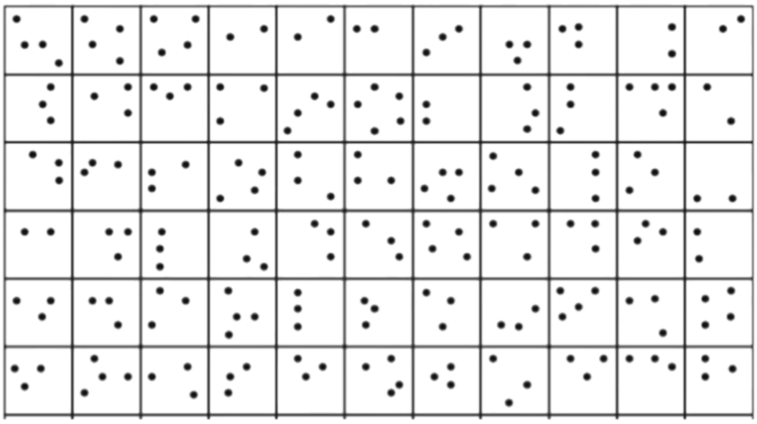


Figure 4. An example of the concentration test.

The paper-based questionnaires were randomly distributed among the students in the investigated study rooms. After distributing the questionnaire, at least one researcher stayed in the study room in case participants had any questions. Students were asked to give informed consent before the start of the survey, and they could withdraw anytime. The time used to complete the questionnaire has been monitored and recorded by the researchers.

2.2. Data Analysis

All the data were imported and analyzed in IBM SPSS Statistics 26.0 (SPSS Inc., Chicago, IL, USA). Before the analyses, the outliers of measurement data were screened out based on Z-scores. Specifically, the z-scores of the measured sound levels were calculated, and the cases where the absolute values of the z-scores were larger than three were considered outliers and excluded. After that, the 15 min A-weighted equivalent sound pressure level ($LAeq_{,15min}$) was calculated based on the cleaned results using Equation (1) [47].

$$LAeq = 10 \log_{10}\left(\frac{1}{T}\sum_{i=1}^{n} t_i \times 10^{\frac{L_i}{10}}\right) \quad (1)$$

where T is the investigated time period, L_i is the measured sound level in dB(A), and t_i is the measurement interval. Furthermore, the 90th percentile (LA90), 10th percentile (LA10), and 50th percentile (LA50) of the background sound levels were calculated to establish the background noise, the significant intermittent noise, and the median noise in the investigated rooms. Additionally, the questionnaires were manually checked, and the cases with 80% or fewer completion percentages were eliminated.

Then, these data were analyzed in the following four steps: First, the mean and standard deviation (SD) of interval or ratio data (e.g., $LAeq_{,15min}$, LA90, LA50, LA10, and concentration test scores) and the frequency of ordinal data (e.g., mood states and acoustic satisfaction) were calculated using descriptive analyses. Second, all the collected data were compared between different study spaces using one-way ANOVA or Chi-square tests. Third, the relationships between these parameters were checked using Pearson correlations on individual and room levels. It is worth mentioning that the specific $LAeq_{,15min}$ was identified and matched with the questionnaire based on the time recorded by the devices and researchers. Since the approximate time to complete the questionnaire was short (less than 15 min), the $LAeq_{,15min}$ was a good indicator of the acoustic quality during the questionnaire process. The time when the students finished the questionnaires was used to match the sound levels. Last, the interaction effect of $LAeq_{,15min}$ and students' mood states on their acoustic satisfaction and concentration performance were analyzed using two-way ANOVA tests. The $LAeq_{,15min}$ in the current study was classified into four groups based on its quartiles to conduct this analysis.

3. Results

3.1. Descriptive Analysis Results

3.1.1. General Information of the Participants

In total, 259 students, including 140 females, 117 males, and two who did not answer, completed the questionnaire. These students were evenly distributed in the four investigated rooms (1G: 57; 1S: 64; 6G: 69; 6S: 69), and the average ages of the students in different investigated rooms were all around 22 years old (1S: 22.4 (3.7); 6G:22.1 (3.2); 6S: 22.6 (4.0)), except for room 1G, where students were relatively younger (20.1 (3.1)). Figure 5 illustrates the mood-related information of the students in different rooms. The statistical analysis results indicated that the students' current feelings varied significantly among the investigated rooms (p = 0.039, Fisher's exact test), and their recent experiences regarding positive events were also significantly different (χ^2 (3, 259) = 14.42, p = 0.002). As is shown in Figure 5, in general, students in room 6G felt pretty good, while students in room 1G felt relatively less good. Additionally, more than 70% of students in rooms 1G, 6G, and 6S experienced positive events recently, while this percentage was around 20% less in room 1S. Regarding the negative event experience, no significant difference was identified among the students in different rooms, and about 60% of students in all these rooms had such experiences.

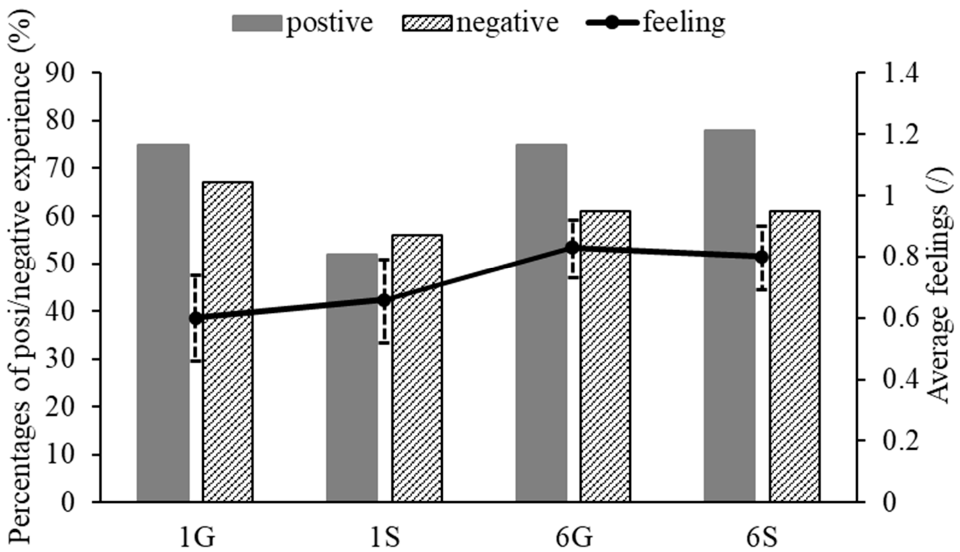


Figure 5. Mood-related information of the students in the investigated rooms. Note: for the feeling results, the vertical error bars are the 95% confidence intervals for the mean values.

In addition, Fisher's exact tests indicated that students' current feelings were significantly related to the negative experiences that they recently experienced, though the relationships were weak (Cramer's V values < 0.2). As shown in Table 1, all the students who felt bad had experienced adverse events recently. Similarly, most (73%) of the students who felt good had experienced positive events. These relationships demonstrated the logical consistency and credibility of students' answers.

Table 1. Relationships between students' recent experiences and mood states.

Experience	Bad (n = 4)		Neutral (n = 63)		Good (n = 192)		χ^2 (p) Value	Cramer's V Value
	Yes	No	Yes	No	Yes	No		
Positive	2 (50%)	2 (50%)	40 (64%)	23 (37%)	140 (73%)	52 (27%)	3.1 (0.192)	0.104
Negative	4 (100%)	0 (0%)	45 (71%)	18 (29%)	109 (57%)	83 (43%)	6.5 (**0.032**)	0.163

Note: results were obtained from Fisher's exact tests since more than 20% of the expected counts in the table were <5; p-values less than 0.05 were marked in bold.

3.1.2. Acoustic Quality in the Study Rooms

According to the checklist results, the main indoor sound source was students talking in the group study rooms. In contrast, the main indoor sound in the self-study rooms was construction noises since some new shelves were installed in room 1S and 6S during the investigation periods. The library is located inside the campus and does not have openable windows, therefore, no apparent outdoor sound sources were identified in most study rooms except for room 1G, where the sounds of campus activities were noticed. Different sound sources led to different acoustic performances in these rooms. Figure 6 shows relatively wide ranges of $LAeq_{,15min}$ in rooms 1G and 6G since students' talking was the main sound source, and their voices were inconsistent. Moreover, the area and maximum occupancy in 6G was larger than 1G, leading to a more significant fluctuation of $LAeq_{,15min}$ in 6G. In contrast, the sound levels in rooms 1S and 6S were relatively constant and high since the renovation was continuously conducted in these rooms.

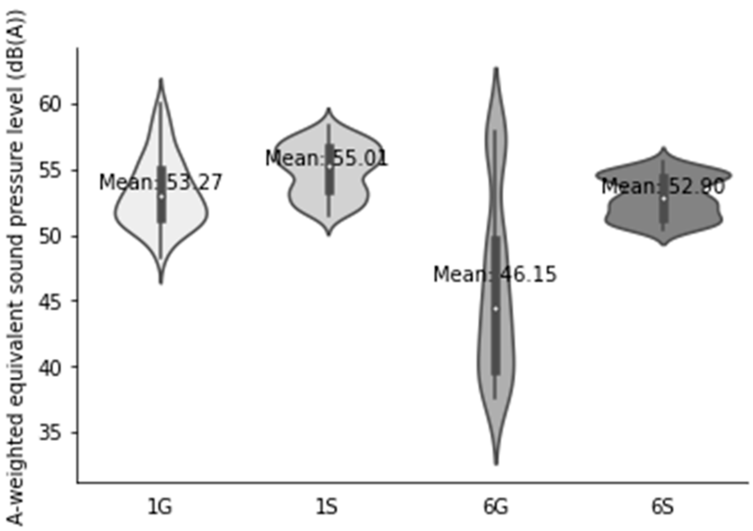


Figure 6. A-weighted equivalent sound pressure levels in the investigated study rooms.

The results of $LAeq_{,15min}$ in the four investigated study rooms are shown in Figure 6. As is established, the mean $LAeq_{,15min}$ in room 6G was the lowest (35.4 dB(A)), followed by room 1G and room 6S (42.5 dB(A)), while it was the highest in room 1S (44.6 dB(A)). According to the one-way ANOVA test result, the difference in $LAeq_{,15min}$ between these study rooms was statistically significant ($F(3, 656) = 158.4$, $p < 0.001$). The post hoc Tukey tests indicated that the differences between the average $LAeq_{,15min}$ in every two rooms, were also significant, except for the difference between the $LAeq_{,15min}$ in 1G and 6S. Furthermore, the ranges of the $LAeq_{,15min}$ in group study rooms, especially in 6G, were more extensive than in self-study rooms.

The LA90, LA50, and LA10 shown in Table 2 indicated that the background sound levels were relatively steady. These parameters have similar trends in these rooms. Specifically, the background sound level was always the lowest in 6G and highest in 1S. Furthermore, the results were always similar in 1G and 6S. However, comparing the results in 1G with 6S is interesting, which shows the LA90 was higher in 6S, although all the other parameters were higher in 1G. The results indicated that the average background noise level was higher in 6S, while considerably high and intermittent noises (as represented by LA10) appeared in 1G during the measurement periods.

The students' opinions of acoustic satisfaction were relatively unified regarding the subjective evaluation results. They were all slightly satisfied with the acoustic quality in these study spaces (see Figure 7). However, their perceptions of the outdoor and indoor sounds differed significantly between the investigated study spaces ($p < 0.05$; see Figure 7). For the outdoor sound perception, students felt quiet in most study rooms, especially in the self-study room on the sixth floor, while students thought the outdoor sounds were noisy only in the self-study room on the first floor. For the indoor sound perceptions, the opposite results were observed. Namely, students felt the indoor sounds were noisy in most study rooms except for the self-study room on the first floor.

Table 2. Background sound levels (dB(A)) in the investigated rooms.

	1G	1S	6G	6S
LA90	51.3 (2.73)	54.5 (1.99)	44.8 (7.14)	52.1 (1.84)
LA50	53.0 (2.64)	55.0 (1.92)	46.2 (6.72)	52.8 (1.66)
LA10	54.7 (2.87)	55.4 (1.82)	47.4 (6.38)	53.3 (1.56)
$LAeq_{,15min}$	53.3 (3.09)	55.0 (1.93)	46.2 (6.90)	52.9 (1.66)

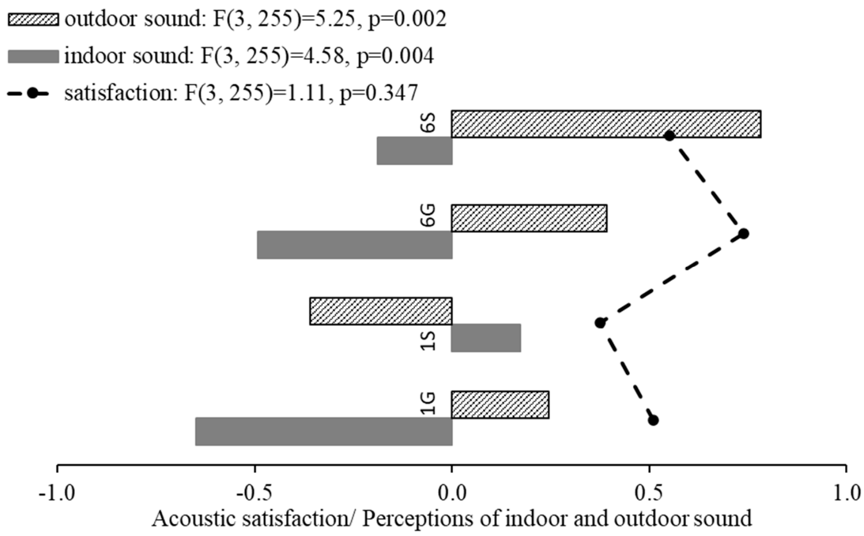


Figure 7. Students' acoustic satisfaction and perceptions of indoor and outdoor sound.

A power analysis was also conducted for sample size estimation based on students' acoustic satisfaction collected from the four study spaces. The results indicated that the effect size was 0.42, which is considered medium using Cohen's criteria [48]; the power was 0.91, meaning there was a 91% chance of finding a statistically significant difference when there is one. On the other hand, with a significance criterion of $\alpha = 0.05$ and power = 0.8, the minimum sample size needed with this effect size is $N = 200$, with 50 in each study space. Thus, the obtained sample size of the current study ($N = 259$) is more than adequate to test the study hypothesis.

Similar results can also be found in students' vote percentages. As shown in Table 3, more than half of the students were unsatisfied with the acoustic quality in the investigated rooms, and the percentage did not change much among different rooms. Furthermore, around half of the students thought the indoor sounds in the scrutinized rooms were noisy. The rates were higher in the group-study rooms than in the self-study rooms. In contrast, fewer students reported that the outdoor sound was noisy in these rooms; the highest percentage of noisy votes was found in room 1S (45%), and the lowest was in room 6S.

Table 3. Percentages of students' acoustic votes in the investigated rooms.

	1G	1S	6G	6S	All
Indoor sound perception (noisy rate)	29 (51%)	27 (42%)	38 (55%)	29 (42%)	123 (48%)
Outdoor sound perception (noisy rate)	18 (32%)	29 (45%)	23 (33%)	12 (17%)	82 (32%)
Acoustic satisfaction (dissatisfaction rate)	8 (14.0%)	13 (20.3%)	7 (10.1%)	17 (24.6%)	45 (17.4%)

3.1.3. Concentration Tests

Figure 8 shows students' concentration test scores in the investigated study spaces. Students in room 6G obtained the highest mean score (34.5), followed by the students in room 6S (33.8), and the lowest mean score was found in room 1S (32.9). No significant difference in concentration scores was identified between the students in different rooms ($F(2, 199) = 0.54$, $p = 0.582$).

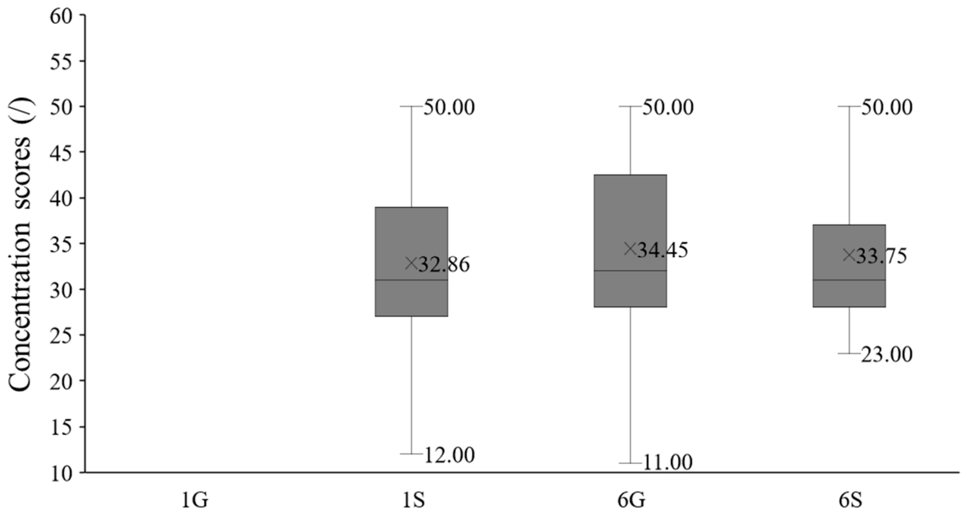


Figure 8. Students' concentration test scores.

3.2. Relationships between the $LAeq_{,15min}$, Students' Mood States, Acoustic Satisfaction, and Concentration Performance

The pairwise relationships between the $LAeq_{,15min}$, students' acoustic perceptions, and their concentration levels were indicated by Pearson correlation coefficients. As shown in Table 4, these parameters seemed irrelevant to each other, except for students' acoustic satisfaction and indoor sound perceptions, which were positively correlated. In other words, students' acoustic satisfaction was mainly decided by their indoor sound perceptions.

Table 4. Pearson correlations between the $LAeq_{,15min}$, students' acoustic perceptions, and concentration levels.

	$\mathbf{LAeq_{,15min}}$	**Indoor Sound Perception**	**Outdoor Sound Perception**	**Acoustic Satisfaction**
Indoor sound perception	0.03 (0.620)			
Outdoor sound perception	−0.07 (0.278)	0.02 (0.706)		
Acoustic satisfaction	−0.02 (0.744)	**0.20 (0.001)**	0.06 (0.346)	
Concentration	0.05 (0.460)	−0.06 (0.407)	0.04 (0.625)	0.05 (0.446)

Note: results were obtained from Pearson correlation analyses; numbers in the parentheses were *p*-values; the *p*-value less than 0.05 was marked in bold.

The same analyses were repeated for the room level, and only the relationship between the $LAeq_{,15min}$ and students' acoustic satisfaction was significant ($r = -0.964$; $p = 0.036$). With increased $LAeq_{,15min}$, students' acoustic satisfaction decreased significantly (Figure 9).

A series of one-way ANOVA analyses were carried out between students' mood states and these parameters to understand the impact of mood states. As shown in Table 5, the significant effects of students' mood states were found on their acoustic satisfaction and concentrations. Specifically, among students who felt good, 85% were satisfied with the acoustic environment, while among students who felt bad, only 25% reported being satisfied. Furthermore, the average concentration level of students who felt good was significantly higher than that of students who felt bad. However, no significant differences were identified in students' perceptions of indoor/outdoor sounds among students with different mood states. Additionally, these results indicated the variation tendencies of $LAeq_{,15min}$ and students' indoor sound perception along with their mood state. Namely, students in learning spaces with higher $LAeq_{,15min}$ tended to feel worse, and students who felt bad tended to perceive the indoor sound as noisier. The impact of mood states on room level was investigated. A series of Pearson correlation analyses were conducted, while the mood states were treated as a continuous variable. However, no significant relationship was identified.

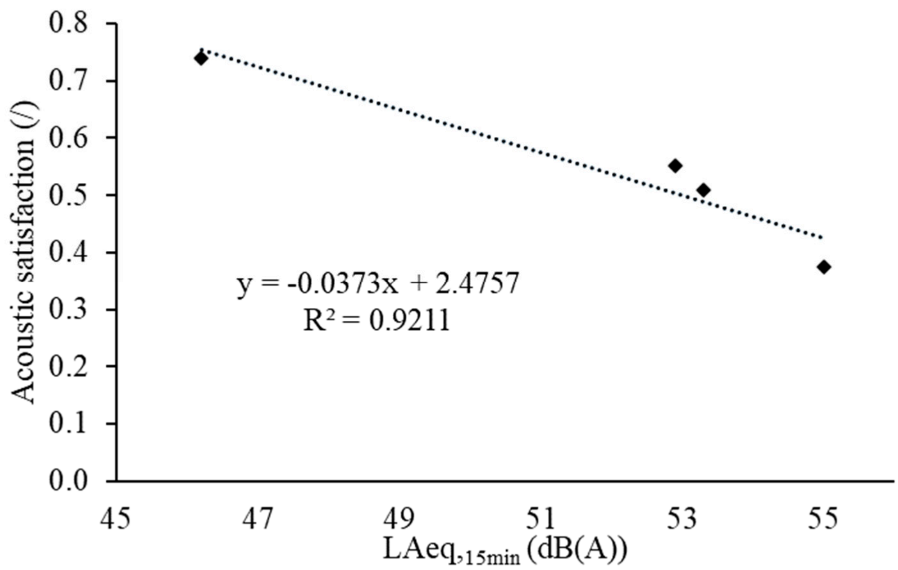


Figure 9. Relationships between $LAeq_{,15min}$ and students' acoustic satisfaction.

Table 5. Relationships between mood state and $LAeq_{,15min}$/students' acoustic perceptions/concentration levels.

	Mood State			F (*p*) Values
	Bad	**Neutral**	**Good**	
$LAeq_{,15min}$	53.4 (2.1)	52.5 (5.5)	51.5 (5.6)	0.98 (0.375)
Indoor sound perception	−1.0 (1.4)	−0.5 (1.3)	−0.2 (1.4)	2.21 (0.112)
Outdoor sound perception	0.8 (2.2)	0.0 (1.5)	0.4 (1.8)	1.07 (0.345)
Acoustic satisfaction	−1.0 (1.6)	0.3 (1.1)	0.7 (1.2)	**5.77 (0.004)**
Concentration	18.0 (6.1)	33.6 (8.5)	34.0 (8.7)	**5.11 (0.007)**

Note: results were obtained from one-way ANOVA analyses; the *p*-value less than 0.05 was marked in bold.

3.3. Interaction Effect between $LAeq_{,15min}$ and Mood States on Students' Acoustic Satisfaction and Concentration Performance

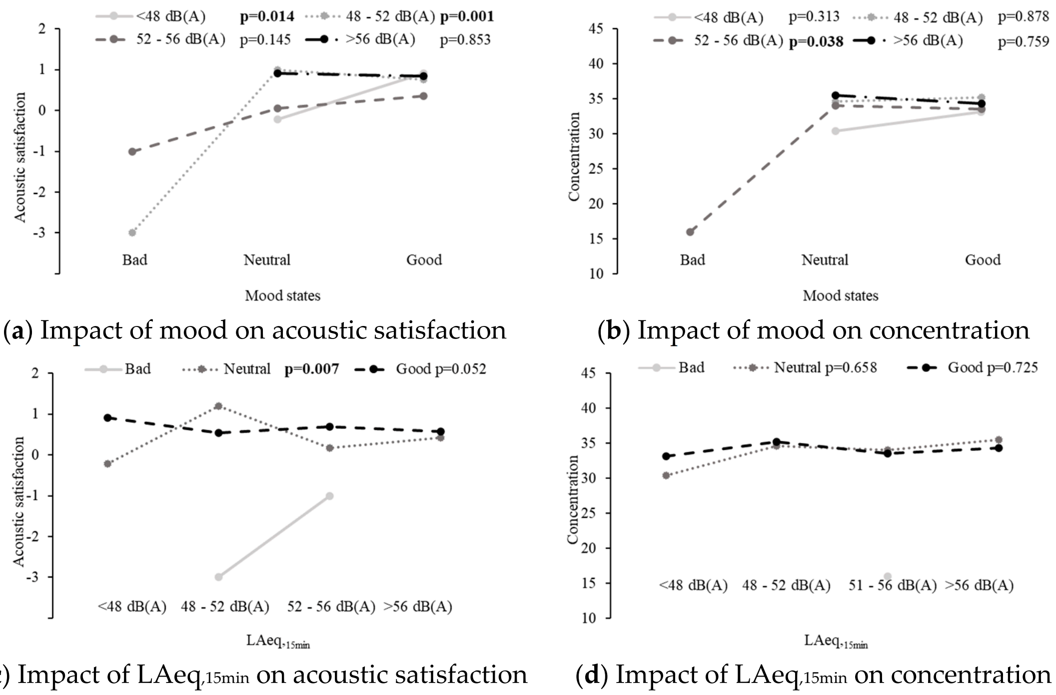
The two-way ANOVA analysis was conducted to further understand the interaction effect of $LAeq_{,15min}$ and mood states on the students' acoustic satisfaction and concentration performance. Similar to the results shown in the above section, the mood state significantly impacted students' acoustic satisfaction and concentration level. Moreover, a significant interaction effect between mood and $LAeq_{,15min}$ was identified on students' acoustic satisfaction, although $LAeq_{,15min}$ alone had no significant impact. Students' mood states affected their acoustic satisfaction differently under different $LAeq_{,15min}$. Related results are shown in Table 6.

Figure 10 illustrates the interaction effect between mood states and $LAeq_{,15min}$ on students' acoustic satisfaction and concentration. It can be seen from Figure 10a that when $LAeq_{,15min}$ was lower than 48 dB(A), students who felt good were significantly more satisfied with the acoustic quality than students who felt neutral (p = 0.014); when $LAeq_{,15min}$ was between 48 and 52 dB(A), students who felt bad were significantly more dissatisfied with the acoustic quality than the students who felt good or neutral (p = 0.001). When the $LAeq_{,15min}$ was higher than 52 dB(A), no significant relationship was identified between students' mood and their acoustic satisfaction. Figure 10b shows that students' concentration was significantly affected by their mood states when $LAeq_{,15min}$ was between 52 and 56 dB(A), and the concentration levels of students who felt bad were substantially lower than the students who felt good or neutral (p = 0.038). According to Figure 10c, when students had neutral moods, they felt more satisfied when $LAeq_{,15min}$ was between 48 and 52 dB(A) compared with other sound levels. In contrast, no significant impact of $LAeq_{,15min}$ was identified on students' acoustical satisfaction when they felt bad or good. Additionally, the results in Figure 10d indicated that $LAeq_{,15min}$ did not impact students' concentration, regardless of mood states.

Table 6. Impacts of $LAeq_{,15min}$ and mood states on the students' acoustic satisfaction and concentration performance.

Dependent Variables	Factors and Factor Interactions	df	Mean Square	F	*p*-Values
Acoustic satisfaction	$LAeq_{,15min}$_group	3	1.741	1.414	0.239
	Mood	2	10.360	8.414	**<0.001**
	$LAeq_{,15min}$_group * Mood	4	3.092	2.511	**0.042**
Concentration	$LAeq_{,15min}$_group	3	53.501	0.707	0.549
	Mood	2	310.611	4.106	**0.018**
	$LAeq_{,15min}$_group * Mood	3	21.275	0.281	0.839

Note: results were obtained from two-way ANOVA analyses; p-values less than 0.05 were in bold; * represents the interaction between two variables.



(**c**) Impact of $LAeq_{,15min}$ on acoustic satisfaction (**d**) Impact of $LAeq_{,15min}$ on concentration

Figure 10. Interaction effect of mood states and $LAeq_{,15min}$ on students' acoustic satisfaction and concentration.

4. Discussion

4.1. Acoustic Quality in the University Library

The $LAeq_{,15min}$ in the measured study rooms in the library were 46.2–55.0 dB(A), which were similar to the background noise levels in the classrooms (43.6–57.3 dB(A)) and lecture halls (38.5–52.2 dB(A)) in the university in Hong Kong [49]. However, the $LAeq_{,15min}$ in the library were relatively lower than the LAeqs in the university's classrooms (57.3–66.3 dB(A)) and lecture halls (57.6–61.0 dB(A)) during the teaching hours. The situation reflects the library context that students usually speak in a low voice, while teachers have to speak loudly in lecture halls or classrooms.

Considering the related standard and students' evaluations, the acoustic quality in the investigated rooms in the university library was not good. Specifically, the average $LAeq_{,15min}$ in all the rooms exceeded the recommended maximum background sound level by Hong Kong BEAM Plus [50] for learning spaces (35 dB(A)), and more than half of the students reported not being satisfied with the acoustic quality in the investigated rooms. Furthermore, the students' perceptions of outdoor sounds indicated that the higher the floor, the lower the outdoor sound could be perceived. The result is consistent with the outcomes of Zhang et al. [51] in residential buildings. Moreover, the results of this questionnaire showed that students in room 1S rated the lowest score towards acoustic satisfaction. In contrast, students in room 6S rated relatively higher, although the background sound type and level were similar in these rooms. One possible reason for the students' different acoustic evaluations in these rooms might be the window view. According to the interaction effect of the sound and visual view found by Lu et al. [52], people's soundscape pleasantness could be positively affected by the view openness and negatively affected by the view complexity in conditions without traffic. Since the window view in room 1S was about students' campus activities, it was more complex and might negatively affect students' evaluations. In contrast, the window view in the rooms on the sixth floor was more open and natural, which might positively affect students' evaluation.

4.2. Impact of $LAeq_{,15min}$ and Mood States on Students' Acoustic Evaluation and Performance

The results of the bivariate analyses indicated that the background sound level had a significantly negative impact on students' acoustic satisfaction in the investigated rooms. It should be pointed out that this impact was only significant at the room level instead of the individual level. Similar results were also reported by Astolfi and Pellerey [53], who found that the average background noise levels in classrooms were significantly related to the students' average evaluations of sound disturbances and intensity in the investigated classrooms; however, no such correlations were identified between the background sound levels and the assessments of each student. Unlike acoustic evaluations, the background sound level had no significant impact on students' concentration performance, no matter at what level. The insignificant effect of background sound level among university students might be explained by the observations of Caviola et al. [54], who compared the impact of background noise on learning performance among students of different ages and indicated that noise level was only significant for young students (11 years old) and gradually disappeared with age. Since the current study participants were all university students with well-developed cognitive functions and capacities to control attention [16], their performance might not be easily influenced by the background sounds. Apart from that, the $LAeq_{,15min}$ of the background sounds in the investigated rooms might be too moderate to generate any effect. According to Liu et al. [55], moderate background sounds (around 50 dB(A), like most cases in the current study) could stimulate the occupants' brains to stay in active conditions and benefit their performance. In comparison, when the $LAeq_{,15min}$ was higher than 60 dB(A) or lower than 40 dB(A), the negative effect appeared because of the auditory fatigue or brain's inactivity (due to the lack of stimuli), respectively. Therefore, a more extensive range of background sound levels should be included in future studies to examine its impact better.

In addition, students' mood states were also found to have significant and positive impacts on their acoustic satisfaction and concentration. The better their moods, the more satisfied they felt with the acoustic environment, and the better they performed. The positive relationship between students' mood states and acoustic satisfaction agrees with Västfjäll's findings, which showed that participants in negative mood states disliked the sounds more than others [33]. Fisher [56] also found a similar positive impact of moods on occupants' satisfaction, but mainly on job satisfaction. These results also partially supported the statements concluded by Lorenzino et al. [57] that people's acoustic perception was influenced more by mood states than by the acoustic quality in the investigated spaces. Although previous studies have rarely examined the relationship between students' mood states and concentration levels, there is plenty of evidence that mood states significantly affect cognitive processes and academic achievement [34,37,58].

Moreover, the two-way ANOVA results revealed a significant interaction effect between $LAeq_{,15min}$ and mood states on students' acoustic satisfaction. For example, when the $LAeq_{,15min}$ was lower than 48 dB(A), students who felt good were more satisfied with the acoustic quality in the study rooms than those who felt neutral; when the $LAeq_{,15min}$ was between 48 and 52 dB(A), students who felt neutral or good were more satisfied than those who felt bad or terrible. When students felt neutral, they were more satisfied with the situation with the $LAeq_{,15min}$ of 48–52 dB(A). Although the impact of $LAeq_{,15min}$ itself was not significantly related to students' acoustic satisfaction at the individual level, the $LAeq_{,15min}$ could moderate the influence of mood states on students' acoustic satisfaction, and mood states might have different impacts under different sound levels. Specifically, it was found that the influence of mood states on students' concentration was significant only when the $LAeq_{,15min}$ was between 52 and 56 dB(A). Under this circumstance, the concentration levels of students with bad moods were significantly lower than others. Nonetheless, no significant interaction effect between the $LAeq_{,15min}$ and students' mood states was identified in their concentration in the current study.

4.3. Implications of the Results

From the above discussion, three suggestions can be summarized to improve the acoustic quality and students' performance in learning spaces. First, given that lower acoustic quality was observed in the rooms on the lower floor, more sound absorption materials should be installed on the lower floors. Technologies to improve the sound isolation of the exterior façade, such as increasing the thicknesses of the external glass sheet and the gas cavity [59], should be considered during the design and construction of educational buildings. Second, considering the possible impact of window views on students' acoustic satisfaction, the windows in study spaces are better for facing natural views than people's activities. Third, since mood state was found to have a more significant influence on students' acoustic satisfaction and concentration than the $LAeq_{,15min}$, more attention should be given to the indoor environment design (such as interior color) that has been proven to be able to improve students' mood states [60,61].

4.4. Limitations and Future Studies

Despite these promising results, two limitations of the study should be noted. The first one is about the acoustic measurement. This study only measured the background sound level because some parameters are impractical in site measurement with subjective surveys. Although sound level is the most used indicator to evaluate the acoustic quality in educational buildings [41], it cannot reflect the overall acoustic performance of the investigated rooms or provide sufficient evidence to explain students' different evaluations. Thus, more acoustic indicators, e.g., reverberation time and speech transmission index, are suggested to be measured for future studies. The second limitation is the small number of investigated rooms. Since the primary purpose of this study was to identify the impact of background sound level and mood states on the individual level, only four study rooms were selected. However, the results indicated that the impact of the background sound level on students' acoustic satisfaction was only significant at the room level. Therefore, future studies are suggested to involve more rooms with a more extensive range of background sound levels to confirm these impacts further.

5. Conclusions

In this study, the background sound level, students' sound perceptions, mood states, and concentration performance were investigated via objective measurement and subjective assessment, respectively, in four study rooms of a university library. The results showed that students' average acoustic satisfaction and concentration levels at the room level were significantly related to the average $LAeq_{,15min}$ in the investigated rooms (r = −0.964; p = 0.036). In the room with lower $LAeq_{,15min}$, students, on average, felt more satisfied with the acoustic quality and had higher concentration levels. However, at the individual level, such relationships were not significant, and instead, students' acoustic satisfaction and concentration levels were more determined by their mood states. The satisfaction rate among students who felt good or neutral was 60% higher than it was among students who felt inadequate. Additionally, students who felt good were more concentrated than those who felt bad. Moreover, the results revealed a significant interaction effect between the $LAeq_{,15min}$ and students' mood states on their acoustic satisfaction. Students' mood states significantly determined their acoustic satisfaction when the $LAeq_{,15min}$ was lower than 52 dB(A). Although no significant interaction effect between the $LAeq_{,15min}$ and students' mood states was identified on their concentration levels, it should be noted when the $LAeq_{,15min}$ was between 52 and 56 dB(A), the students' mood states could significantly affect their concentration levels.

These results implied that to improve students' acoustic comfort and learning performance in study rooms, the designers of education buildings might pay more attention to the interior design, which could significantly influence students' mood states and the acoustic quality and window views in the study rooms on the lower floors. This research contributes to understanding more about how the $LAeq_{,15min}$ and mood states affect students' acoustic satisfaction and concentration and, therefore, informs on how to make better decisions during building design and refurbishment.

Author Contributions: Conceptualization, D.Z.; methodology, L.-T.W. and D.Z.; software, D.Z.; validation, D.Z.; formal analysis, L.-T.W. and D.Z.; investigation, L.-T.W. and D.Z.; resources, L.-T.W. and K.-W.M.; data curation, L.-T.W. and D.Z.; writing—original draft preparation, D.Z.; writing—review and editing, L.-T.W. and K.-W.M.; visualization, D.Z.; supervision, L.-T.W. and K.-W.M.; project administration, K.-W.M.; funding acquisition, L.-T.W. and K.-W.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the General Research Fund, Research Grants Council of the Hong Kong Special Administrative Region, China (Project no. 15217221, PoyU P0037773/Q86B) and partially supported by the PolyU internal funds (P0040864 and P0043831).

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Gatersleben, B.; Griffin, I. Environmental stress. In *Handbook of Environmental Psychology and Quality of Life Research*; Springer: Berlin/Heidelberg, Germany, 2017; pp. 469–485.
2. Cohen, S. Sound Effects on Behavior. *Psychol. Today* **1981**, *15*, 38–49.
3. Benfield, J.A.; Nurse, G.A.; Jakubowski, R.; Gibson, A.W.; Taff, B.D.; Newman, P.; Bell, P.A. Testing Noise in the Field: A Brief Measure of Individual Noise Sensitivity. *Environ. Behav.* **2014**, *46*, 353–372. [CrossRef]
4. Shalkouhi, P.J.; Nassiri, P.; Abbaspour, M.; Sekhavatjou, M. Evaluation of background sound quality using NCB. *Build. Acoust.* **2009**, *16*, 149–158. [CrossRef]
5. Hygge, S. Classroom experiments on the effects of different noise sources and sound levels on long-term recall and recognition in children. *Appl. Cogn. Psychol.* **2003**, *17*, 895–914. [CrossRef]
6. Zhang, D.; Tenpierik, M.; Bluyssen, P.M. The effect of acoustical treatment on primary school children's performance, sound perception, and influence assessment. *E3S Web Conf.* **2019**, *111*, 02046. [CrossRef]
7. Ali, S.A.A. Study effects of school noise on learning achievement and annoyance in Assiut city, Egypt. *Appl. Acoust.* **2013**, *74*, 602–606. [CrossRef]

8. Shield, B.; Dockrell, J.E. External and internal noise surveys of London primary schools. *J. Acoust. Soc. Am.* **2004**, *115*, 730–738. [CrossRef] [PubMed]
9. Sato, H.; Bradley, J.S. Evaluation of acoustical conditions for speech communication in working elementary school classrooms. *J. Acoust. Soc. Am.* **2008**, *123*, 2064–2077. [CrossRef] [PubMed]
10. Zannin, P.H.T.; Marcon, C.R. Objective and subjective evaluation of the acoustic comfort in classrooms. *Appl. Ergon.* **2007**, *38*, 675–680. [CrossRef]
11. Bluyssen, P.M.; Zhang, D.; Kurvers, S.; Overtoom, M.; Ortiz-Sanchez, M. Self-reported health and comfort of school children in 54 classrooms of 21 Dutch school buildings. *Build. Environ.* **2018**, *138*, 106–123. [CrossRef]
12. Braat-Eggen, P.E.; Van Heijst, A.; Hornikx, M.M.; Kohlrausch, A.A. Noise disturbance in open-plan study environments: A field study on noise sources, student tasks and room acoustic parameters. *Ergonomics* **2017**, *60*, 1297–1314. [CrossRef]
13. Scannell, L.; Hodgson, M.; García Moreno Villarreal, J.; Gifford, R. The Role of Acoustics in the Perceived Suitability of, and Well-Being in, Informal Learning Spaces. *Environ. Behav.* **2016**, *48*, 769–795. [CrossRef]
14. Yang, W.; Kang, J. Acoustic comfort evaluation in urban open public spaces. *Appl. Acoust.* **2005**, *66*, 211–229. [CrossRef]
15. Gheller, F.; Lovo, E.; Arsie, A.; Bovo, R. Classroom acoustics: Listening problems in children. *Build. Acoust.* **2020**, *27*, 47–59. [CrossRef]
16. Klatte, M.; Bergström, K.; Lachmann, T. Does noise affect learning? A short review on noise effects on cognitive performance in children. *Front. Psychol.* **2013**, *4*, 578. [CrossRef] [PubMed]
17. Klatte, M.; Hellbrück, J.; Seidel, J.; Leistner, P. Effects of Classroom Acoustics on Performance and Well-Being in Elementary School Children: A Field Study. *Environ. Behav.* **2010**, *42*, 659–692. [CrossRef]
18. Klatte, M.; Lachmann, T.; Meis, M. Effects of noise and reverberation on speech perception and listening comprehension of children and adults in a classroom-like setting. *Noise Health* **2010**, *12*, 270–282. [CrossRef]
19. Szalma, J.L.; Hancock, P.A. Noise Effects on Human Performance: A Meta-Analytic Synthesis. *Psychol. Bull.* **2011**, *137*, 682–707. [CrossRef] [PubMed]
20. Zhang, D.; Tenpierik, M.; Bluyssen, P.M. Interaction effect of background sound type and sound pressure level on children of primary schools in the Netherlands. *Appl. Acoust.* **2019**, *154*, 161–169. [CrossRef]
21. Picou, E.M.; Gordon, J.; Ricketts, T.A. The effects of noise and reverberation on listening effort in adults with normal hearing. *Ear Hear.* **2016**, *37*, 1–13. [CrossRef]
22. Clark, C.; Martin, R.; van Kempen, E.; Alfred, T.; Head, J.; Davies, H.W.; Haines, M.M.; Barrio, I.L.; Matheson, M.; Stansfeld, S.A. Exposure-effect relations between aircraft and road traffic noise exposure at school and reading comprehension: The RANCH project. *Am. J. Epidemiol.* **2006**, *163*, 27–37. [CrossRef] [PubMed]
23. Ljung, R.; Sorqvist, P.; Hygge, S. Effects of road traffic noise and irrelevant speech on children′s reading and mathematical performance. *Noise Health* **2009**, *11*, 194–198. [CrossRef] [PubMed]
24. Shield, B.; Dockrell, J. The effects of classroom and environmental noise on children's academic performance. In Proceedings of the 9th International Congress on Noise as a Public Health Problem (ICBEN), Foxwoods, CT, USA, 21–25 July 2008.
25. Jafari, M.J.; Khosrowabadi, R.; Khodakarim, S.; Mohammadian, F. The effect of noise exposure on cognitive performance and brain activity patterns. *Open Access Maced. J. Med. Sci.* **2019**, *7*, 2924–2931. [CrossRef] [PubMed]
26. Masullo, M.; Maffei, L.; Iachini, T.; Rapuano, M.; Cioffi, F.; Ruggiero, G.; Ruotolo, F. A questionnaire investigating the emotional salience of sounds. *Appl. Acoust.* **2021**, *182*, 108281. [CrossRef]
27. Han, Z.; Kang, J.; Meng, Q. Effect of sound sequence on soundscape emotions. *Appl. Acoust.* **2023**, *207*, 109371. [CrossRef]
28. Jiang, B.; Xu, W.; Ji, W.; Kim, G.; Pryor, M.; Sullivan, W.C. Impacts of nature and built acoustic-visual environments on human's multidimensional mood states: A cross-continent experiment. *J. Environ. Psychol.* **2021**, *77*, 101659. [CrossRef]
29. Zhang, B.; Kang, J. Effect of environmental contexts pertaining to different sound sources on the mood states. *Build. Environ.* **2022**, *207*, 108456. [CrossRef]
30. Benfield, J.; Taff, B.; Newman, P.; Smyth, J. Natural sound facilitates mood recovery. *Ecopsychology* **2014**, *6*, 183–188. [CrossRef]
31. Jo, H.; Song, C.; Ikei, H.; Enomoto, S.; Kobayashi, H.; Miyazaki, Y. Physiological and psychological effects of forest and urban sounds using high-resolution sound sources. *Int. J. Environ. Res. Public Health* **2019**, *16*, 2649. [CrossRef]
32. Correia, A.W.; Peters, J.L.; Levy, J.I.; Melly, S.; Dominici, F. Residential exposure to aircraft noise and hospital admissions for cardiovascular diseases: Multi-airport retrospective study. *BMJ* **2013**, *347*, f5561. [CrossRef]
33. Västfjäll, D. Influences of current mood and noise sensitivity on judgments of noise annoyance. *J. Psychol. Interdiscip. Appl.* **2002**, *136*, 357–370. [CrossRef]
34. Mehta, K.J. Effect of sleep and mood on academic performance-at interface of physiology, psychology, and education. *Humanit. Soc. Sci. Commun.* **2022**, *9*, 16. [CrossRef]
35. Mayer, J.D.; McCormick, L.J.; Strong, S.E. Mood-congruent memory and natural mood. *Pers. Soc. Psychol. Bull.* **1995**, *21*, 736–746. [CrossRef]
36. Bohn-Gettler, C.M.; Rapp, D.N. Depending on my mood: Mood-driven influences on text comprehension. *J. Educ. Psychol.* **2011**, *103*, 562–577. [CrossRef]
37. Martin, E.A.; Kerns, J.G. The influence of positive mood on different aspects of cognitive control. *Cogn. Emot.* **2011**, *25*, 265–279. [CrossRef] [PubMed]

38. Valiente, C.; Swanson, J.; Eisenberg, N. Linking Students' Emotions and Academic Achievement: When and Why Emotions Matter. *Child Dev. Perspect.* **2012**, *6*, 129–135. [CrossRef] [PubMed]
39. Bisson, M.A.S.; Sears, C.R. The effect of depressed mood on the interpretation of ambiguity, with and without negative mood induction. *Cogn. Emot.* **2007**, *21*, 614–645. [CrossRef]
40. Kaida, K.; Itaguchi, Y.; Iwaki, S. Interactive effects of visuomotor perturbation and an afternoon nap on performance and the flow experience. *PLoS ONE* **2017**, *12*, e0171907. [CrossRef]
41. Hamida, A.; Zhang, D.; Ortiz, M.A.; Bluyssen, P.M. Indicators and methods for assessing acoustical preferences and needs of students in educational buildings: A review. *Appl. Acoust.* **2023**, *202*, 109187. [CrossRef]
42. Tang, S.K. Performance of noise indices in air-conditioned landscaped office buildings. *J. Acoust. Soc. Am.* **1997**, *102*, 1657–1663. [CrossRef]
43. The Chartered Institution of Building Services Engineers. *CIBSE TM68: Monitoring indoor Environment Quality*; The Chartered Institution of Building Services Engineers: London, UK, 2022.
44. Forgas, J.P. On Feeling Good and Getting Your Way: Mood Effects on Negotiator Cognition and Bargaining Strategies. *J. Pers. Soc. Psychol.* **1998**, *7*, 565–577. [CrossRef] [PubMed]
45. Olsson, L.E.; Gärling, T.; Ettema, D.; Friman, M.; Ståhl, M. Current mood vs. recalled impacts of current moods after exposures to sequences of uncertain monetary outcomes. *Front. Psychol.* **2017**, *8*, 66. [CrossRef] [PubMed]
46. Nijenhuis, J.T.; Van Der Flier, H. The use of safety suitability tests for the assessment of immigrant and majority group job applicants. *Int. J. Sel. Assess.* **2004**, *12*, 230–242. [CrossRef]
47. Menge, C.W. The One-Minute Leq Measurement Method. *J. Urban Econ.* **1982**, *11*, 333–347.
48. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*; Academic Press: Cambridge, MA, USA, 2013.
49. Lee, M.; Mui, K.; Wong, L.; Chan, W.; Lee, E.; Cheung, C. Student learning performance and indoor environmental quality (IEQ) in air-conditioned university teaching rooms. *Build. Environ.* **2012**, *49*, 238–244. [CrossRef]
50. BEAM Society Limited. *BEAM Plus Existing Buildings Version 2.0*; BEAM Society Limited: Hong Kong SAR, China, 2016.
51. Zhang, J.; Li, T.; Cui, P.; Yin, Q.; Dai, C. Research on the Differences of Outdoor Sound Perception and Sound Preference between Urban and Rural Residential Areas. *For. Chem. Rev.* **2021**, *1*, 456–486.
52. Lu, Y.; Tan, J.K.A.; Hasegawa, Y.; Lau, S.-K. The interactive effects of traffic sound and window views on indoor soundscape perceptions in the residential area. *J. Acoust. Soc. Am.* **2023**, *153*, 972–989. [CrossRef] [PubMed]
53. Astolfi, A.; Pellerey, F. Subjective and objective assessment of acoustical and overall environmental quality in secondary school classrooms. *J. Acoust. Soc. Am.* **2008**, *123*, 163–173. [CrossRef] [PubMed]
54. Caviola, S.; Visentin, C.; Borella, E.; Mammarella, I.; Prodi, N. Out of the noise: Effects of sound environment on maths performance in middle-school students. *J. Environ. Psychol.* **2021**, *73*, 101552. [CrossRef]
55. Liu, H.; He, H.; Qin, J. Does background sounds distort concentration and verbal reasoning performance in open-plan office? *Appl. Acoust.* **2021**, *172*, 107577. [CrossRef]
56. Fisher, C.D. Mood and emotions while working: Missing pieces of job satisfaction? *J. Organ. Behav.* **2000**, *21*, 185–202. [CrossRef]
57. Lorenzino, M.; D'Agostin, F.; Rigutti, S.; Bovenzi, M.; Fantoni, C.; Bregant, L. Acoustic comfort depends on the psychological state of the individual. *Ergonomics* **2020**, *63*, 1485–1501. [CrossRef] [PubMed]
58. Tyng, C.M.; Amin, H.U.; Saad, M.N.M.; Malik, A.S. The influences of emotion on learning and memory. *Front. Psychol.* **2017**, *8*, 1454. [CrossRef] [PubMed]
59. Bliūdžius, R.; Miškinis, K.; Buhagiar, V.; Banionis, K. Sound Insulation of Façade Element with Triple IGU. *Buildings* **2022**, *12*, 1239. [CrossRef]
60. Kurt, S.; Osueke, K.K. The Effects of Color on the Moods of College Students. *SAGE Open* **2014**, *4*, 1–12. [CrossRef]
61. Yildirim, K.; Akalin-Baskaya, A.; Hidayetoglu, M. Effects of indoor color on mood and cognitive performance. *Build. Environ.* **2007**, *42*, 3233–3240. [CrossRef]