An Experimental Study on the Influence of Environmental Noise on Students' Attention

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Summary
The aim of this study was to explore the influences of environmental noise on individuals′ attention in learning spaces. The environmental noise with different sound source compositions and characteristics were divided into three typical levels, namely low 55dB, medium 65dB, high 75dB, based on the field survey data of 10 typical schools in a high-density city, Shenyang, China. To simulate the interference of external noise on learning spaces, audios of three typical levels recorded in actual environments were played in laboratory, with their SPL reduced to low-45dB, medium-55dB, high-65dB, respectively. Attention tests were conducted on 20 undergraduate student participants by visual tracking tasks and a telemetry eye tracker was used to record the eye-movement data. The task took pictures with multiple interlacing curves as experimental materials, and participants were asked to track the curves with their eyes and speak out the number and the letter connected by one curve. "Accuracy", "Reaction time" and "The average number of fixation points (completing one curve)" were taken as indices. The experiment used within-participants design to eliminate the influence of individual differences. Latin square design was taken to avoid the order effect. Participants were arranged to practice in advance to avoid the practice effect. The results showed that there were significant differences on the accuracy ($F=4.692$, $P=0.013<0.05$; Mean: 45-0.60, 55-0.55, 65-0.54), reaction time ($F=6.813$, $P=0.017<0.05$; Mean: 45-7.71s, 55-8.39s, 65-8.49s), the average number of fixation points ($F=4.171$, $P=0.023<0.05$) under the influence of three typical levels of environmental noise. In conclusion, it was found that a higher environmental noise level led to lower accuracy and the longer reaction time, and attention was disturbed more seriously; and, a higher environmental noise level required more fixation points to capture information which means more efforts were needed to maintain the attention.

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1. Introduction

In the past 20 years, the process of urbanization characterized by massive population concentration and large-scale urban expansion has developed rapidly in China [1]. The rapid accumulation of population and limited livable land make high density an inevitable outcome of China's mega cities. In high density cities, the urban function is highly complex [2], the buildings are dense and high [3], and the traffic network is saturated [4].The characteristics of high density city bring serious environmental noise problems, more and more people are disturbed by environmental noise [5]. Environmental noises endanger residents' health, impair hearing and the cardiovascular system [6] [7] [8] [9]. Mental health also affected by environmental noise, it causes annoyances and pressures [10], and is an unfavorable factor for the recovery of the acoustic environment [11].

A school is an important place for students to improve their cognitive ability. The noisy urban is a direct factor of the poor sound environment in many schools [12] [13]. As background noises, the urban environmental noises invade the learning space and have negative influences on students' cognitive performances, such as reading, memory and mathematics ability. Different environmental noise levels and sound source types have different effects on students' cognitive performance: studies showed that the higher the SPL of environmental noise, the more significant the impact on students' reading and mathematics ability [14][15][16][17]; aircraft noise is significantly related to students' memory [18][19], while there is no significant correlation between railway/road traffic noise and long-term/short-term memory [20][21][22].

Attention serves as a filter, affecting both the type and quantity of information that is used and is crucial to other cognitive abilities. It is a vulnerable psychological resource that can be disturbed easily. Kahneman defined attention as a process of allocating limited processing capacity [23]. Carrasco proposed that attention is a selective process because individuals have a limited capacity to process vast amounts of visual stimuli and must choose which to highlight [24]. To explore the influences of environmental noise on students' attention, some studies have been conducted. The result of the survey of students near Heathrow Airport showed that there was no significant correlation between aircraft noise and continuous attention [25]. The RANCH study did not found a significant correlation between aircraft noise/road traffic noise and continuous attention [26]. Cognitive tests were conducted on 174 students who exposed to high aircraft noise, and the results showed that the high aircraft noise is significantly correlated with visual attention [27]. Previous studies assessed the impact of environmental noise on students' attention through the results of attention testing. However, they were unable to measure levels of attention because of the lack of devices or software programs that effectively track the cues to which managers respond when processing accounting information. More than 80% information exchanged between humans, and the outside world is by the eyes. Recent years Eye Gaze Tracking Technology developed rapidly, it is a technique that explore how to accurately and non-intrusively track the human visual process. The eye tracker can accurately obtain the information of Explicit Attention and Implicit Attention without any interference. And it can measure the interaction between human factors and the environment more intuitively and accurately.

Taking Shenyang as a high density city sample, this study explores the influences of environmental noise on individuals′ attention in learning spaces by an eye movement experiment.

2. Method

To explore the influences of environmental noise on individuals ' attention in learning spaces, the experiment was designed. The experiment was carried out in the Eco-Building Physics Technology and Evaluation Laboratory of Shenyang Jianzhu University. The experiment was arranged in 8:00-12:00 and 14:00-18:00 on weekdays, and it is time for students to do cognitive activities on ordinary days. The background noise level of the laboratory was respectively measured in the three days before the formal experiment, and it was found that the level of the background noise is about 35dB. During the experiment, the temperature and light were controlled in a suitable condition.

2.1. Participants

20 undergraduates with good health, normal hearing, normal vision and no mental illness were selected from a university in Shenyang as

participants. The sex ratio of the participants was 1:1 and the age ranged from 18 to 20, they are all in the same grade and majored in the same profession. Moreover it helps to avoid the factors such as gender, age, education level effecting the results of the experiment. Before the experiment, participants were not allowed to take anything that may affect attention.

2.2. Experiment Design

（1）Stimulant material

A field survey of environmental noise around 10 typical schools in Shenyang were carried out through sound source surveys and acoustic measurement. The results showed that the environmental noise can be divided into three typical levels, namely low 55dB, medium 65dB, high 75dB. Their sound source compositions and characteristics were different: 75dB-continuous traffic noise & significant whistle sound; 65dB-continuous traffic noise & whistle sound & indistinct society activity sound; 55dB-intermittent traffic sound & whistle sound & bird sound & conversation & hawking sound.（Table Ⅰ）

Table I. Sound source of three typical levels.

Level	*LAeq(dBA)*	*Sound sources*
High	71.22-75.88	continuous traffic
		significant whistle
Medium	64.94-67.31	continuous traffic
		whistle sound
		indistinct society
Low	52.78-59.41	intermittent traffic
		whistle sound
		bird sound
		conversation
		hawking sound

The stimulus materials for the experiment were audios of three typical levels recorded in actual environment. It was estimated that when the window area of learning space meet the "Assessment standard for green building GB/T50378-2014", the external wall can reduce the SPL of the environmental noise by 10 dB with windows opening [28]. To simulate the interference of external noise on learning spaces, the loudspeaker was hidden in the windowsill in advance and audios of typical levels were respectively played in the laboratory, with their SPL reduced to low-45dB, medium-55dB, high-65dB. The Bruel and Kjaer hand held sound level meter, Type 2250, was used to measure the environmental noise during the experiment period.

（2）Experiment Task

Taking the visual tracking test as the experiment task. It has been verified that the visual tracking task used to test the attention stability of adolescents has good reliability and validity [29]. The task took pictures with multiple interlacing curves as experimental materials (Figure 1). Participants were asked to track the curves with their eyes without the assistant of other items and speak out the number and the letter connected by one curve. To make sure the tasks have the same degree of difficulty, the task pictures of the three typical levels were the transverse image and longitudinal image of one picture.

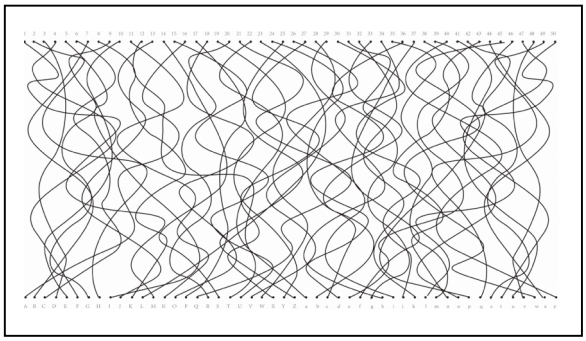

Figure 1.The picture of experiment task.

（3）Indicators

"Accuracy", "Reaction time" and "The average number of fixation points (completing one curve)" were taken as indices of attention. "Accuracy" is the ratio of the correct number to the total number of curves. The *Reaction time* was defined as the ratio of the schedule time of task to the number of curves completed by participants. A tape recorder was set up to record the answer of tests and the environmental noise in the laboratory. The Tobii telemetry eye tracker was used to track and record the eye movement of participants during experiment [30]. The typical eye movements include fixation, saccade, smooth pursuit. Moreover, the indexes of eye movement include fixation duration, fixation number, saccade count, saccade time, blink count etc. [31]. The study take the *average fixation points (completing one curve)* as the eye movement index. When the attention was distracted, more fixation points were used to lock the target information, more attention is consumed.

（4）statistical analysis

The data of experiment were analysed by repeated measurement analysis of variance using the General Linear Model in SPSS21.0.

2.3. Procedure

Before the experiment, the participants were arranged to familiarize themselves with the laboratory environment. To avoid incorrect operations, the experiment procedure and items need to attention were informed to the participants in advance. Participants were also arranged to practice the tasks to avoid the practice effect. The whole preparation phase lasts about 20 minutes. After the preparation, the experimenter left the laboratory to avoid the interference to participants ' attention during the tests.

The eye movement data was recorded by the eye tracker during experiment (Figure2). The participants were guided to calibrated eye tracker by the experimenter who are in the control room at first. During the calibration, the participants were asked to observe the calibration points appeared on the screen. The eye tracker will test by both the Bright pupil and the Dark pupil to identify the most suitable tracking mode for the current light conditions and participants' eye characteristics. After calibration, the experimental task is automatically played by the computer in the form of presentation documents, and the participants follow the instruction to perform the experiment. The task consisted of 50 curves and would be displayed for 240 seconds on the screen, and the results of the pre experiment suggested that the setting is reasonable. The participants were asked to keep the sitting posture in calibration during the test to avoid the eye movement can't be tracked. The audio of environmental noise were continuously played during the test, and the volume and progress were regulated by the experimenter in the control room to ensure participants hear the same sound during the same test.

The experiment used within-participants design to eliminate the influence of individual differences. The participants were required to take three attention tests successively, to avoid the fatigue effect, the participants were divided into 10 groups, the 2 participants in the same group take the test alternately. When one was tested, the other had a rest in the lounge. And participants are asked not to perform any attention-consuming behavior during rest. Latin square design was taken to avoid the order effect. In order to avoid mutual interference between participants, participants were asked not to discuss experimental content with each other.

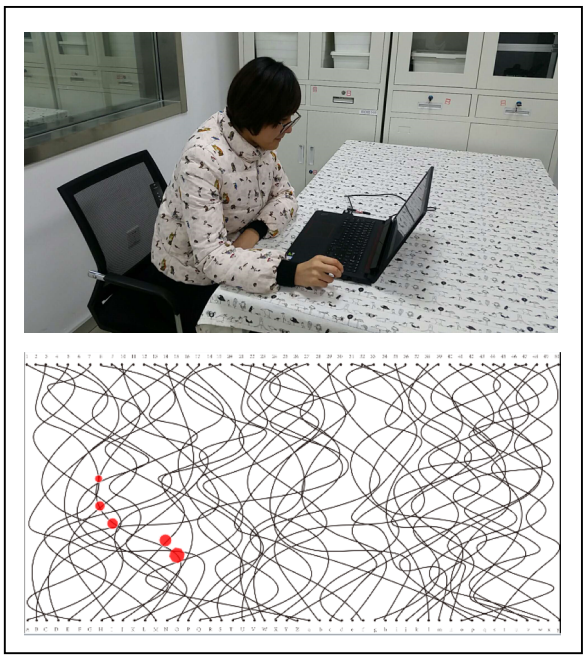

Figure 2. The eye movement tracked by eye tracker.

3. Results

3.1. Accuracy

The accuracy of visual tracking test under three typical levels were analyzed. Moreover, the results suggested that most participants had the highest accuracy under the influence of low environmental noise (75%). A very few participants had the highest accuracy under the influence of high level-65dBA (10%) and medium level−55dBA (15%) environmental noise. More than half of the participants' test accuracy decreased with the increase of environmental noise level (55%). (Figure 3)

The statistical results of the accuracy showed that: there were significant differences of accuracy among the three typical levels of environmental noise ($F=4.69$，$P=0.013<0.05$); with the increase of environmental noise level, the accuracy of visual tracking test decreased, and the average accuracy of the three typical levels respectively were: low -0.54, medium -0.55, high -0.60. After further analysis, it was found that there is an hugely significant difference in accuracy between the low level and medium level（$0.003<0.01$），but no significant difference was found between medium level and high level environmental noise. The results suggested that the higher the level of environmental noise, the greater the impact on attention. (Table Ⅱ)

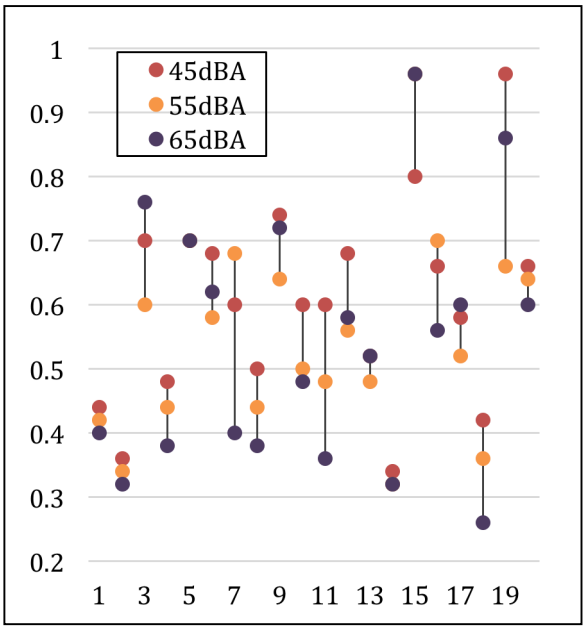

Figure 3. The accuracy of the participants.

Table Ⅱ. The variance analysis results of accuracy.

LAeq(dBA)	*Mean*	*Std.*	*F*	*P*
45dBA	0.60	0.15	4.69	0.013
55dBA	0.55	0.15		
65dBA	0.54	0.19		

3.2 Reaction time

The reaction time of the visual tracking test under three typical levels were analyzed. It was found that most participants had the shortest reaction time at low environment noise level (65%); 20% of the participants had the shortest reaction time under the influence of middle level ambient noise; 15% of the participants had the shortest response time under the influence of high level environmental noise; with the increase of the environmental noise level, the reaction time of 35% participants was also increased. (Figure 4)

The statistical results of the reaction time showed that: there were significant differences in the reaction time among the three typical levels of environmental noise ($F=5.04$，$P=0.011<0.05$); with the increase of environmental noise level, the reaction time of visual tracking test also increased, and the average reaction time of the three typical levels respectively were: low -7.71s, medium -8.39s, high -8.49s. After further analysis, it was found that there is an hugely significant difference of reaction time between the low level and medium level （ $0.003 < 0.01$ ） ， but no significant difference was found between medium level and high level environmental noise. The result suggested that when effected by the higher the level of environmental noise, the participants take more time to complete a curve. (Table Ⅲ)

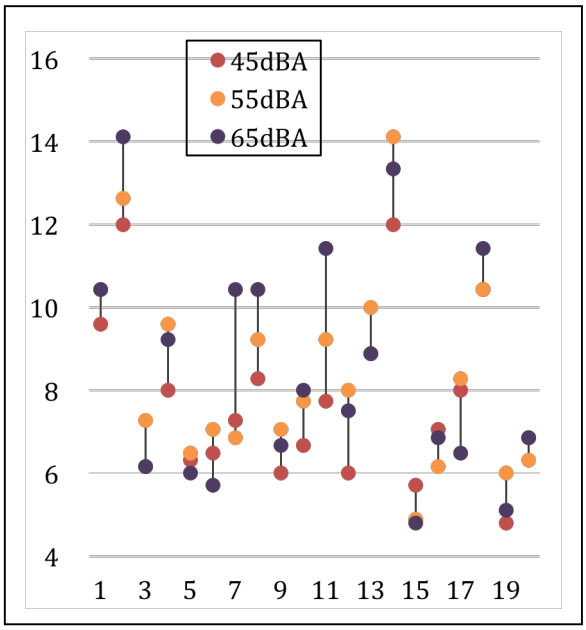

Figure 4. The reaction time of the participants.

Table Ⅲ. The variance analysis results of the reaction time.

LAeq(dBA)	*Mean*	*Std.*	*F*	*P*
45dBA	7.71	2.0	5.04	0.011
55dBA	8.39	2.33		
65dBA	8.49	2.74		

3.3 The average number of fixation points

After analyzing the average number of fixation points (complete one curve) of visual tracking test under three typical levels, it was found that nearly half of participants spent the least average number of fixation points at low environment noise level (45%); 20% of the participants had the least average number of fixation points under the influence of middle level environmental noise; 35% of the participants had the least average number of fixation points under the influence of high level environmental noise; with the increase of the environmental noise level, the average number of fixation points of 25% participants increased. It means that when effected by the higher the level of environmental noise, the participants take more fixation points to complete a curve. (Figure 5)

The statistical results of the average number of fixation points (complete one curve) showed that: there were significant differences in the average number of fixation points (complete one curve) among the three typical levels of environmental

noise (F=5.17， P=0.023＜0.05); with the increase of environmental noise level, the average number of fixation points to complete one curve also increased, and the mean value of the average number of fixation points (complete one curve) of the three typical levels respectively were: low - 19.68, medium -21.86, high -21.80. After further analysis, it was found that there is an hugely significant difference of average number of fixation points (complete one curve) between low level and medium level (0.004＜0.01); while a significant difference was found between the low level and the high level; no significant difference was found between medium-level and high-level environmental noise. When effected by the higher the level of environmental noise, the participants took more fixation points to complete a curve. (Table Ⅳ)

Figure 5. The average number of fixation points of the participants.

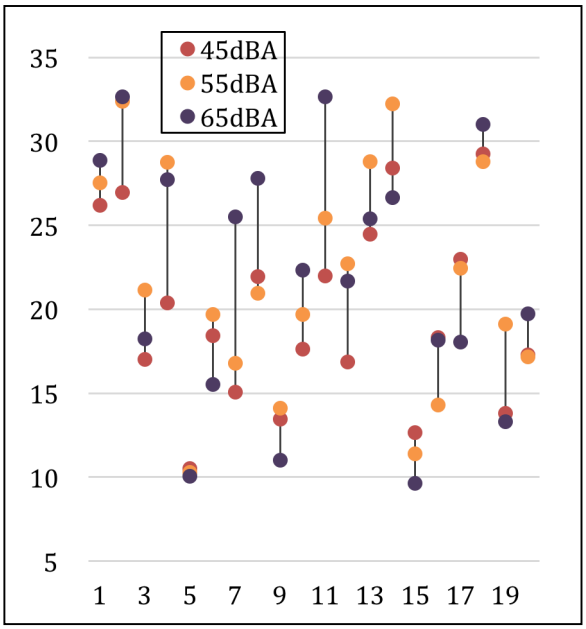

Table Ⅳ. The variance analysis results of the average number of fixation points.

LAeq(dBA)	*Mean*	*Std.*	*F*	*P*
45dBA	19.68	5.45	5.17	0.023
55dBA	21.86	6.65		
65dBA	21.80	7.44		

Generally speaking, with the increase of the environmental noise level, the accuracy of visual tracking test decreases, the reaction time increases, and the average number of fixation points (complete one curve) increases. When disturbed by the high level environmental noise, the participants take more efforts to maintain the attention level, however the performance of the visual tracking test still declined. Also, a small number of participants performed better in the high-level environmental noise, it's may be due to the individual's preferences for sound sources.

4. Conclusion

The findings of this study provide further evidence for the influence of environmental noise on individuals ′ attention in learning spaces. In conclusion, it was found that a higher environmental noise level led to lower accuracy and the longer reaction time, and attention was disturbed more seriously; and, a higher environmental noise level required more fixation points to capture information which means more efforts were needed to maintain the attention. The results suggest that the environmental noises of high density cities have a serious impact on students' attention, more attention should be given to reduce the environmental noise.

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