Influence of Color and Brightness Condition on Annoyance Evaluation Caused by Road Traffic Noise in Indoor Environment

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ABSTRACT

Through laboratory experiments, how the color and brightness condition affected noise annoyance evaluation of road traffic noise with noise level of $L_{Aeq.20sec}$ of 35, 45, 55 and 65dB was explored in the situation of study and living rooms. The visual factors consisted of four colors and three brightness levels. Altogether 30 subjects participated in the experiments. The results showed that comparing with color condition, the influence of brightness condition on noise annoyance caused by road traffic noise was more obvious in the indoor environment. Low brightness condition significantly increased subjective noise annoyance. Furthermore, color and brightness had interaction effects on noise annoyance evaluation caused by road traffic noise. Therefore, it was possible to attenuate noise effects by improving lighting condition or creating a reasonable combination of color and brightness conditions.

INTRODUCTION

As concerns on the living environment grow, noise problem has caught more and more attention of people, which is also an increasingly serious problem for residence. According to the survey of acoustic environment in Tianjin in 2006, 75% of city residents believed that road traffic noise was the main noise sources of city. The quality of residential acoustical environment directly affects people's life, work and health. It has become a basic requirement for the construction of "green housing" to improve the quality of residential acoustical environment and provide a quiet living environment for the residents. Noise annoyance is a generally applicable subjective evaluation index, which characterize the general and comprehensive damage on people caused by noise source in specific situations. Compared with other effects caused by noise, noise annoyance evaluation can be directly associated with human universal comfort degree and subjective condition , and the annoyance degree has become the main reference index to measure noise effect and make noise policy.

Influence of audio-visual interaction on noise annoyance is a research started from the end of last century which tried to reduce noise annoyance by sense of vision. The main purpose of those studies was to create comfort visual scenes to “cover” the hearing discomfort. The research was more common in Europe and Japan, which object mainly focused on the change of source color and the application of green plants in the outdoor environment. Our group have studied the effects of color and brightness on noise annoyance evaluation. However, previous study only chose single color as the object. Whether the results can be applied to the actual scenes still need to be discussed. In this study, specific indoor scenes were set to research the effect of color and brightness on noise annoyance evaluation.

In this study, a laboratory research method was used to explore how the visual factors influence the annoyance evaluation caused by traffic noise through changing the color (red, yellow, green, blue) and brightness (high, medium, low) of the indoor

environment including the study and living room. Through statistical analysis, this research aimed at finding the effect of scene, color, brightness and sound pressure level on the noise annoyance evaluation and to discuss how to create a "quiet" space in the indoor environment.

METHODS

Experimental subjects

30 subjects who came from Tianjin University participated in all the experiments of this study and their average age was 23.8 years old. The ratio of male to female was 2:3.

Audio-visual stimuli

Four main factors were considered in this experiment: the type of indoor scenes, the color and brightness of the wall and the road traffic noise level. The study and living room were chosen as the indoor scenes for this study. A graphical 3D model of the real scenes was made in Google SketchUp. The visual factors consisted of four colors and three brightness levels. Considering that color with high chromatic were rarely used in the real indoor environment, red, yellow, cyan and green were selected with saturation of 6. The brightness level had three levels: 'H'(high), 'M'(midium) and 'L'(low), marked as 5, 6.5, 8 in the brightness standard. Figure 1 showed the visual stimuli in this experiment. The audio signal was recorded in the urban city. Four fragments of traffic noise level with $L_{Aeq.20sec}$ of 35, 45, 55 and 65dB were obtained within Cooledit software.

Altogether combination of 2×4×3×4 audio-visual stimuli were scheduled for the experiment.

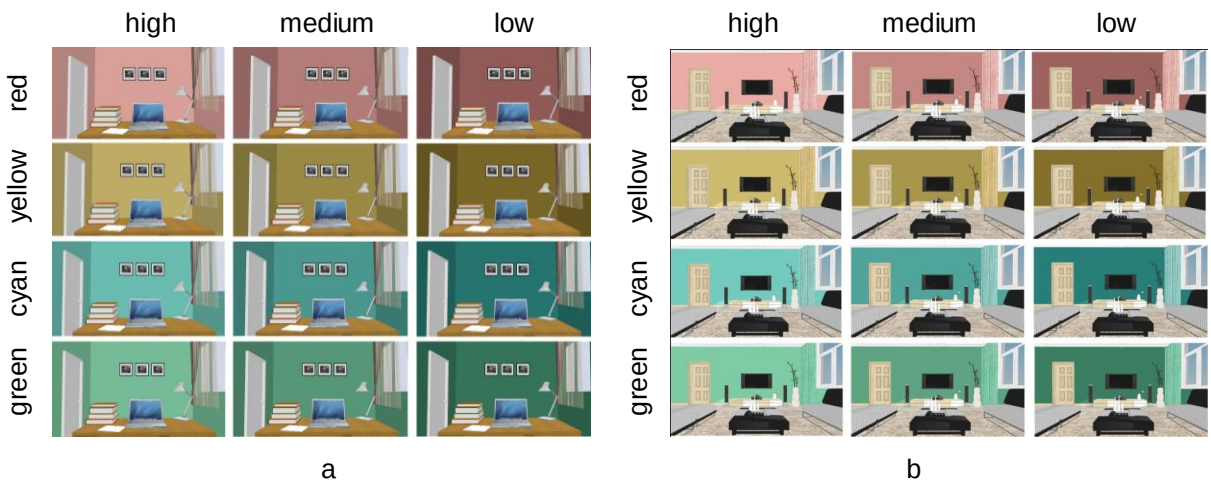


Figure 1 the indoor scenes in the experiment(a:study room , b:living room)

Experimental design

The experiment was carried out in an semi-anechoic chamber. Audio-visual stimuli were presented using 47 inch Panasonic plasma TV and loudspeaker. While the visual stimuli appeared in the TV screen, the road traffic noise would be broadcasted through the loudspeaker. Three subjects were seated in the middle of the anechoic chamber and the chairs were placed with angle less than 60 degree in order to remove the influence of chromatic aberration. The experiment setting was shown in Figure 2.

During the experiment, each audio-visual stimulus was played for 20 seconds, and than the subjects were asked to use 5-point verbal scale (not at all annoyed, sight annoyed, moderately annoyed, very annoyed, extremely annoyed) to estimate the annoyance caused by the audio signal.

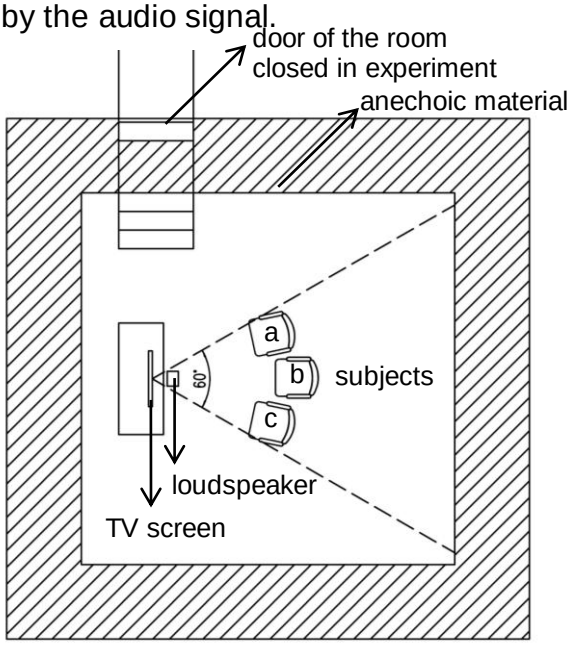


Figure 2. the experiment setting

RESULTS

Variance analysis of the noise annoyance evaluation

Table 1 shows the analysis of variance of annoyance evaluation caused by road traffic noise. As can be seen from the table, both brightness and noise level affected noise annoyance evaluation significantly in the indoor environment, and they also had significant interaction effect on the annoyance evaluation. The influence of color was not significant, but the interaction of color and noise level appeared significant, as well as color and brightness.

Table 1 Variance analysis of the noise annoyance evaluation

Dependent Variable:evaluation

Souce	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3736.933[a]	95	39.336	123.245	.000
Intercept	21785.500	1	21785.500	68256.930	.000
Brightness	2.338	2	1.169	3.663	.026*
Level	3660.073	3	1220.024	3822.502	.000**
Color	1.704	3	.568	1.779	.149
Scene	.009	1	.009	.027	.869
Brightness * Level	7.334	6	1.222	3.830	.001**
Brightness * Color	10.537	6	1.756	5.502	.000**
Brightness * Scene	1.026	2	.513	1.607	.201
Level * Color	27.317	9	3.035	9.510	.000**
Level * Scene	.465	3	.155	.486	.692
Color * Scene	.879	3	.293	.918	.431
Error	888.567	2784	.319		
Total	26411.000	2880			
Corrected Total	4625.500	2879			

Analysis of the influence of brightness on the annoyance

Through statistical analysis, the difference of the noise annoyance evaluation given by subjects between three different brightness conditions ('H', 'M', 'L') was significant at 0.05 level. The annoyance in low brightness condion was obviously higher than other two conditions as shown in figure 3. Consequently, avoiding the use of color with low brightness was an appropriate solution to improve acoustic comfort in the indoor environment.

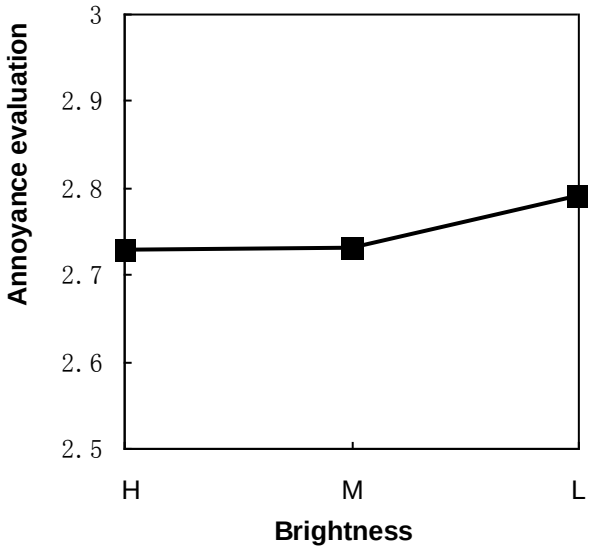


Figure 3 the result of noise annoyance evaluation in different brightness conditions

(1:not at all annoyed, 2:sight annoyed, 3:moderately annoyed, 4:very annoyed, 5:extremely annoyed)

From the figure 4 it could be shown that the variety of noise annoyance evaluation influenced by brightness was different under each color conditions. For instance, with the increase of brightness, the noise annoyance decreased obviously for red condition. Through statistical analysis, the difference was significant at 0.01 level. For green and cyan, the annoyance evaluation was lowest in medium brightness condition.Comparing the four figures, we could found that the difference of annoyance between diffetent brightness was more significant for red and green than yellow and cyan. Therefore, in the indoor environment, when choosing warm colors as the overall color, it would be a good suggestion to select some colors with high brightness. On the contray, if the overall color was cold colors such as green and cyan, whether high brightness or low brightness were not benificial to improve the indoor acoustic environment. It was better to choose cold colors with medium brightness.

Figure 5 shows the influence of brightness on traffic noise annoyance evaluation in different noise level. As can be seen from the figure, the veriation trend of noise annoyance evaluation was similar with noise level of 35, 45 and 55dB, appearing that the lower the brightness was, the higher the noise annoyance was. However, when noise level was 65dB, the annoyance evaluation was lowest in medium brightness. As a result, when the traffic noise level of indoor environment was lower, which means that the residential area was far away from the city roads, improving the overall brightness of the environment could further reduce the annoyance caused by traffic noise. Conversely, when the noise level was higher, medium brightness would be helpful to reduce the annoyance caused by traffic noise.

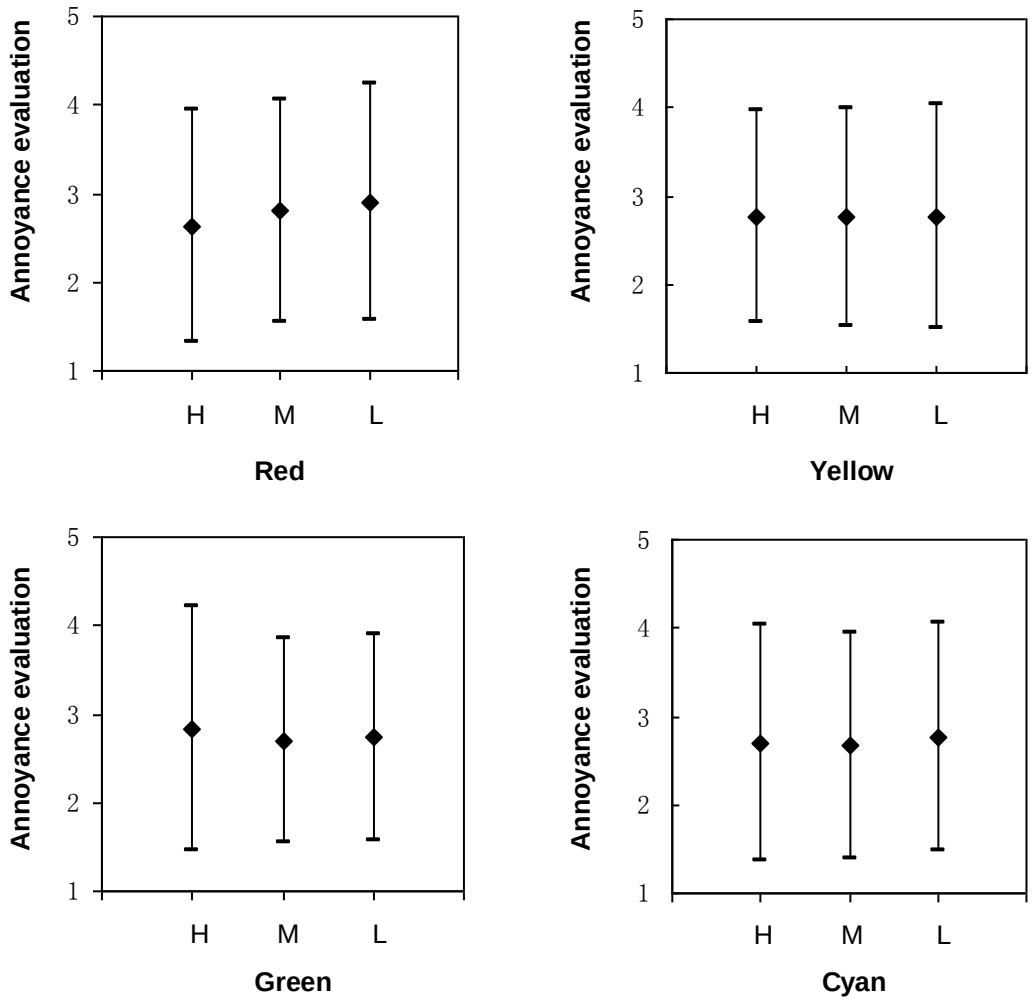
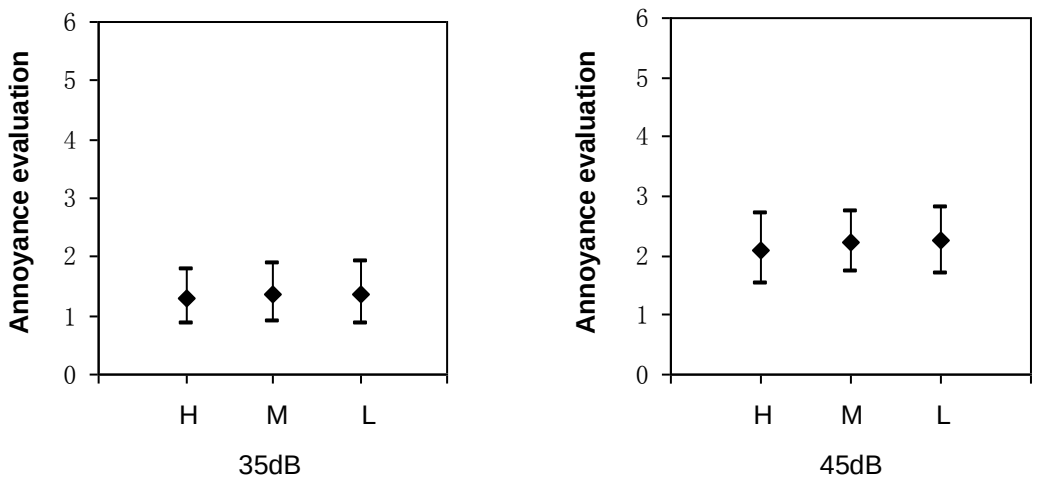


Figure 4 the influence of brightness on annoyance evaluation in different color conditions
(1:not at all annoyed, 2:sight annoyed, 3:moderately annoyed, 4:very annoyed, 5:extremely annoyed)



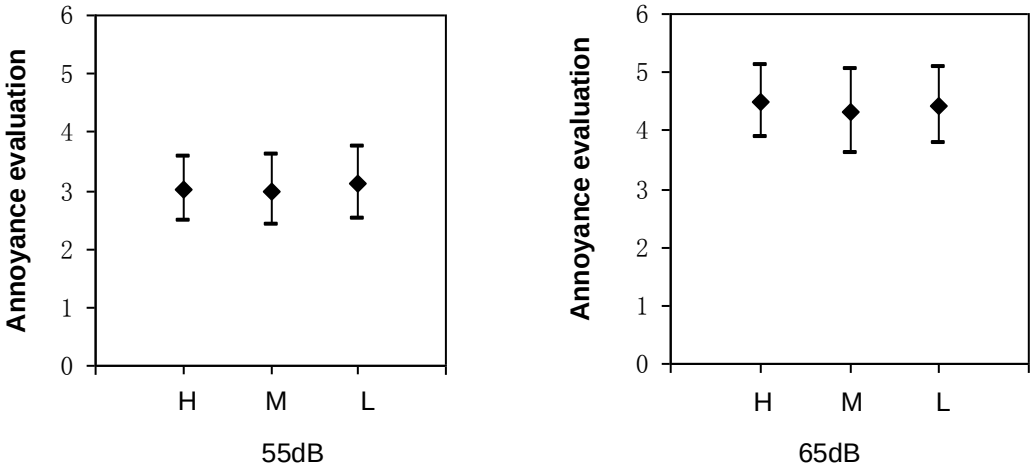


Figure 5 the influence of brightness on annoyance evaluation in different noise level

(1:not at all annoyed, 2:sight annoyed, 3:moderately annoyed, 4:very annoyed, 5:extremely annoyed)

Analysis of the influence of color on the annoyance

Table 2 Variance analysis of the noise annoyance evaluation in different brightness conditions

Dependent Variable:evaluation

brightness	Souce	Type Ⅲ Sum of Squares	df	Mean Square	F	Sig.
High	Color	5.608	3	1.869	6.372	.000**
	Level	1342.458	3	447.486	1525.222	.000**
	Scene	.417	1	.417	1.420	.234
	Color * Level	13.483	9	1.498	5.106	.000**
	Color * Scene	1.158	3	.386	1.316	.268
	Level * Scene	.625	3	.208	.710	.546
Midium	Color	2.653	3	.884	2.599	.051
	Level	1103.868	3	367.956	1081.252	.000**
	Scene	.096	1	.096	.283	.595
	Color * Level	16.403	9	1.823	5.356	.000**
	Color * Scene	.984	3	.328	.963	.409
	Level * Scene	.419	3	.140	.410	.746
Low	Color	4.053	3	1.351	4.031	.007**
	Level	1209.278	3	403.093	1202.669	.000**
	Scene	.551	2	.551	1.644	.200
	Color * Level	12.434	9	1.382	4.122	.000**
	Color * Scene	.786	3	.262	.840	.504
	Level * Scene	.845	3	.282	.782	.472

Table 2 shows the variance analysis of the noise annoyance evaluation in three different brightness conditions. It could be found from the table that in addition to noise level, the influence of color on noise annoyance evaluation was significant in high and low brightness conditions (significant at 0.01 level), which was not in medium brightness. However, there was a very significant interaction on annoyance evaluation between color and noise level in every brightness condition. Therefore, while the overall brightness of the indoor environment was given, it was also possible to improve the indoor comfort degree through choosing a reasonable color in order to attenuate the noise effect.

CONCLUSIONS

Comparing with color condition, the influence of brightness condition on noise annoyance caused by road traffic noise was more obvious in the indoor environment. But color and brightness had interaction effects on the noise annoyance evaluation. Therefore, it was possible to improve the indoor visual conditions and attenuate noise effects by creating a reasonable combination of color and brightness factors.

Low brightness condition significantly increased subjective noise annoyance. Consequently, it was better to avoid using colors with too low brightness in the indoor environment . when choosing warm colors as the overall color, such as red and yellow, it would be a good suggestion to select some colors with high brightness. On the contray, if the overall color was cold colors such as green and cyan, medium brightness color would be a good choice.

Finally, it was an effective way to change the indoor visual conditions and improve the indoor environmental comfort degree by creating a reasonable combination of visual factors, such as changing the color of wall, floor and furniture to regulate the whole environmental color or changing the lighting conditions to adjust indoor environmental brightness. To sum up, in the indoor environment, it was possible to attenuate noise effects by creating a reasonable combination of non acoustic factors such as color and brightness.

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