Influence of visual factors on noise annoyance evaluation caused by road traffic noise in indoor environment

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ABSTRACT

Through laboratory experiments the variation of noise annoyance caused by road traffic noise with $L_{Aeq.20sec}$ of 35, 45, 55 and 65dB under different visual conditions in study and living rooms was explored. The experimental result shows that in the indoor environment the influence of brightness perception on noise annoyance caused by road traffic noise was more obvious, and the effect of color perception on noise annoyance evaluation was not significant though color and brightness had an interaction effect on noise annoyance evaluation. Therefore, both improving the lighting conditions and creating a reasonable combination of color and brightness condition was helpful for the noise control in the indoor environment.

Keywords: Visual Factors, Noise Annoyance Evaluation, Indoor Environment I-INCE Classification of Subjects Number(s): 63.2

1. INTRODUCTION

As rapid development of China, noise problem becomes a serious problem for residence. According to the social survey on acoustic environment held in Tianjin in 2006, 75% of urban resident believed that road traffic noise was the main noise sources in 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 resident. 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 general comfort degree and subjective situation, and the annoyance extent could be used as the main indicator to evaluate noise effect and make noise policy.

Studies on influence of audio-visual interaction on noise annoyance began from the end of last century. The main purpose of those studies was to create comfort visual scenes to “cover” the hearing discomfort. In the former study held by our research group have explored the effects of color and brightness on noise annoyance evaluation caused by road traffic noise in experiment conditions. Whether the results can be applied to the actual scenes still needs more discussions. In this study, specific indoor scenes were set to explore the effect of color and brightness on noise annoyance evaluation caused by road traffic noise.

In this study, laboratory experiments were 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 such as the study or the living room. Through statistical analysis, the effect of scene, color, brightness and sound pressure level on the noise annoyance evaluation caused by road traffic noise would be found and how to create a "quiet" space from visual design in the indoor environment would be discussed.

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2. METHOD

2.1 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.

2.2 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 road traffic noise which was recorded along the roads in Tianjin. Four fragments of road traffic noise with noise level of $\boldsymbol{L}_{Aeq.20sec}$ of 35, 45, 55 and 65dB were obtained by using Cooledit software.

Altogether 96 audio-visual stimuli were used for the experiment.

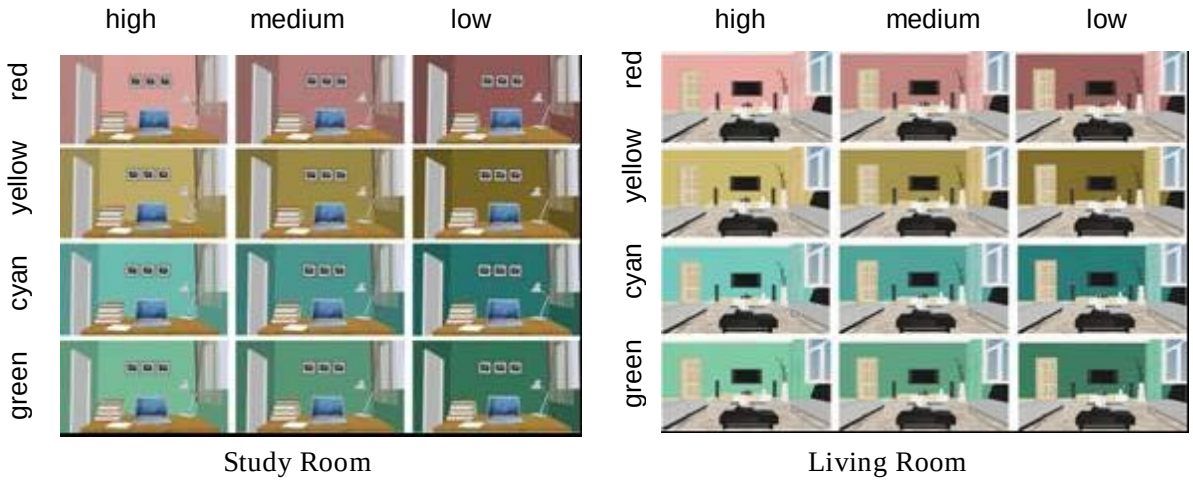

Figure 1 – The indoor scenes with different color and brightness of walls

2.3 Experiment 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 on 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. After that the subjects were asked to evaluate the annoyance caused by the audio signals using 5-point verbal scale (not at all annoyed, sight annoyed, moderately annoyed, very annoyed, extremely annoyed).

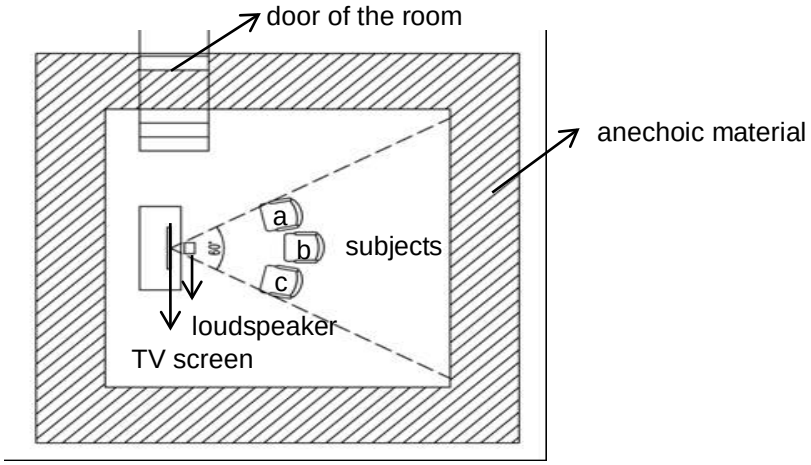

Figure 2 – The experimental settings

3. RESULTS AND DISCUSSIONS

3.1 Variance Analysis of the Noise Annoyance Evaluation

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

Table 1 –Variance analysis of the noise annoyance 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			

3.2 Analysis of the Influence of Brightness on the Annoyance

Through statistical analysis, the difference of the noise annoyance evaluation given by subjects among the 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 to use the color with low brightness was an appropriate solution to improve acoustic comfort in the indoor environment

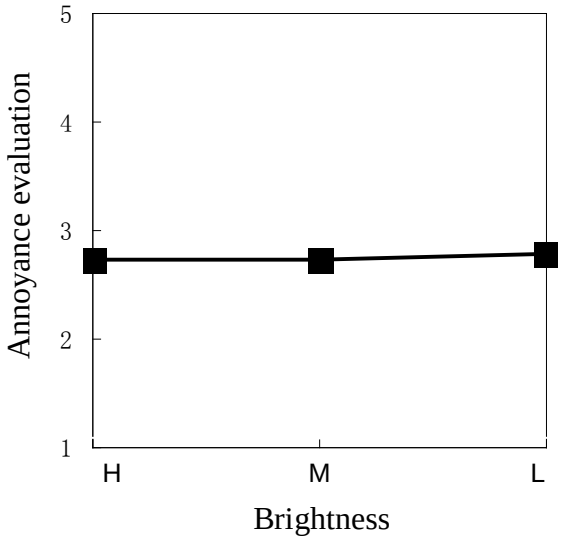

Figure 3–The result of noise annoyance evaluation in different brightness conditions (1:not at all annoyed, 2:sightly annoyed, 3:moderately annoyed, 4:very annoyed, 5:extremely annoyed)

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.

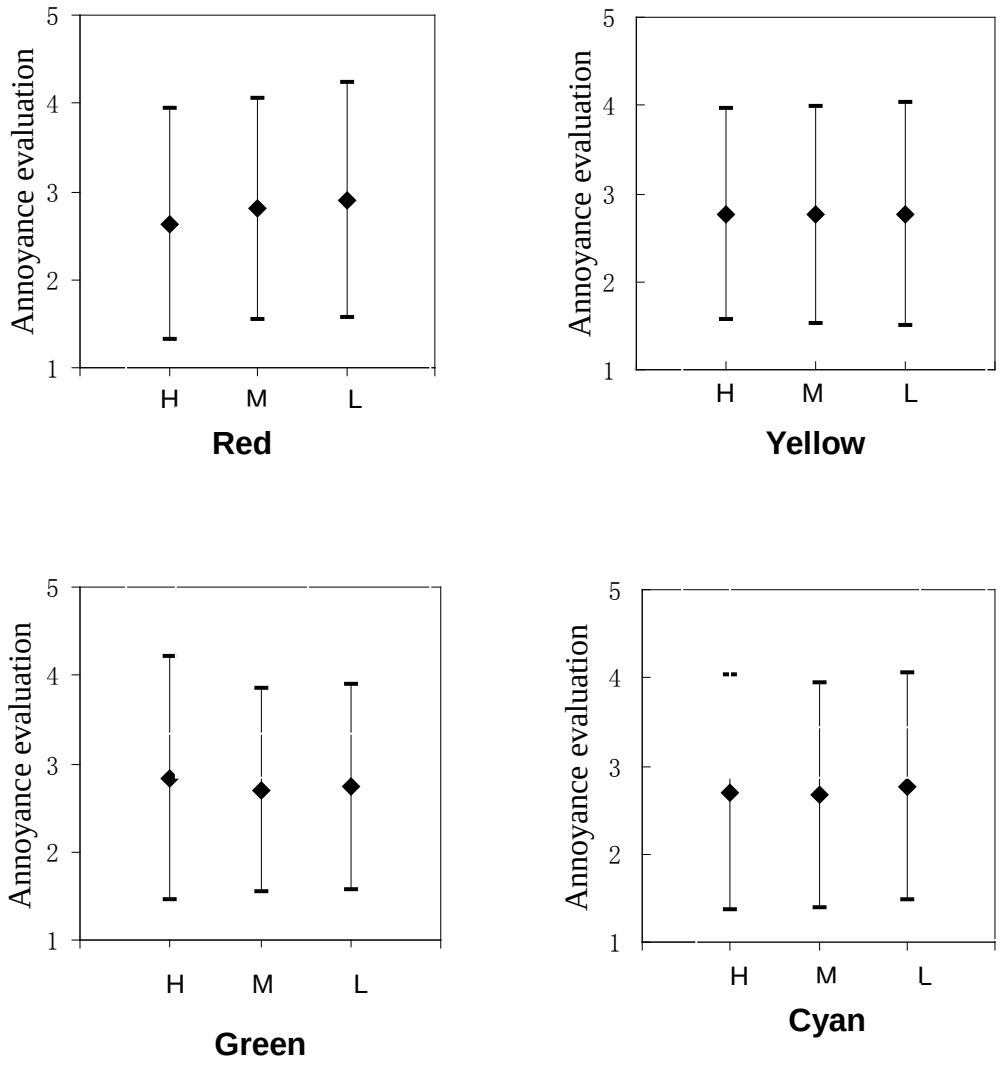

Figure 4– The influence of brightness on annoyance evaluation in different color conditions (1:not at all annoyed, 2:sightly annoyed, 3:moderately annoyed, 4:very annoyed, 5:extremely annoyed)

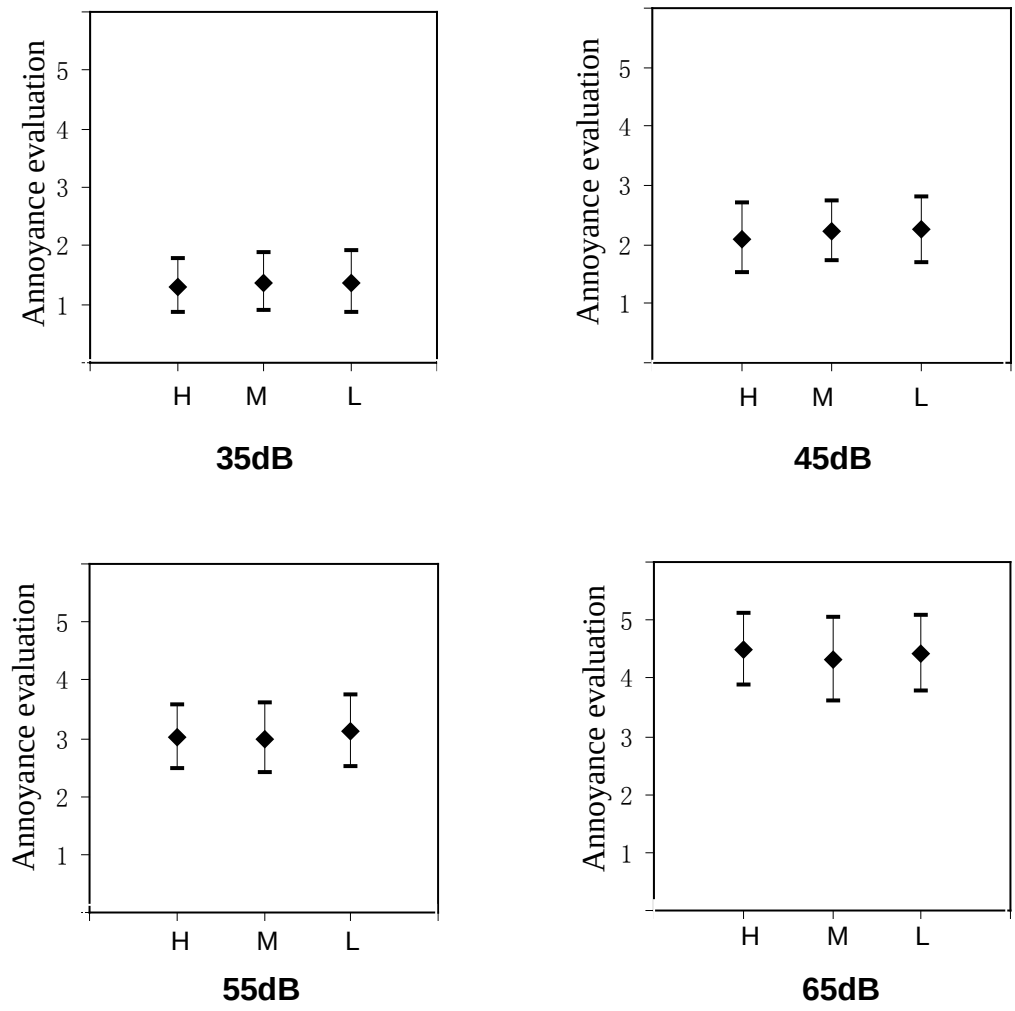

Figure 5–The influence of brightness on annoyance evaluation under different noise level (1:not at all annoyed, 2:sightly annoyed, 3:moderately annoyed, 4:very annoyed, 5:extremely annoyed)

3.3 Analysis of the Influence of color on the annoyance evaluation

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). However, color had no significant influence on noise annoyance evaluation in medium brightness conditions. Color and noise level had a very significant interaction on noise annoyance evaluation whatever brightness condition was. Therefore, if the overall brightness condition 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 adverse effect brought by road traffic noise.

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

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
Medium	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

4. 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 high brightness. On the contray, if the overall color was cold colors such as green and cyan, medium brightness of the 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 adverse effects brought by road traffic noise by creating a reasonable combination of non acoustical factors such as the color and the brightness.

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