On the Study of Effects of Views to Water Space on Noise Annoyance Perceptions at Homes

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ABSTRACT

Noise annoyance poses various adverse effects on health and well-being of human beings. Earlier studies have shown that greenery views perceived from the apartments can reduce traffic-induced noise annoyances as a result of audio-visual effects. This study intended to explore whether similar noise annoyance moderation effects could be provided by perception of water spaces. Specifically, this study aimed to explore and quantify the effects of different types of water views on noise annoyance. The relationship between restorative capacity of water and noise annoyance was also revealed. Three residential estates in Hong Kong with views to rivers and seas respectively were selected for this study. One thousand four hundred and forty-six respondents were successfully administered via a series of questionnaire surveys, and the noise levels at homes were predicted using CRTN method. Results were analyzed to formulate multivariate ordered logit models linking noise annoyance, views to different types of water spaces and personal characteristics of the respondents. Findings from the study can facilitate urban planners and building designers in planning water spaces near residential estates so as to reduce noise annoyance. Other than the findings arising from this study, the methodology formulated in this study can be applied to study the effect of perception of other types of water spaces.

Keywords: noise annoyance, water spaces, soundscape
I-INCE Classification of Subjects Number(s): 63.2

1. INTRODUCTION

World Health Organization has identified environmental noise as a threat to public health (1) and noise annoyance affected the well-being of individuals (2). Previous studies showed that degree of noise annoyance was positively related to exposed noise level (3,4) and the number of noise events (5). In addition, non-acoustical factors have also been found to play a crucial role in causing annoyance (6,7). Personal characteristics, such as noise sensitivity (8,9), could affect an individual's noise annoyance rating (10).

The degree of noise annoyance was also found to be affected by the visual settings of an environment (11,12). Visibility of noise source could lead to higher noise annoyance (13). Individuals who could see wind turbines from their homes would assign a higher noise annoyance rating at the same noise level (14). On the contrary, visibility of natural environment was generally found to be able to moderate noise annoyance. A positively evaluated landscape could lead to lower noise annoyance rating (15). In particular, greenery was found to possess the ability of moderating noise annoyance. Residents perceived "better" availability of green area could lower long-term noise annoyances from traffic noise (16). Individuals' noise annoyance at homes could be reduced if there were greenery views from their apartments (17).

Besides greenery, there were also studies focusing on the effect of aquatic environments on noise annoyance. People were found to be in favor of landscape containing water (18), and water space was usually found to be preferred due to its aesthetic quality (19). In a study focusing on eliciting the

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preferences of residents living near a canal, 66% of respondents stated that they would still choose houses near a canal if they moved (20). People in Hong Kong were willing to pay by 3% more for having a full sea view in their apartments (21). Laumann et al. (22) found that aquatic environments provided cognitive restoration and relaxation, which could enhance well-being of individuals. Natural and built scenes containing water could induce higher perceived restorative power than those without water (23).

However, there were also studies which showed contrary results that aquatic scene might not bear the capability of enhancing human well-being or providing restoration. For example, Van den Berg et al. (24) reported that the presence of water did not exert significant influence on the affective restoration.

In short, earlier efforts had mainly been put on revealing the relationship between water and restorative power. However, there were few studies focused on the relationship between water view and noise annoyance. Although Li et al. (10) showed that sea view from homes could increase the likelihood of the residents to feel less annoyed by traffic noise, the question of whether different types of water features will provide different degree of noise annoyance moderation has yet to be explored. Also, there were also thoughts that views to water space could provide relaxation and restoration, which can enhance well-being of individuals (25). It would be natural to have a hypothesis that restorative quality provided by water view is the major reason for reducing the noise annoyance.

Of the main interest of this study is to reveal if views to different types of water space, in particular river and sea, can provide different degree of noise annoyance moderation capability. Also, this study aimed to reveal the relationship between restorative capability of water and noise annoyance.

2. METHODOLOGY

2.1 Questionnaire Survey

Questionnaire surveys were used as the main survey tool in this study. The questionnaire form comprised three major sections. The first section aimed at eliciting the perceived water and greenery view of the respondents at home. A five-point verbal scale was used to rate the amount of water or greenery views respondents perceived at homes (‘None’, ‘A Little Bit’, ‘Some’, ‘A Lot’ and ‘Plenty’). As a pilot study, respondents with water view perceived from their apartment in Shatin and Tai Po sites were also asked to rate the level of restorative capability of the view using a five-point verbal scale (‘Not at all’, ‘Slightly’, ‘Moderately’, ‘Very’ and ‘Extremely’).

The second section aimed at eliciting the self-reported noise annoyance induced by road traffic in the past 12 months. An eleven-point numerical scale (‘0’ stands for ‘Not at all annoyed’ and ‘10’ stands for ‘Extremely annoyed’) as recommended by ISO standard 15666 (26) was used to rate the level of noise annoyance. Besides noise annoyance, respondents were also asked if they feel annoyed by obnoxious smells, dust and dirt, as well as vibrations and tremors induced by road traffic. These questions were asked so as to remind them of other possible annoyance problems from road traffic (27).

In the third section, personal details such as age, education level, marital status and self-reported noise sensitivity together with the details of the dwellings were inquired. Respondents were inquired about the location, orientations and floor levels that their apartments were located.

2.2 Site Selection

Three residential sites were selected to conduct the questionnaire surveys and potential respondents would be randomly selected from these sites. . These sites were selected based on the following criteria. First, road traffic noise was the main noise source to the site. Second, since one of the objectives of the study was to reveal if different types of water features would moderate the noise annoyance ratings, residents living in some apartments should be exposed to (i) a sea view, (ii) a river view or (iii) both. As a result, the first selected site was located in Tsuen Wan, where sea views could be seen from some apartments of a housing estate. The second was located in Shatin, where some residents were exposed to a river view. The third site was located in Tai Po, where residents would be exposed to a sea view, a river view or both. Figures 1 to 3 are maps showing surroundings of these sites.

2.3 Noise Level Prediction

The noise levels at the respondents’ homes were predicted so as to facilitate the determination of the relationship between noise levels and annoyance ratings. Since it is impossible to access to each apartment of the buildings to perform noise measurements, noise levels were predicted by using Calculation of Road Traffic Noise (CRTN) method (28). The noise estimation from CRTN is mainly based on the distance between the main road and the apartment, traffic volume and the ratio of heavy vehicles. With the information provided by the respondents, CRTN method was applied to predict the noise levels at 1m from the façade of the buildings.

In order to validate the estimations of noise levels, noise level measurements were also taken in the sites. Sound levels at different floor level (roof top, mid-level and ground floor level) and different locations (1m from the façade) of the buildings were measured. Sound level measurements were taken at peak hours during sunny days. Traffic parameters for CRTN prediction were also recorded using video camera when sound level measurements were carried out.

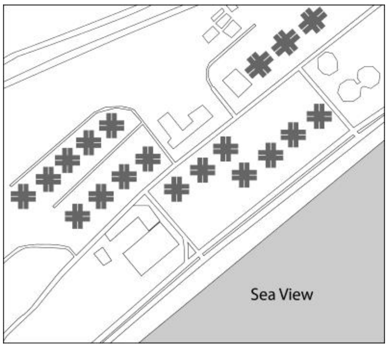

Figure 1 – Tsuen Wan Site

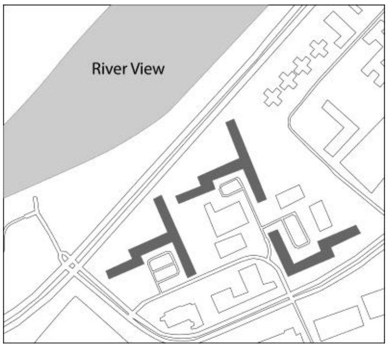

Figure 2 – Shatin Site

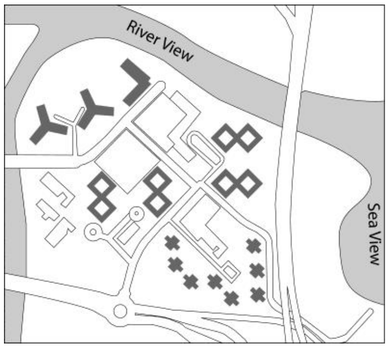

Figure 3 – Tai Po Site

3. RESULTS AND DISCUSSIONS

3.1 Participants' And Dwellings' Characteristics

After conducting a full-scale questionnaire survey, relevant information was extracted from a total number of 1496 responses for performing data analysis. The range of noise levels at 1m from façade of apartments was estimated to be 49-75 dbA, with mean and standard deviation of 65.0 and 3.1 respectively. The mean and standard deviation of noise annoyance ratings were found to be 4.1 and 2.3. Table 1 shows the personal and dwelling characteristics of the responses and Figure 4 shows the distribution of noise levels at homes.

Data analysis of the survey results were divided into two parts. The first part focused on the restorative capability of the water view and the second part aimed at revealing if different types of water features would affect noise annoyance rating differently.

3.2 Water Restorative Capability and Noise Annoyance

Given the question about restorative capability of water view was asked in two of the three sites, only data extracted from these two sites was used to analyze the relationship between restorative capability and noise annoyance. For simplicity, the annoyance ratings were segmented into two groups - highly annoyed (annoyance rating equal to or higher than 7), and slightly or moderately annoyed (annoyance rating lower than 7). Meanwhile, levels of restorative capability were also segmented into two groups - moderately or highly restorative (levels of restorative capability equal to or higher than 3) and slightly restorative (levels of restorative rating lower than 3). Due to the ordinal nature of these two grouped variables, crosstabs and Spearman's rank correlation analysis were applied to analyze the data. The p-value of Chi square test of crosstabs was found to be 0.035. It could be concluded that there was relationship between restorative capability of water view and noise annoyance rating at 5% significance level. The Spearman correlation coefficient was found to be -0.116 (significant at 0.035). The annoyance rating would become lower when the restorative capability was higher. This implied that residents would feel less annoyed if they perceived the water view to be more restorative.

Most previous studies postulated that the power of aquatic environment in enhancing well-being came from aesthetics of the environment. This part of study suggested that the restorative capability of the environment might also play a role. In particular, individuals with a higher self-rated restorative capability of water view tended to be less annoyed. More in depth studies were suggested in order to understand the full picture concerning the relationship between restorative power and individual's well-being. It will also be worth studying the interaction effects of aesthetics and restorative power on individual's well-being.

Table 1 – Personal and dwelling characteristics

Description	Number (Percentage)
Gender	
Male	648 (43.3%)
Female	848 (56.7%)
Age	
≤19	110 (7.4%)
20-29	202 (13.5%)
30-39	341 (22.8%)
40-49	353 (23.6%)
50-59	317 (21.2%)
≥60	173 (11.6%)
Marital Status	
Single	449 (30.0%)
Married	1047 (70.0%)
Education Level	
Elementary or high school	914 (61.1%)
College	455 (30.4%)
Post-graduate or above	127 (8.5%)
Time of Stay at Home	
≤6 hours a day	531 (35.5%)
>6 hours a day	965 (64.5%)
Apartment Floor Level	
1-5 /F	269 (18.0%)
6-10 /F	245 (16.4%)
11-15 /F	210 (14.0%)
16-20 /F	231 (15.4%)
21-25 /F	148 (9.9%)
26-30 /F	192 (12.8%)
31-35 /F	127 (8.5%)
36-40 /F	74 (4.9%)

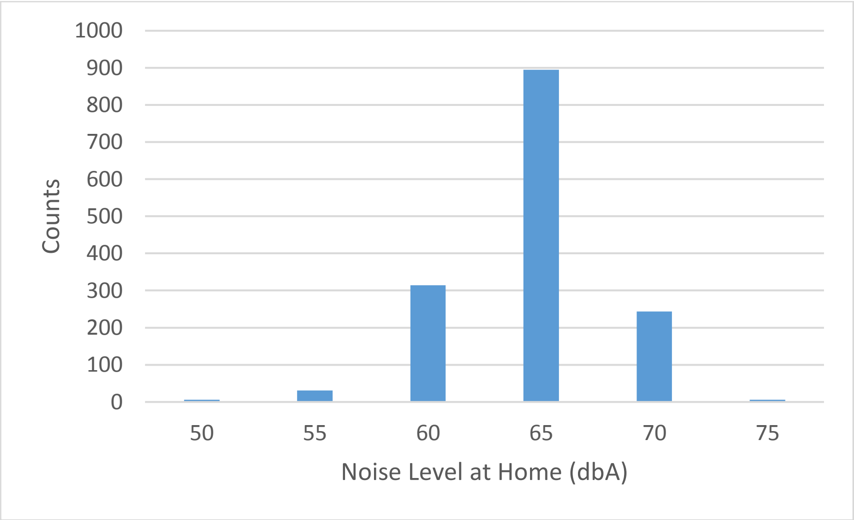

Figure 4 – Distribution of noise levels at homes

3.3 Water Features and Noise Annoyance

In the second part of the analysis, a probabilistic model linking noise annoyance with the parameters affecting the annoyance levels was formulated using all 1496 responses. Since the annoyance rating was ordinal in nature, ordered logit model was considered an appropriate model to predict the occurrence of a particular annoyance rating. The probability of assigning a particular annoyance rating y is:

$$P(Annoyance\ rating = y) = \frac{1}{1 + \exp(Z - \mu_y)}$$

where Z is a function of parameters which affect the annoyance rating, μ_y is the threshold value estimated for annoyance rating y. It is assumed that Z is a linear additive function:

$$Z = \sum_{k=1}^{n} \beta_k X_k + \varepsilon$$

where β_k's represent the coefficient estimates for the independent variables X_k's such as age, education level, gender, self-rated sensitivity, perceived water view and noise level at the respondents' homes. When formulating the model, the original eleven-point annoyance ratings were regrouped into three levels. The three levels were coded as 0, 1 and 2 to represent low, moderate and high annoyance levels. Some of the independent variables were also regrouped into fewer levels. Table 2 shows the coding of the independent variables used to form the model.

Table 2 – Coding of independent variables

Variables	**Coding**
Gender	0 (Male) 1 (Female)
Age	0 (Below 40 years old) 1 (40 years old or above)
Marital Status	0 (Single) 1 (Married)
Education Level	0 (Below postgraduate) 1 (Postgraduate or above)
Time Staying At Home	0 (6 Hours or below everyday) 1 (Above 6 hours every day)
Floor Level of Apartment	0 (25th floor or below) 1 (Above 25th floor)
Health Status	0 (Bad and moderate health status) 1 (Good health status)
Noise Sensitivity	0 (Low sensitivity) 1 (Moderate Sensitivity); 2 (High Sensitivity)
Perceived Greenery	0 (No greenery at all) 1 (Greenery can be perceived)
Noise Level At Home	Numerical scale, in dbA
Perceived Water View	0 (No water view at all) 1 (Sea can be perceived) 2 (River can be perceived) 3 (Both seas and river perceived)
Perceived Noise Barrier	0 (No noise barrier at all) 1 (Noise barrier without vegetation) 2 (Noise barrier with some vegetation) 3 (Noise barrier with plenty of vegetation)
Site	0 (Tsuen Wan) 1 (Shatin) 2 (Tai Po)

The validity of the formulated ordered logit model can be checked by a few factors. The p-value of likelihood ratio Chi square test was estimated to be smaller than 0.00001, which rejected the null hypothesis that all coefficients were zero at 1% significance level. The validity of the model could further be reflected by McFadden's ρ^2, which was estimated to be 0.14. The goodness-of-fit of the model was considered reasonable. Table 3 shows the results of the constructed ordered logit model.

Table 3 – Coding of independent variables

Variables	**Estimated Coefficients**
Gender	0.07
Age	0.59**
Marital Status	-0.08
Education Level	0.97**
Time Staying At Home	0.53**
Floor Level of Apartment	-0.28*
Health Status	-0.35*
Noise Sensitivity	
1	0.81**
2	1.19**
Perceived Greenery	-1.42**
Noise Level At Home	0.133**
Perceived Water View	
1	-0.45**
2	-0.13
3	-1.25*
Perceived Noise Barrier	
1	0.86*
2	1.63*
3	1.33**
Site	
1	-0.02
2	-0.01
Cut Points	
Annoyance Level 1	8.14
Annoyance Level 2	11.41

*significant at 5% level
**significant at 1% level

Results of the ordered logit model showed that increase in noise level at home would lead to an increase in annoyance level, which was in line with the expectation that noise level was positively correlated with noise annoyance rating. Similar to results from previous studies (8,9), results derived from this study indicated that increase in self-rated noise sensitivity would also lead to a higher annoyance level. Of other personal characteristics, individuals who were older than 40 years or rated themselves healthy would have a higher annoyance rating. Education level could also affect noise annoyance. Individuals with a postgraduate degree or above would rate the noise annoyance higher. Residents who stayed more than 6 hours at home a day tended to be more annoyed. Location of apartments could also affect noise annoyance rating. Annoyance rating of individuals who live above 25th floor would be lower. The estimated coefficients for the variable "Site" were found to be statistically insignificant, which means that noise annoyance rating is not site specific.

Of the main interest of the results is that an individual having a sea view or both sea and river view at home would report a lower annoyance rating. Interestingly, having a river view only might not be able to moderate an individual's annoyance rating. This might be due to the amount of water being perceived or building views behind the river which might influence the noise annoyance levels. Further studies are needed to explore this. Besides, a greenery view at home could also moderate noise annoyance. When comparing with greenery, annoyance moderation capability of greenery view from home was found to be better than water views, no matter it was a sea view or the combination of sea and river views.

By assuming the mean value of other independent variables, it was possible to estimate the probability of assigning different annoyance ratings for various views of water features. Table 4 shows the probability computed.

Table 4 – Probability of assigning different annoyance ratings for various views of water features

Water Views	**Probability**		
	Annoyance 0	Annoyance 1	Annoyance 2
Sea View	0.482	0.479	0.040
Both Sea and River View	0.674	0.308	0.018

It could be concluded the capability of noise annoyance moderation was different for different types of water features. It can further be seen that the probability of assigning low annoyance rating was higher when having both sea and river views from home. On the contrary, the probability of assigning moderate or high noise annoyance rating was higher if individuals could only perceive sea views from their apartments.

4. CONCLUSIONS

In this study, it was found that restorative capability of water view could be related to noise annoyance at home. In short, views with higher restorative rating would lead to lower annoyance rating. Besides, relationship between noise annoyance and different types of water features were successfully revealed. In particular, views with sea or both sea and river could provide noise moderation effect. It is expected that the methodology adapted in this study can be used to reveal the relationship between noise annoyance and other types of water features.

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