On the study of the effects of sea views, greenery views and personal characteristics on noise annoyance perception at homes

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Noise annoyance has caused significant adverse impacts on human beings and numerous efforts have been spent on mitigating annoyance problems. Natural greenery has been shown to be able to moderate annoyance problems at home but this conclusion was drawn without properly controlling the potential confounding factors. Furthermore, few have explored the moderation effect of a sea view. Accordingly, this study formulated a multivariate model to examine the impacts of natural views as well as personal characteristics on annoyance perception. A housing estate was selected in Hong Kong as the survey site for which some of the residents were exposed to greenery views, sea views, or both from their homes. Eight hundred and sixty-one responses were collected via questionnaire surveys and analyzed using an ordered logit model. The results suggest that both a greenery view and a sea view can moderate annoyance responses. Several individual's personal characteristics are found to affect individuals' annoyance perception. The duration of time spent daily at home is shown to have an influence on the moderation impact exerted by a greenery view, while the age of an individual is shown to have an influence on noise moderation effect exerted by a sea view. © *2012 Acoustical Society of America*. [DOI: 10.1121/1.3681936]

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I. INTRODUCTION

Noise annoyance has caused significant adverse impacts on the well-being of residents.[1–3] It is estimated that about 30% of the population in the European Union suffers from noise annoyance.[4] The number of noise complaints continues to rise sharply in both developed and developing countries.[5,6] In order to mitigate noise problems, a majority of past and even current efforts have been focused on lowering sound pressure levels as they have often been thought to be linked with noise annoyance.[7–10] Higher sound levels generally lead to higher annoyance,[11] even though different types of sounds moderate noise annoyance to different degrees.[12,13] The number of noise events are also found to influence noise annoyance perception.[14] On the other hand, there is growing evidence that the noise annoyance perception varies with individual's personal characteristics. However, the exact relationships between personal characteristics and noise annoyance have not yet been well established and some results are even conflicting. Miedema and Vos[15] found that more educated individuals tended to report higher annoyance, but Klæboe *et al.*[16] and Fields[17] did not find any relationship between education status and noise annoyance perception. Pathak *et al.*[18] revealed that unmarried people were more significantly affected by noise annoyance but Klæboe *et al.*[16] and Fields[17] did not find any relationship between marital status and annoyance responses. Klæboe *et al.*[16] found that the youngest group suffered more from noise annoyance, but Miedema and Vos[5] found that not only the younger group but also the older group suffered more from noise annoyance. Above all, noise sensitivity is the only personal characteristics that has been confirmed to exert influences on the perception of noise annoyance.[15,17] More sensitive individuals have higher annoyance responses. Other personal characteristics like age and education attainment may also have an influence on noise annoyance perception, but their effects have not been fully confirmed. The divergence in findings may be due to the difference in demographic or cultural characteristics of the samples used in different studies.

Besides acoustical and personal characteristics, aesthetically pleasing scenes have been shown to be able to influence an individual's noise annoyance response by altering the perception of soundscape. Bad visual scenes could contaminate judgments of what is being heard.[19] Visibility of noise sources or wind turbines directly from homes generally made their residents suffer more from noise annoyance.[20,21] By contrast, a positively evaluated landscape,[22] a simple presence of, or a better accessibility to parks and nearby green spaces could lower dissatisfaction with traffic noise[23] or could reduce the long-term noise annoyances of resident dwellers.[24] Despite so, most of the past efforts tended to only suggest that there was an association between the existence of natural greenery and noise annoyance reduction. It is only until recently that the amount[24] and the nature of greenery have been shown to exert different moderation effects on noise annoyance.[25]

The observations that a pleasing visual greenery view can moderate noise annoyance responses can be explained by resorting to findings from a number of psychology and acoustic related literature that visual conditions can modify the auditory perception of subjects.[26] Perception of nature attracts and holds a person's attention effortlessly and to some degree involuntarily. Being in nature gives a person a

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sense of being away from daily routines that impose demands on directed attention, thus reducing stress from the acoustical environment.[27] Stress from urban life in general, such as noise from traffic, may motivate people to look for a natural environment,[28] as contact with the natural environment promotes a relatively effective way for reducing stress compared to the ordinary urban environment.[29]

Apart from greenery environments, aquatic environments have received growing attention lately as people tend to appreciate the aesthetic value of water.[30,31] Water is one of the most important and attractive visual elements of the landscape.[32] Water features generally received favorable ratings because of their association with scenic beauty.[33,34] People in general differentiated landscapes with and without water and favored landscapes with water.[35,36] People had strong preferences for water and were even willing to pay more for a view with water.[37]

However, there is mixed evidence about the positive impacts of water sources on individuals' well-being or their restorative power. On one hand, aquatic environments are thought to be able to enhance individuals' well-being by providing cognitive restoration and relaxation.[38] Water spa is often associated with therapy, relaxation, and restoration. Natural and built scenes containing water were associated with higher preferences, greater positive effect, and higher perceived restorative power than those without water.[39] Arguably, certain visual properties of aquatic environments contribute to the attractive and potentially restorative characteristics. For example, water reflects light in interesting ways and certain lines and patterns of light are considered to be more restorative than others.[40] On the other hand, water sources have not been shown to provide restoration and relaxation effects. A scene containing water was not found to have a greater capability of alleviating fear, anger, and stress compared to a scene without water.[41] The presence of a creek was not found to lower stress, anger, depression, and tension.[28] In view of inconclusive evidence on the restorative effects provided by water sources, it is hypothesized in this study that perception of a sea view can moderate noise annoyance at home and the length of stay at home will affect its moderation effect. Above all, noise annoyance is influenced by sound properties, personal characteristics, and environmental characteristics. A conceptual model has been formulated to depict the above picture and is shown in Fig. 1.

Based upon the interrelationships shown in the conceptual model, a multivariate stochastic model has been constructed by embracing annoyance rating as the dependent variable and all the confirmed and potential factors as the independent variables (except for the number of noise events which tends to be associated with annoyance aroused in very short time frame). Given the perception of greenery views and sea views are included, the constructed model can subsequently be used for estimating the size of moderation effects exerted by the perception of sea and greenery views on noise annoyance perception. Additionally, it is also our intent to examine whether the noise annoyance moderation effects of sea and greenery views vary with an individual's personal characteristics by including the interaction terms into the model.

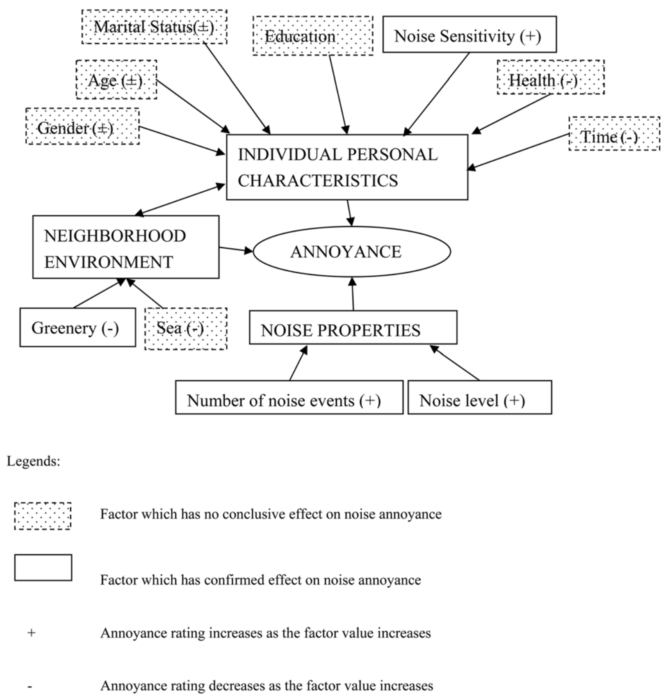


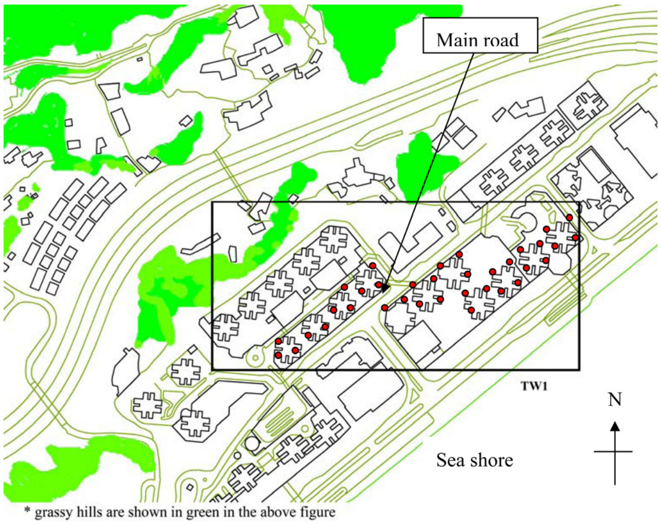
FIG. 1. A conceptual model showing the relationship between noise annoyance and its factors.

II. METHODOLOGY

A. Studied sites

Field studies were conducted in order to examine whether a sea view would increase the likelihood in moderating an individual's annoyance response at home, and to examine whether a respondent's personal characteristics would exert impacts on his annoyance response. Residential estates are ideal survey locations as their residents are exposed to different types of views but are having similar noise sources in their homes. In addressing these objectives, the studied estate was selected according to two major criteria. First, some of its residents were exposed to sea views, greenery views, or both from their homes so that their impacts could be compared. Second, the estate should embrace several high-rise housing blocks, and road traffic was the major noise source. Based on the above criteria, an estate was selected from Tsuen Wan (see Fig. 2 for the neighborhood map of the studied site). The sea is situated at the southeast direction of the estate. Grassy hills, which are the major type of greenery that can be perceived by some of the residents in the studied estate, are mainly situated at the west and north direction of the estate. Residents from this targeted estate were randomly approached for the survey.

Based on the information of home orientation and floor level provided by respondents in the surveys, a Calculation of Road Traffic Noise[42] (CRTN) prediction model was applied to estimate the noise levels to which respondents were exposed at the façades of their homes. CRTN estimates traffic noise level mainly based on the distance of the receiver point from the road, the traffic volume on the road, the light-to-heavy vehicle ratio, and the average vehicle speed. CRTN has been widely applied to predict noise level



Sound measurement points for buildings in the residential estate

FIG. 2. (Color online) The neighborhood and the building block layout map for the surveyed estate in Tsuen Wan.

on a building façade when direct access to residential homes is not possible.[15,43] This method has also been validated for predicting the noise level at a simple road-façade system in Hong Kong within a standard error of 2 dB.[44] The site-specific constants embedded in the CRTN prediction model were derived using the data collected by site measurements at both the ground and roof level of each studied building.

Four Brüel & Kjær sound level meters (2 type 2238F and 2 type 2260B) were used for measuring the equivalent sound pressure levels (L_{Aeq}) and the percentile levels L_{A10} and L_{A90} in the present study. These four meters were divided into two groups and each group consisted of one type 2238F and one type 2260B meter. During each measurement, each group of meters was set in a particular orientation with the type 2238F meter at the roof-top and the type 2260B meter at the podium level. All the microphones were fixed at 1 m away from the roof-top façade or the podium boundary wall. Each measurement lasted for 30 min and the measurement orientations were changed after each measurement. Noise measurements were carried out between 10:00 to 17:00 on sunny days.

The traffic parameters associated with the CRTN prediction model for computing the concerned road noise levels were recorded using video cameras at the same time when the noise measurements were carried out. These data enabled necessary noise level corrections to be made to reflect the worst scenario situation under the CRTN framework.

The noise levels at the respondents' home façades were estimated using the distance correction formula depicted in the CRTN model and the measured podium level noise levels (in the right orientation). The measured roof-top noise levels were also used in such prediction separately, but the difference between the two predictions are in general within 2 dB(A), which is within the range of the CRTN prediction accuracy. The predictions using podium level noise levels were adopted in the foregoing statistical analysis.

B. Survey instrument

This study is a part of a larger study exploring the effects of nature on noise annoyance moderation. Survey was designed to collect data for formulating a quantitative model to examine the noise annoyance responses at homes. Researchers and student helpers were recruited and trained to conduct the survey. The surveys were conducted between 10:00 a.m. and 4:00 p.m. on consecutive Saturdays and Sundays. During the surveys, respondents were randomly approached on the footpaths near the main road around the residential estate as shown in Fig. 2 and were invited for the survey if they had indicated that they were residents. Respondents agreed to participate in the survey were instructed to mark their responses.

Questionnaire was used as a major survey instrument. The questionnaire form is generally similar to the one adopted in one of our earlier studies[25] but has been modified to facilitate the investigation of the effects of sea views, receptors' personal characteristics on their noise annoyance perception. It comprises two major sections. The first section contains an eleven-point numerical scale for eliciting respondents' annoyance ratings for their homes (0–10 graded: "0" for "not at all" and "10" for "extremely"). The second section aims at collecting information on individuals' personal characteristics. A five-point scale (1–5 graded: "1" for "very sensitive" and "5" for "not sensitive at all") was used for respondents to report the levels of noise sensitivity themselves. Also, a five-point scale (1–5 graded: "1" for "very bad" and "5" for "very good") was utilized for respondents to report their current health conditions. An additional question on the duration of time spent at home daily was also included with a four-point scale (1–4 graded: "less than 6 hours," "between 6 and 12 hours," "between 12 and 18 hours," and "more than 18 hours") for analyzing the effect of duration of time spent at homes on individuals' noise perception.

Respondents were requested to report whether they had any sea views at homes on a dichotomous scale (0–1 graded: "no" and "yes"). Meanwhile, they were also requested to report the amount of greenery vegetation to which they were exposed from their homes on a three-point scale (0–2 graded: "no greenery vegetation," "a little greenery vegetation," and "plenty of greenery vegetation"). Besides sea and greenery views, each respondent was also requested to provide information on the orientation of his/her home and the floor level on which his/her home resided.

The data collected on these scales were then used for formulating dichotomized scales to facilitate later multivariate analysis. The dichotomized scale for age, time spent at home and level of education attainment were formulated based on 50-percentile value of the respondents' population. For example, the respondents were dichotomized into two age groups (one above and equal to 40, and one below 40). Table I shows a set of dichotomized codings assigned for the multivariate analysis.

Response data would be excluded from our analysis if respondents failed to provide all the necessary information. Consequently, 861 valid responses are used in our final model formulation. The attribute levels and codings assigned

TABLE I. Summary statistics of the personal and dwelling characteristics of the respondents and their assigned codings in the development of the ordered logit model.

Description	Number of counts	Assigned codings
GENDER (gender)		
Male	394 (46%)	0
Female	467 (54%)	1
AGE (age)		
≤29	97 (11%)	0
30–39	241 (28%)	0
40–49	284 (33%)	1
50–59	179 (21%)	1
≥60	60 (7%)	1
MARRIAGE (marital status)		
Not married	136 (16%)	0
Married or others	725 (84%)	1
EDU (education level)		
High school or below	440 (51%)	1
College or above	421 (49%)	0
SENSITIVITY (noise sensitivity)		
Very sensitive	80 (9%)	0
Quite sensitive	262 (30%)	0
Average	369 (43%)	0
Not quite sensitive	102(12%)	1
Not sensitive at all	48 (6%)	1
HEALTH (self-reported health status)		
Very bad	38 (4%)	
Bad	154 (18%)	0
Average	386 (45%)	0
Good	213(25%)	0
Very good	70 (8%)	1
TIME (Daily time spent at home)		
Less than 6 h	297 (34%)	0
Between 6 and 12 h	438 (51%)	1
Between 12and 18 h	112 (13%)	1
More than 18 h	14 (2%)	1
GREEN1 (a little greenery view)		
No	233 (27%)	0
Yes	628 (73%)[a]	1
GREEN2 (plenty of greenery view)		
No	809 (94%)	0
Yes	52 (6%)[b]	1
SEA (sea view)		
No	353 (41%)	0
Yes	508 (59%)	1
OCCUPATION[e]		
Self-employed	102 (12%)	N/A
Employed	522 (61%)	N/A
Student	7 (1%)	N/A
Housewife	117 (14%)	N/A
Retired	69 (8%)	N/A
Others	24 (3%)	N/A
Noise levels at homes	55.4–69.5 dB(A)[c] [average 64 dB(A)]	N/A[d]
Total number of respondents	861	N/A

[a]Three hundred and eighty-eight of these respondents whose homes also have sea views at the same time.
[b]Twenty of the respondents whose homes have sea views at the same time.
[c]Sound pressure levels at respondents' homes, which are the energy-equivalent levels based on the thirty-minute measurements inside the residential buildings predicted using the CRTN model.
[d]Continuous dB level is used in coding.
[e]Total does not add up to 100% as some respondents refused to reveal their occupation.

for the studied factors in our model development are shown in the last column of Table I.

Ordered logit model was chosen to model the annoyance responses collected during the survey. Given its output is always confined to values between 0 and 1, ordered logit model is always used to predict the probability of occurrence of a particular outcome, for example, the probability of assigning a low annoyance rating in this study. Basically, ordered logistic regression is a form of regression which exists to handle the case for which the dependent variable has classes more than two and is not continuous in nature. The ordered nature of the regression model fits our need in modeling the annoyance responses from respondents as the annoyance responses were collected using an ordinal 11-point scale which is discrete (not continuous) in nature.

Ordered logistic regression was used to determine the percent of variance in the dependent variable that can be explained by the independents. Of particular, the logit estimates can be used to rank the relative importance of independents. The independents can be of any types such as ordered category and continuous category and the values of any independent variable can be ranged from negative infinity to positive infinity. This caters for the analysis of socioeconomic variables which are ordered in nature and acoustical variable which are continuous in nature.

McFadden's ρ^2 is used to evaluate the goodness of fit of the multivariate model. McFadden's ρ^2 is analogous to R-square commonly applied in linear regression in that the log likelihood of the intercept model can be regarded as the total sum of squares while the log likelihood of the full model can be regarded as the sum of square errors. The log likelihood of the full model will be relatively small in case this model is more likely to occur, and therefore a small ratio of log likelihoods indicates that the full model is better fit than the intercept model.[45]

A logit function can be formulated from the ordered logit model estimates and used to predict the probability for an individual to assign a particular annoyance rating. The probability of assigning a particular annoyance rating can be estimated as follows:

$$\mathrm{P}(\text{annoyance} = \mathrm{y}) = \frac{1}{1 + \exp(Z_i - \mu_y)}, \tag{1}$$

where Z_i assumes different value at different sound pressure level i, μ_y is the threshold value for annoyance rating y estimated for the ordered logit model and y ranges from 1 to 10. The dependent variable Z_i is assumed to be a linear additive function of the independent variable x_i:

$$Z_i = \sum_i \beta_i x_i + \varepsilon, \tag{2}$$

where β_i is the coefficient pertaining to x_i.

Equation (1) can be used to estimate the probability for an individual to assign a specific annoyance rating (i.e., 0, 1, 2, etc.) if the values of the variables listed in Eq. (2) are known. For the interests of this study, it would be meaningful to estimate the probabilities of giving a low annoyance response, i.e., an annoyance rating of lower than or equal to 4 by summing up the individual probabilities for assigning an annoyance rating from 0 to 4. The probabilities can be used to compute the odds ratio for giving a low annoyance response under a specific condition according to Eq. (3):

$$odds\ ratio = \frac{\frac{p_1}{1-p_1}}{\frac{p_2}{1-p_2}}, \quad (3)$$

where p_1 and p_2 represent the probabilities for assigning a low annoyance response for the particular groups to be compared

III. RESULTS

A trial run was conducted in September 2008 to remove any ambiguities arising from the content of the survey design and the method of delivering the survey. A full-scale survey was undertaken in October 2008 and finished in February 2010. Passers-by were randomly approached in the studied estate and invited for surveys. 1205 face-to-face surveys were successfully administered, 861 of which had provided adequate information for predicting the noise levels at the façades outside homes.

Table I shows the personal and dwelling characteristics of all the respondents. 61% of the respondents were over 40 years old. Nearly half of the respondents had received high school education or below. 61% of the respondents were employed and 12% were self-employed. Only a small percentage of the respondents were housewives (14%) or retirees (8%). The noise level at 1 m outside the façade of individual respondent's home was predicted to be lying within a range of 55–70 dB(A), with an average of 64 dB(A).

Table II shows a breakdown by the number of respondents according to different types of views at homes. Of the 861 surveyed respondents, 240 of whom had a little greenery view at homes, 32 had plenty of greenery view, and 100 had a sea view. 388 respondents had a little greenery view and a sea view at homes, while 20 had a sea view and plenty of greenery view at homes. The remaining 81 respondents did not have any sea or greenery view.

Figure 3 shows a breakdown by number of the respondents according to different annoyance ratings assigned for their homes. The frequency profile for the assigned annoyance ratings generally follows a normal distribution but slightly skews towards the lower end. A relatively small proportion of the respondents (24%) assigned extreme ratings (i.e., either an annoyance rating of 2 or below or an annoyance rating of 9 or above). 62% assigned an annoyance rating between 3 and 6.

TABLE II. A breakdown by the numbers of respondents according to the types of views at homes.

Type of view at home	Number of respondents
A little greenery view only	240
Plenty of greenery view only	32
Sea view only	100
A little greenery view and a sea view	388
Plenty of greenery view and a sea view	20
Do not have any greenery view or sea view	81
Total	861

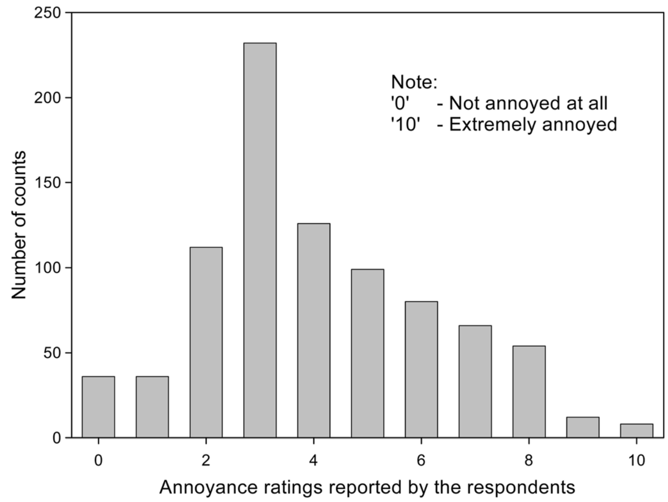


FIG. 3. A breakdown by numbers of the respondents according to the annoyance ratings.

A. Model for predicting annoyance ratings

Responses collected during surveys were used for constructing the following ordered logit model:

$$\begin{aligned} Y_i^* = &\beta_{NOISE}NOISE + \beta_{AGE}AGE + \beta_{EDU}EDU \\ &+ \beta_{GENDER}GENDER + \beta_{MARRIAGE}MARRIAGE \\ &+ \beta_{HEALTH}HEALTH + \beta_{SENSIVITY}SENSITIVITY \\ &+ \beta_{TIME}TIME + \beta_{SEA}SEA + \beta_{GREEN1}GREEN1 \\ &+ \beta_{GREEN2}GREEN2 + \varepsilon_i, \end{aligned} \quad (4)$$

where β_k s represent the coefficient estimates for factors X_k, Y_i^* is the noise annoyance rating assigned by a respondent for his home on an 11-point scale, NOISE represents the sound pressure level at the respondent's home [expressed in terms of $dB_{Leq}(A)$], AGE represents the age group into which the respondent falls, EDU represents education level, GENDER represents gender, MARRIAGE represents marital status, HEALTH represents self-rated health status, SENSTIVITY represents self-rated auditory sensitivity, TIME represents duration of time spent at home, SEA represents sea views, GREEN1 and GREEN2 are dummy codings used for representing different amount of greenery views to which the respondent's home was exposed.

GREEN1 refers to visibility of a little greenery view at home and GREEN2 refers to visibility of plenty of greenery views at home. This follows a standard procedure recommended for econometric regression analysis in handling qualitative and categorical variables.[46] This segmentation procedure enables the investigation on whether different amount of greenery would lower the annoyance ratings to different degree.

As the constructed ordered logit model is reasonably fit by the data (with a McFadden's ρ^2 value of 0.17), it can be used to portray the annoyance responses. Table III lists the estimated coefficient values for various factors. The sign of the coefficient gives the direction of relationship between the studied factor and the annoyance rating. The signs obtained for the various factors are in line with our priori expectations. For example, a positive coefficient for age suggests that the assigned annoyance rating is higher if an individual belongs to the older group. Meanwhile, a negative coefficient obtained for noise sensitivity suggests that the assigned annoyance rating will be lowered if an individual is considered himself to be "not noise sensitive at all" instead of "very noise sensitive." The coefficient value of the variable NOISE gives the rate of change in likelihood of assigning a particular annoyance rating with respect to a change of 1 dB(A) noise level. The positive coefficient suggests a higher annoyance rating for an increment in noise level.

The likelihood in assigning a particular annoyance rating for home is influenced by many factors in addition to the sound pressure level at home. Age, education level, health status, noise sensitivity, duration of time spent daily at home, and greenery and sea views were all found to exert influences (i.e., significant at 95% confidence level). On the contrary, gender and marital status were not found to alter the likelihood (i.e., insignificant at 95% confidence level).

TABLE III. Coefficient estimates for the ordered logit model portraying the noise annoyance relationship at homes.

Model fitting information			
Number of observations			861
Log likelihood function			−1513.304
McFadden's ρ^2			0.17
Attribute	Coefficient (β)	p-value	Odds ratio
Index function for probability			
Constant	−1.588	0.109	N.A.
NOISE	0.061	0.000[a]	N.A.
AGE	0.543	0.000[a]	0.58[b]
EDU	−0.313	0.000[a]	1.37[c]
GENDER	0.042	0.612	N.A.
MARRIAGE	−0.071	0.369	N.A.
HEALTH	−0.320	0.000[a]	1.38[d]
SENSITIVITY	−0.485	0.000[a]	1.62[e]
TIME	−1.408	0.000[a]	4.09[f]
SEA	−0.919	0.054[a]	2.51[g]
GREEN1 (a little)	−1.738	0.000[a]	5.69[h]
GREEN2 (plenty)	−1.911	0.000[a]	6.76[h]
Threshold parameters for index			
μ_1	0.000	0.000[a]	N.A.
μ_2	0.444	0.000[a]	N.A.
μ_3	1.214	0.000[a]	N.A.
μ_4	2.244	0.000[a]	N.A.
μ_5	2.776	0.000[a]	N.A.
μ_6	3.245	0.000[a]	N.A.
μ_7	3.756	0.000[a]	N.A.
μ_8	4.445	0.000[a]	N.A.
μ_9	5.534	0.000[a]	N.A.
μ_{10}	6.076	0.000[a]	N.A.

[a]Significant at 95% confident level.
[b]Increase in odds if the age of an individual is "equal to or greater than 40."
[c]Increase in odds if the education attainment of an individual is "college" or above.
[d]Increase in odds if an individual does not rate his health condition as "good" or "very good."
[e]Increase in odds if an individual rates his noise sensitivity status as average, sensitive, or very sensitive.
[f]Increase in odds if an individual spends less than half of a day at home.
[g]Increase in odds if an individual does not have any sea view at home.
[h]Increase in odds if an individual does not have any greenery view at home.

B. Likelihood of giving low annoyance responses

Table III lists the model estimates for the developed ordered logit model. The estimate values can be used to predict the probabilities for giving a low annoyance response under a set of individual characteristics and noise level e.g. an average surveyed individual personal characteristics and average noise exposure level, i.e., 64 dB(A). Table IV shows the computed probabilities for individuals having different personal characteristics to give a low annoyance response. For instance, the probability for an average individual to give a low annoyance response at 63 dB(A) is 0.46, and drops to 0.44at 64 dB(A) and further drops to 0.43 at 65 dB(A). This trend is in line with our expectation since the likelihood of assigning a lower annoyance rating decreases with an increase in the noise level at home.

On the other hand, the probabilities of giving low annoyance responses at 64 dB(A) are computed to be 0.49 and 0.37 for younger (aged below 40) and older respondents (aged above 40), respectively. There is a 49 and 37 % chance that a younger individual and an older individual will give a low annoyance response, respectively.

Further, there is a 60% chance that an individual will give a low annoyance response if he has a longer stay at home (i.e., spending more than 12 hours daily at home). The chance significantly lowers to 27% if an individual has a shorter stay at home (i.e., spending less than 12 hours at home). Moreover, there is a 55% chance that an individual having a sea view at home to give a low annoyance response and the probability of giving a low annoyance response is higher if he has a greenery view at home (65% for a little greenery view and 69% for plenty of greenery view).

C. Interaction effects between sea, greenery views, and personal characteristics

A sea view or a greenery view can help relieve the noise annoyance problem. It is further hypothesized that the size of moderation effects varies with some personal characteristics. To further investigate this, we have segmented our data according to different personal characteristics. Eight interaction terms (GREEN1 × AGE, GREEN2 × AGE, GREEN1 × Time, GREEN2 × Time, SEA × TIME, SEA × AGE, GREEN1 × SEA and GREEN2 × SEA) have been introduced in order to investigate whether there are any interaction effects between the perception of natural views and personal characteristics on noise annoyance perception. The final model form becomes

$$
\begin{aligned}
Y_i^* = &\beta_{NOISE}NOISE + \beta_{AGE}AGE + \beta_{EDU}EDU + \beta_{GENDER}GENDER + \beta_{MARRIAGE}MARRIAGE \\
&+ \beta_{HEALTH}HEALTH + \beta_{SENSIVITY}SENSITIVITY + \beta_{TIME}TIME + \beta_{SEA}SEA + \beta_{GREEN1}GREEN1 \\
&+ \beta_{GREEN2}GREEN2 + \beta_{GREEN1\times AGE}GREEN1 \times AGE + \beta_{GREEN2\times AGE}GREEN2 \times AGE \\
&+ \beta_{GREEN1\times TIME}GREEN1 \times TIME + \beta_{GREEN2\times TIME}GREEN2 \times TIME + \beta_{SEA\times TIME}SEA \times TIME \\
&+ \beta_{SEA\times AGE}SEA \times AGE + \beta_{GREEN1\times SEA}GREEN1 \times SEA + \beta_{GREEN2\times SEA}GREEN2 \times SEA + \varepsilon_i. \qquad (5)
\end{aligned}
$$

Table V shows the logit coefficient estimates for the model shown in Eq. (5). Results from Table V suggest that an interaction effect exists between perception of greenery views and duration of time spent at home, and between perception of sea views and age of individuals. The values of the estimates can be used to estimate the impacts of an individual's personal characteristics on annoyance moderation.

1. Greenery views and time spent at homes

Results from Table V suggest that an interaction effect exists between the perception of greenery views and the duration of time spent at home ($p < 0.05$ for GREEN1 × TIME and GREEN2 × TIME). The combined effect of greenery views and the duration of time spent at home was determined by using the coefficient values shown in Table V. For example, the overall effect of longer time spent and a little greenery view is equal to the summation of the individual effect of time spent, individual effect of a little greenery view, and the interaction effect between a little greenery views and longer time spent [i.e., $1/\exp(-1.408 + (-1.822) + 1.055)$ (coefficients from Table V) $= 8.8$ (which is shown in Table VI)]. Table VI shows all the computed odds ratios of giving a low annoyance response by a particular group of individuals after taking into account the interaction effects.

Likewise, for an individual having a shorter stay at home, the existence of plenty of greenery views at home is determined to be 7.3 times more likely to feel less annoyed than not having any greenery view (odds ratios $= 7.33$). It can be seen from Table VI that the likelihood drops to 6.2 times if only a little greenery view is perceived from his home instead (odds ratios $= 6.18$). On the contrary, for an individual who has a longer stay at home, the likelihoods of feeling less annoyed are similar irrespective of whether his

TABLE IV. Probabilities of giving a low annoyance response.

Respondent group	Probability of giving a low annoyance response
(A) An average individual	
63 dB(A)	0.46
64 dB(A)	0.42
65 dB(A)	0.43
(B) At 64 dB(A)	
AGE (age)	
< 39	0.49
≥40	0.37
EDU (education level)	
College or above	0.39
High school or below	0.46
HEALTH (self-reported health status)	
Average or below	0.39
Good or very good	0.46
SENSITIVITY (noise sensitivity)	
Very sensitive, sensitive or average	0.37
Not sensitive or not sensitive at all	0.49
TIME (daily time spent at home)	
Shorter stay (i.e., < 12 hours daily)	0.27
Longer stay (i.e., ≥ 12 hours daily)	0.60
GREEN1 (a little greenery view)	
No	0.23
Yes	0.65
GREEN2 (plenty of greenery view)	
No	0.23
Yes	0.69
SEA (sea view)	
No	0.30
Yes	0.55

TABLE V. Coefficient estimates for the ordered logit model after taking into account the interaction effects.

Model fitting information		
Number of observations		861
Log likelihood function		−1503.018
McFadden's ρ^2		0.17
Attribute	**Coefficient (β)**	**p-value**
Index function for probability		
Constant	−0.124	0.896
NOISE	0.057	0.000[a]
AGE	0.464	0.000[a]
EDU	−0.289	0.000[a]
GENDER	0.055	0.521
MARRIAGE	0.070	0.381
HEALTH	−0.310	0.000[a]
SENSITIVITY	−0.504	0.000[a]
TIME	−1.408	0.000[a]
SEA	−1.146	0.000[a]
GREEN1	−1.822	0.000[a]
GREEN2	−1.992	0.002[a]
GREEN1 × AGE	0.198	0.345
GREEN2 × AGE	−0.276	0.509
GREEN1 × TIME	1.055	0.000[a]
GREEN2 × TIME	1.256	0.009[a]
SEA × TIME	−0.211	0.195
SEA × AGE	0.439	0.010[a]
GREEN1 × SEA	0.135	0.464
GREEN2 × SEA	−0.678	0.089

[a]Significant at 95% confident level.

TABLE VI. Odds ratios of assigning a low annoyance response for different personal and dwelling characteristics which have interaction effects. Note that (1) level 0 of SEA, GREEN1, GREEN2 refer to not having any sea view, not having any greenery view, having a little greenery view, having plenty of greenery view, respectively, and 1 if otherwise. (2) Level 0 of TIME refers to shorter stay at home and 1 if otherwise. (3) Level 0 of AGE refers to a younger individual and 1 if otherwise.

Personal and dwelling characteristics	Coefficient (β) from Eq. (5)	p-value	Odds ratio
Younger individuals do not have any sea view at homes	0	0.000	1.00
Older individuals do not have any sea view at homes	0.464	0.000	0.63[a]
Younger individuals who have sea views at homes	−1.146	0.000	3.15[a]
Older individuals who have sea views at homes	−0.243	0.000	1.28[a]
Shorter stay at home with no greenery	0	0.000	1.00
Longer stay at home with no greenery	−1.408	0.000	4.09[b]
Shorter stay at home with a little greenery	−1.822	0.000	6.18[b]
Longer stay at home with a little greenery	−2.175	0.000	8.80[b]
Shorter stay at home with plenty of greenery	−1.992	0.000	7.33[b]
Longer stay at home with plenty of greenery	−2.144	0.000	8.53[b]

[a]Odds ratios computed relative to no visibility of sea and younger individuals.
[b]Odds ratios computed relative to no visibility of any greenery and shorter stay at home.

home has plenty or just a little greenery view (odds ratio 8.53 vs 8.80).

2. *Sea views at home and age*

Similarly, results from Table V also suggest that there is an interaction effect between perception of sea views and the age of an individual ($p < 0.05$ for SEA $\times$ AGE). Unlike greenery views, no interaction effect is observed between perception of sea and the duration of time spent at home ($p > 0.05$ for SEA $\times$ TIME). On the contrary, the age of an individual is found to influence the likelihood of the moderation effect of a sea view but not a greenery view on noise annoyance. A younger individual having a sea view at home is 3.2 times more likely to feel less annoyed than a younger individual not having any sea view at home (odds ratio = 3.15). Likewise, an older individual having sea views at home is only 1.3 times more likely to feel less annoyed than a younger individual whose home does not have any sea view (odds ratio = 1.28).

IV. DISCUSSIONS

To our knowledge, this is the first study that has successfully formulated a multivariate quantitative model to estimate the impacts of sea and greenery views, as well as individual personal characteristics on the noise annoyance responses at homes in the presence of many confounding factors.

Our present study suggests that the existence of sea views at homes can increase the likelihood of feeling less annoyed by noise at homes, which tends to confirm the restorative capability of sea. However, the moderation effects of noise annoyance due to sea view exposures may be stronger or weaker than those of greenery view exposures even though people tend to have stronger preferences for sea views.[39,47,48] This suggest that the annoyance moderation effects or restorative effects for different types of nature sceneries are not necessarily related to the degrees of preferences by individuals.

The duration of time spent daily by an individual at home affects his perception of noise. An individual is more likely to feel less annoyed by noise if he has a longer stay at home. This is probably due to so-called "habituation" or "adaptation" effect.[49] An individual becomes more adapted to a noise stimulus if it is presented continuously or repeatedly to an individual and therefore the response to that noise stimulus diminishes gradually. However, this is somewhat different than an earlier finding that a longer stay during daytime would provoke higher annoyance.[50]

On the other hand, the existence of a greenery view at home tends to lessen the time adaptation effect even though the combined effect of longer time exposure to a greenery view is still greater than the individual effect of a greenery view or time alone. For an individual having a longer stay at home, a sea view is shown to be more likely to reduce noise annoyance than a little or plenty of greenery views. Also, it does not appeal to be any difference for him to have plenty or a little greenery view at home. On the other hand, a sea view at home can benefit the younger individuals more than the older individuals by provoking a higher likelihood of reducing noise annoyance.

Nevertheless, it is noteworthy pointing out that our study design suffers from several shortcomings which may limit the generalization of our findings. Firstly, all our sampled respondents are drawn from a single housing estate despite a sufficient large number of its residents being sampled in this study. Secondly, due to resources constraints, the entire data collection period lasted for more than one year as surveys were only conducted during weekends and Sundays. This is based on an assumption that there were no major changes in sceneries and ambient noise levels of the studied sites such that the residents' perceptions would not alter in a long survey period. Thirdly, sampling bias may arise such that it may impair the representativeness of our findings. In order to minimize the sampling bias, in designing the sampling strategies, we had instructed our researchers and student helpers to randomly selected respondents from all ages, except for minors, The surveys were conducted between 10:00 a.m. and 4:00 p.m. on Saturdays and Sundays so as to minimize the chance of under-representing a majority of the working population who is required to work during weekdays. In fact, it can be seen from the statistical breakdown of the characteristics of the respondents that this sampling bias has been minimized. Fourthly, our model analysis is limited in the sense that it only includes a limited number of factors, e.g., sound pressure level in dB(A) as the major sound property parameter. However, it does not include other sound properties, view of roadways, length of residence, or personal attitudes towards sound which may have impacts on annoyance. Further studies and analysis should be conducted to embrace these factors. Also we assumed that there were no other dominant nearby or indoor noise source which might influence annoyance responses at homes. Fifthly, we only limited the scope of the study to cover only grassy hill and coastal sea. Consequently, our findings in relation to that the moderation effects of a sea view and a greenery view on noise annoyance are only valid for the built environment sceneries containing these two types of settings. Finally, we did not attempt to differentiate the types of settings and proportion of water sources despite the type of settings and proportion of waterscapes have been shown to exert influences on their moderation effects. Accordingly, it would be valuable to extend the investigation to other types of water sources like river, or fountains contained in gardens and parks before a more generalized effect of water sources can be studied.

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