Modelling noise annoyance responses to combined sound sources and views of sea, road traffic, and mountain greenery

Chi Kwan Chau, Tze Ming Leung, Jing Mei Xu, and Shiu Keung Tang

Citation: The Journal of the Acoustical Society of America **144**, 3503 (2018); doi: 10.1121/1.5083833
View online: https://doi.org/10.1121/1.5083833
View Table of Contents: https://asa.scitation.org/toc/jas/144/6
Published by the Acoustical Society of America

Modelling noise annoyance responses to combined sound sources and views of sea, road traffic, and mountain greenery

Chi Kwan Chau,[a] Tze Ming Leung, Jing Mei Xu, and Shiu Keung Tang
Department of Building Services Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong Special Administrative Region

(Received 3 July 2018; revised 22 November 2018; accepted 26 November 2018; published online 26 December 2018)

This paper studies the effect of human perception of visual and audio settings in an urban environment on annoyance. Video clips were projected onto a window panel of a living room to simulate neighborhood views containing different percentages of sea, mountain greenery, and road. These video clips were combined with audio stimuli corresponding to the congruent traffic and sea sounds. 246 participants were presented with 11 audio-visual stimuli and requested to respond to questions after the presentation. The collected responses were used to formulate a multivariate ordered logit model to predict the probability of evoking a high annoyance response. The findings revealed that views embracing mountain greenery close-by could enhance annoyance, which is contrary to other findings that greenery could always moderate noise annoyance. In addition, a 60% sea view was found to be able to yield 1 dB equivalent reduction in total sound pressure level. The trade-off was comparable to that achieved by having sea sound at a level 5 dB higher than road traffic noise. Exposure to road traffic noise level being 3 dB higher than sea sound level (i.e., signal-to-noise ratio = −3) together with a 60% sea view could provide an additional 1.5 dB equivalent reduction. © *2018 Acoustical Society of America*. https://doi.org/10.1121/1.5083833

[KVH] Pages: 3503–3513

I. INTRODUCTION

Excessively high noise exposure causes annoyance, impairs productivity (Björk *et al.*, 2006; Zimmer *et al.*, 2008), and may even pose adverse health impacts such as myocardial infarction (Babisch *et al.*, 2005; Willich *et al.*, 2006). Inevitably, it will impose significant adverse impacts on well-being and health, and incur a financial burden in the society. In response, considerable effort and resources have been spent on monitoring and mitigating the noise impacts in dense urban areas. However, most mitigation measures proposed or implemented have been mainly targeting sound pressure level reductions (Klæboe *et al.*, 2000; Korfali and Massoud, 2003; Sato *et al.*, 1999; Schultz, 1978). Unfortunately, ample evidence suggested that the relationship between exposure to sound pressure level and noise annoyance was not as strong as anticipated (Can *et al.*, 2011; Torija *et al.*, 2012). The influence of non-acoustical factors in relation to source, receiver, and context on community's noise reactions has been determined to be as significant as pure acoustical factors (Gidlöf-Gunnarsson *et al.*, 2007; King *et al.*, 2009). In view of this, problems arising from noise-induced annoyance can be resolved by also taking into account of major non-acoustical factors, e.g., behavioral and psychological factors, which influence responses due to unwanted sounds.

In cities highly exposed to a multitude of noise sources, alternative approaches are often needed to complement the traditional noise reduction strategies for resolving noise annoyance problems. To this end, several approaches to soundscape have been proposed. Attempts have been made to improve the acoustical environment by adding wanted sounds (e.g., water sounds, birdsongs) to unwanted sounds (e.g., road traffic noises) (Leung *et al.*, 2017; Jeon *et al.*, 2010). Water sounds in urban soundscapes containing combined sound sources have been repeatedly shown to be able to improve the acoustical environment by increasing the preference ratings (Galbrun and Ali, 2012; Jeon *et al.*, 2010, 2012; You *et al.*, 2010) or by reducing the perceived loudness of road traffic noise (Axelsson *et al.*, 2014; Nilsson *et al.*, 2010). However, human sound perception varies with the types of water sounds. For example, stream sounds produced higher preference ratings than waves in lakes when added to road traffic noises (Jeon *et al.*, 2010). Stream and lake sounds were more preferable to other types of natural sounds when added to road traffic and construction noises (Jeon *et al.*, 2010). Water sounds having a higher frequency content were rated as preferable (Watts *et al.*, 2009).

Alternative approaches capitalizing on the intricate effect of audio-visual interaction to moderate noise annoyance responses (Brown, 2012; Van Renterghem and Botteldooren, 2016) have also been actively investigated as earlier evidence suggested that responses in a bi-modal situation were quite different from those in a uni-modal situation (Galbrun and Calarco, 2014; Pheasant *et al.*, 2010). A number of studies showed that certain types of visual settings were able to alter human auditory perception (Erber, 1975; Galbrun and Calarco, 2014; Jeon *et al.*, 2011a; Preis *et al.*, 2015), although their influences were found to be greater on vision-dominated people (Sun *et al.*, 2018). Generally, visibility of built environments tended to undercut human perception of the acoustic environment. Views of built features like wind turbines

---

[a] Electronic mail: chi-kwan.chau@polyu.edu.hk

(Pedersen and Larsman, 2008; Szychowska *et al.*, 2018) aggravated noise annoyance problems. Not surprisingly, various types of natural scenes (De Coensel *et al.*, 2010; Gidlöf-Gunnarsson and Ohrström, 2010; Jeon *et al.*, 2011b) have been shown to be able to enhance acoustic comfort (Fastl, 2005; Jeon *et al.*, 2012; Li, 2006; Zhang and Kang, 2007). Greenery views moderated the long-term noise annoyance of dwellers (Gidlöf-Gunnarsson and Öhrström, 2007; Li *et al.*, 2010; Ulrich *et al.*, 1991). Views of vegetative noise barriers (Hong and Jeon, 2014; Maffei *et al.*, 2013) and sea views (Li *et al.*, 2010) could also moderate noise annoyance responses.

The relationship between noise annoyance response and views of different settings is attributable to a particular type of environmental features having the noise annoyance moderation capability, which is the likelihood of the features contained in a view to invoke a noise annoyance response lower than those under the baseline condition (Leung *et al.*, 2017). Noise annoyance moderation capacity varies with the type of natural features. Views of greenery were found to have stronger moderation capability than views of water space (Li *et al.*, 2010). Even for the same type of natural feature, auditory perception varies with its setting. Views of greenery were found to have stronger moderation capability in wetlands than in urban parks (Li *et al.*, 2010), while sea views had stronger annoyance moderation capability than urban river views (Leung *et al.*, 2017).

Auditory perception was found to be influenced by the number of natural features perceived in a view. Generally, the noise annoyance moderation capability of a visible environmental feature was considered to be proportional to its perceived percentage within a view. Views of moderate proportion of greenery were found to be able to render dwellers less annoyed by road traffic noise than views of only a small proportion of greenery (Li *et al.*, 2010). The prevalence of being moderately annoyed was found to be lower with a higher percentage of outdoor greenery viewed through the window (Van Renterghem and Botteldooren, 2016). Moreover, carefully designed proportions of audio-visual stimuli could contribute to the perception of tranquility in urban green space (Pheasant *et al.*, 2008; Pheasant *et al.*, 2010).

Quite often, the effect of multiple environmental features in a composite view on moderating noise annoyance was assumed to be independent of each other and the size of their combined effect was just a summation of size of their independent effects (Li *et al.*, 2010). In addition, the moderation capability was also affected by the distance of an environmental feature from the view inside a dwelling. The ability of a closer view of water space to moderate children frolic sound was found to be stronger than that of a distant view of water space, which was suggested to be attributed to coherence between source and sound (Ren and Kang, 2015). However, it is doubtful whether similar observations will be obtained for mountain greenery. A mountain greenery view is quite different from a horizontal water space view since the former will induce considerably different degrees of intervention at different distances from the viewer. There is a concern that obstruction of views may impede noise annoyance moderation capability.

Few quantitative information is available regarding the effects of composite visual scenes and water sounds on moderating the annoyance in dwellings induced by road traffic noise. In addition, it is uncertain whether there are any interaction effects between visual scenes and sounds in combined visual and sound settings.

Accordingly, the first objective of this study aims to construct a multivariate quantitative model to estimate how noise annoyance varies with the type and composition of neighborhood environmental features as well as the composition of road traffic and sea sound. The model intends to determine the tradeoff ratios between visual and acoustical factors in the moderation of noise annoyance. Second, it aims to quantify the effect of different proportions and distance of sea and road views, and mountain greenery views on noise annoyance when exposed to road traffic noise combined with sea sound. Finally, it aims to investigate whether there are any interaction effects between visual and acoustical factors for the combined exposure to the two modes of stimulus.

II. METHODOLOGY

A series of experiments was performed in this study to reveal the effects of different types, composition of neighborhood scenes on annoyance induced by exposure to both sea and road traffic sound.

A. Experiments

The experiments were carried out in an experimental room purposely constructed inside the building acoustics testing facility in the Hong Kong Polytechnic University. The setting of the experimental room was to mimic the living room setting of a dwelling in a public housing block in Hong Kong (Figs. 1 and 2). Figure 3 shows the layout plan of the living room constructed inside the test room set-up. The dimensions of the room were 2.4 m (w) × 3.5 m (l) × 3.5 m (h). A panel of windows of 2.2 m (w) × 1.7 m (h) was placed on the external wall of the living room. Special daylight reflection films were adhered to the entire window panel in order to allow projected videos to be watched inside the room, but remain opaque in the absence of the projections. A

FIG. 1. (Color online) The living room exterior.

FIG. 2. (Color online) The living room setting.

projector and two loudspeakers were placed in a separate room behind the windows of the living room. Videos were projected onto the window panel to simulate the situation that residents could see the outside neighborhood scenes through the window panel. By doing so, participants could only perceive the composite outside scenes and soundscape without realizing that there was an experimental setup behind the window panel.

1. Preparation of visual and audio stimuli

Three types of environmental features were studied: mountain greenery, sea and traffic road. Each of these features contributed to 0%, 30%, or 60% of the total view area in a composite neighborhood scene perceived through the window. The percentage of an environmental feature within a view corresponded to the ratio of the number of pixels of that environmental feature to the total number of pixels of the entire view. For those scenes containing a two-lane road, images of running vehicles on the road were keyed into the video in sync with the vehicular sound synthesized from site-recorded clips adjusted for the sound arrival time delay and receiver-source distance effect due to source motion (Tam *et al.*, 2012). The video clips and images were captured from residential areas in Hong Kong and modified via "Adobe Photoshop CS6" and "Adobe After Effects." In order to facilitate comparison, a clear sky scene was constructed as the baseline neighborhood view (i.e., greenery = 0, sea = 0, and road = 0). In total, 17 types of composite scenes were generated.

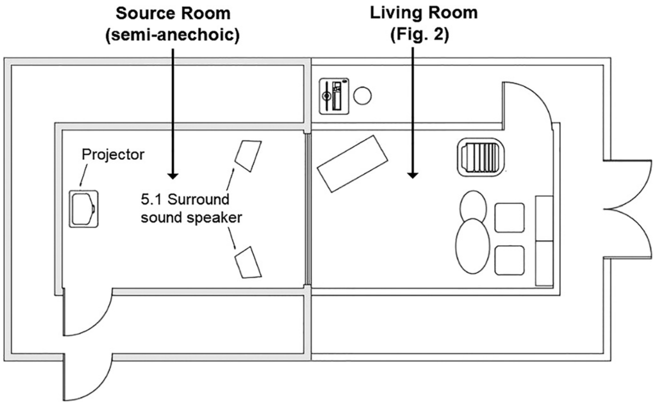

FIG. 3. Layout plan of the test room set-up.

Road traffic sound was recorded using a binaural microphone along the roadside of residential area in a half-hour clip, which was tested to ensure that no other disturbing sounds were present before extracting a 30-s clip for each composite scene. Water sound (i.e., sea wave sound used in the experiments) was purchased from a professional audio effect website (www.prosoundeffects.com). Sound levels of the clips were adjusted using software "Audacity" and Bruel & Kjaer 4128C "Head and Torso Simulator" (HATS). The HATS embracing a head mounted on a torso represents the international average dimensions of an adult. The HATS was equipped with two microphones near the ear region. The sound signals received by the microphones were transmitted to an analyzer for analyzing their acoustical properties. Immediately prior to the experiments, the sound signals from the sound clips were input into the simulator to measure the sound levels that would have been heard by a participant.

Both single sound source and mixed sound sources were prepared for the experiments. For the single source sound clips, the sound levels of road traffic or sea were set to either 55, 60, or 65 dBA. For the combined sound source clips, the road traffic sound levels were set to 55, 60, or 65 dBA to portray the commonly exposed road traffic noise levels in Hong Kong. The signal-to-noise ratio (*SNR*) of the two sound sources increased from −6 to 9 dB, in a step of 3 dB. *SNR* is the difference in *SPL*s between sea and road traffic. A negative *SNR* value denotes that the *SPL* of road traffic is higher than that of sea, and vice versa (Table I).

Keeping all combinations of video and sound clips would give a total of 18 (combined audio settings) × 17 (visual settings) = 198 composite scenarios. To reduce the total number of combinations presented to each participant to avoid degradation in response quality, an efficiency design was performed with the aid of software "SAS" to reduce the total number of combinations by neglecting high order interactions. The efficiency design for maximum likelihood estimation is based on the *D*-efficiency value, which is the optimality criterion of the data matrix that results in the minimization of the parameter estimates (NIST/SEMATECH, 2013). Finally, 36 composite visual and audio scenarios were generated for the experiments with a *D*-efficiency of 0.9421. The 36 composite visual and audio scenarios were further divided into three groups in a random manner. Only one group of the video clips would be presented to each participant in one set of experiments.

TABLE I. Scenarios containing both road traffic noise and sea sound. Note that positive sign of *SNR* denotes that level of sea sound is higher than that of traffic noise; negative sign of *SNR* denotes that the level of sea sound is lower than that of road traffic noise.

SPL of traffic noise (dBA)	*SNR* (dB)					
55	−6	−3	0	3	6	9
60	−6	−3	0	3	6	9
65	−6	−3	0	3	6	9

2. Experimental setup and questionnaire design

A structured questionnaire form was prepared for collecting responses from participants. The questionnaire was divided into four sections. Personal information (e.g., gender, age, current position) was collected in the first section. Participants were asked to report their self-assessed noise sensitivity and health status on two five-point verbal scales, respectively. The second section was earmarked for eliciting participants' acoustic annoyance-pleasantness ratings when exposed to two single sound sources separately (i.e., road traffic noise and sea sound) at different *SPL*s. In this section, six single source sound clips were presented consecutively to participants while they were exposed to the baseline neighborhood view. Participants were required to give an annoyance-pleasantness rating to each sound clip using a 21-point verbal scale (where "−10" denotes "*Extremely annoyed*," "0" denotes "*Neutral*," "10" denotes "*Extremely pleasant*"). The scale posits noise annoyance as the feeling of displeasure due to the adverse effect of noise at one end and the anti-thesis of noise annoyance at the other end of the continuum (Lindvall and Radford, 1973). The third section examined the effects of different composite visual and audio cues on the participants responding to the sound sources. The composite scenarios were constructed from sound clips of a combined source of road traffic sound and sea sound at 55, 60, and 65 dBA, and images of greenery, sea and road in various proportions (see Fig. 4). Participants were asked to give a noise annoyance rating to each scenario using an 11-point verbal scale (where "0" denotes "*Not annoyed at all*," "10" denotes "*Extremely annoyed*"). They needed to assign a rating to indicate the level of dominance of a particular type of sound source they perceived via a 11-point scale (where "0" denotes "*Water sound dominant*," "5" denotes "*No dominant sound*," "10" denotes "*Traffic noise dominant*"). The fourth section aimed at revealing the participants' visual preferences of the neighborhood scenes viewed from living room setting. They ranked their order of preference for each individual scene out of the 11 composite neighborhood scenes (Fig. 4) projected on the window panel. Their scores would fall into the range between "0" for the "*Least preferred*" and "10" for the "*Most preferred*." Throughout the experiments, participants were asked to relax and read magazines as if they were having leisure reading at homes.

B. Descriptive analysis

The mean annoyance ratings were computed for different video scenes (i.e., *Scene A* to *Scene K*) perceived by the participants at different *SPL*s. Chi-square tests were performed for each type of neighborhood scenes at 55, 60, and 65 dBA to reveal whether there were any significant differences in their mean annoyance ratings.

C. Model formulation

An ordered logit model was formulated to analyze the noise annoyance response data collected from the questionnaire surveys for the experiments. The McFadden's ρ^2 was applied to estimate the maximum likelihood of the final model. McFadden's ρ^2 is analogous to R^2 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 squared errors. The ratio of the likelihoods gives the level of improvement over the intercept model offered by the full model. High McFadden's ρ^2 value indicates a higher likelihood in model prediction (Kleinbaum and Klein, 2010).

For facilitating model formulation, the original ratings of 11-point scale were recoded into three categories of responses, i.e., low, medium, and high. The following general form of the ordered-logit model was used to estimate the latent variable Z as a linear function of independent variables (Hamilton, 2006):

$$Z = \sum \beta_i x_i + \varepsilon, \tag{1}$$

where x_i represents an independent variable such as the percentage of sea views, percentage of greenery views, percentage of road views, *SPL*, and self-rated noise sensitivity; β_i represents the coefficients of the independent variables; and ε is a logistically distributed error.

Given our major focus was to reduce high annoyance responses, only the probabilities of evoking a high annoyance response were computed and presented. The probability of evoking a high annoyance response, which depends on the value of Z and cut points μ_n, was computed by

$$\begin{aligned} Pr(Annoyance = \text{“}High\text{”}) &= \Pr(\mu_2 < Z) \\ &= 1 - \frac{1}{1 + e^{(Z-\varepsilon-\mu_2)}}. \end{aligned} \tag{2}$$

Apart from estimating the probabilities of evoking a high annoyance response, it would be more meaningful to interpret how much a scenario is better or worse than another in order to evoke a high annoyance response. Odds ratio was calculated to indicate the differences by using the probabilities of evoking a high annoyance response under a specific scenario,

$$odds\,ratio = \frac{\dfrac{p_1}{1-p_1}}{\dfrac{p_0}{1-p_0}}, \tag{3}$$

where p_0 and p_1 represent, respectively, the probability of "*baseline*" scenario (in which the percentage of greenery, sea and road = 0, *SNL* = 0, and *SPL* = 55 dBA) and the probability of another scenario within the group at a high annoyance response.

III. RESULTS

246 participants successfully completed our laboratory experiments. However, as a quality assurance procedure, 31 responses were excluded from our data analysis due to missing information or conflicting responses. Table II summarizes the personal characteristics of the participants. 42% of the participants were males. Most of them were

	Proportion of Environmental Features		
Scene	Greenery	Sea	Road
A	60%	0%	30%
B	60%	30%	0%
C	0%	60%	30%
D	0%	0%	0%
E	0%	0%	30%
F	30%	0%	0%
G	30%	0%	30%
H	30%	60%	0%
I	30%	0%	60%
J	0%	30%	0%
K	0%	30%	60%

FIG. 4. (Color online) Composite neighborhood scenes.

undergraduate students aged between 20 and 29 years old. An overwhelming majority of the participants rated their noise sensitivity and health status as "*Fair*" or "*Sensitive/Good*."

The second section of the experiment revealed the acoustic annoyance-pleasantness ratings assigned by participants when exposed to two specific sound sources. Figure 5 shows the mean acoustic annoyance-pleasantness ratings ("*10* to *−10*", where "*10*" denotes "*Extremely annoyed*" and "*−10*" denotes "*Extremely pleasant*") for different types of single-source sound clips and also combined sounds with different view settings at different *SPL*s.

TABLE II. Summary statistics of the personal characteristics of the participants.

Description		Number of counts
Gender	Male	91(42%)
	Female	124(58%)
Age	19 or below	49(23%)
	20–29	163(76%)
	30–39	3(1%)
	40 or above	0
Noise Sensitivity	Very insensitive	0
	Insensitive	7(3%)
	Fair	81(38%)
	Sensitive	120(56%)
	Very sensitive	7(3%)
Health Status	Very healthy	0
	Healthy	2(1%)
	Fair	84(39%)
	Unhealthy	120(56%)
	Very unhealthy	9(4%)

Figure 5 shows that the mean acoustic annoyance-pleasantness ratings for the scenarios featuring sea sound only were −5.3, −2.5, and −0.6 at 55, 60, and 65 dBA, respectively. The majority of the participants perceived sea sound "comfortable" at all three sound levels, while the mean ratings increased with *SPL*. The mean ratings were 3.8, 4.8, and 6.8 at 55, 60, and 65 dBA, respectively for road traffic sound. The mean ratings for road traffic sounds were positive even at low *SPL*s, while the rating increased with *SPL*. This suggested that road traffic sounds were considered "uncomfortable" at all three sound levels. For the scenarios containing both combined sounds and composite visual scenes, the mean ratings were 4.1, 5.3, and 6.9 at 55, 60, and 65 dBA, respectively. The mean rating increased with *SPL* irrespective of the type of composite visual scenes perceived.

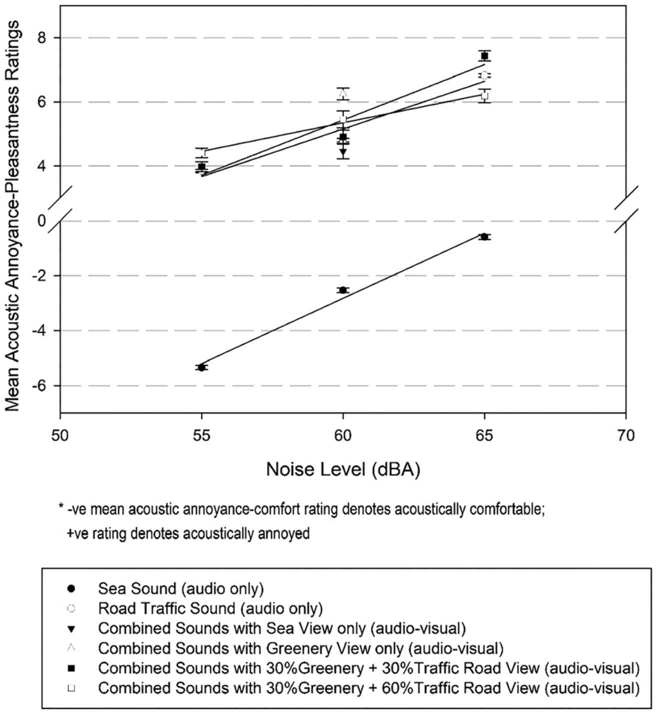

FIG. 5. The mean acoustic annoyance-pleasantness ratings for single and combined sound.

Even at higher sea sound contribution (i.e., a higher *SNR*), participants could only moderately perceive the water sound as a dominant type (*WDom*) of sound (*WDom* was moderately and negatively correlated with *SNR* ($r = 0.535$, $p < 0.01$)). Individuals who perceived road traffic sounds to be annoyed gave higher annoyance ratings for the same scene compared to those who did not perceive road traffic sounds to be annoyed [$\chi^2(2) = 63.883$, $p = 0.000$]. Table III summarizes the correlations between the acoustical and visual variables.

A. Multivariate ordered logit model for predicting the probability of evoking a high annoyance response

Ordered logit models were formulated using the valid responses obtained from the questionnaire surveys in the experiments. To facilitate model formulation, some of the categorical or ordinal responses had been regrouped and recoded. For example, the 11-point annoyance ratings were re-coded into one of three groups, i.e., low (0–2), medium (3–6), or high annoyance responses (7–10) according to the annoyance ratings indicated in the questionnaire responses. As it was hypothesized that there might be some potential interaction effects between different types of neighborhood scenes (i.e., *greenery view* × *road view*), and between visual and acoustic variables (i.e., *sea view* × *SNR*). These two interaction terms were added to the model specification. In addition, it was hypothesized that the probability of evoking a high noise annoyance response would vary with an individual's preferences for visual and audio cues, the effects of which were measured by introducing dummy variables to the model. Stepwise approach was adopted in the model formulation with an input sequence following the order of main effect variables, interaction terms, and personal characteristics and perception. A variable would be included into the model only if all the following three criteria had been met: (i) it was significant at 95% level, (ii) its inclusion would significantly increase the McFadden ρ^2 value without causing any multi-collinearity effects, and (iii) its inclusion would not alter the significance of other variables. Multi-collinearity tests had also been performed among all the variables in order to provide more comparable predictions and avoid unnecessarily high standard errors on the model coefficients. No strong multi-collinearity effects had been observed between variables in the final model (with all VIFs < 10) (Belsley *et al.*, 1980; Menard, 2002) (see Table IV).

The final form of the ordered logit model to predict the probability of evoking a high annoyance response is shown as follows:

$$\begin{aligned} Z = {} & \beta_{SPL} \cdot SPL + \beta_{SNR} \cdot SNR + \beta_{WDom} WDom \\ & + \beta_G G + \beta_S Sea + \beta_R Road + \beta_{G \times Road} G \\ & \times Road + \beta_{S \times SNR} Sea \times SNR + \beta_{NTS} NTS + \varepsilon. \end{aligned} \quad (4)$$

TABLE III. Summary table of correlations between acoustical and visual variables.

	WDom	NTS	Greenery	Sea	Road	Greenery × Road	Sea × *SNR*	*SNR*	Total *SPL*
Noise Annoyance	−0.061[a]	0.158[a]	0.073[a]	0.006	−0.017	−0.029	−0.032	0.171	0.556[a]
SNR	0.535[a]	0.009	−0.071[a]	0.015	−0.027	−0.126[a]	−0.142[a]	—	0.558[a]
Total SPL	0.175[a]	0.028	0.020	0.099[a]	−0.092[a]	−0.121[a]	0.080[a]	0.558[a]	—
WDom	—	0.002	−0.093[a]	0.067[a]	−0.010	−0.100[a]	−0.087[a]	0.535[a]	−0.175[a]

[a]p-value ≤ 0.001.

Table V lists the description of all the coded variables in the model.

A McFadden's ρ^2 value of 0.266 was obtained for the model, suggesting an excellent goodness-of-fit of the models for the collected responses. McFadden ρ^2 value of 0.2–0.4 represents an excellent fit (McFadden, 1973), which is analogous to a range of values between 0.7 and 0.9 in r^2 value for a linear regression model. Table VI lists the estimated coefficient values of all the statistically significant variables. For continuous variables, a positive coefficient indicates that the probability of evoking a high annoyance response increases with the value of the variable, given all the other variables in the model being held constant. A negative coefficient indicates the probability of evoking a high annoyance response decreases as the value of the variable increases. For categorical and dichotomized variables, the coefficient value shows the increase/decrease in the probability value when the variable changes from the "baseline level" (usually the first group of this variable, coded as "*0*") to the studied level, given all else held constant. The higher the absolute coefficient value, the larger the effect size per unit of the variable.

The validity of the formulated ordered logistic model suggested that the view composition, *SPL*, and combined sound sources composition were statistically significant predictors of high annoyance responses.

As expected, the odds ratio increased with total *SPL*, i.e., the total sound level of road traffic and sea. The odds of high noise annoyance response increased by a factor of 1.47 per dB increase in total *SPL* (*CI*, 1.42–1.51, $p < 0.01$). In addition, the odds ratio varies with the composition of road traffic noise and sea sound in the combined sound source, i.e., signal-to-noise ratio. The odds increased by a factor of 0.921 per dB increase in *SNR*, i.e., per dB increase in difference in sound levels between sea and road traffic noise (*CI*, 0.897–0.945, $p < 0.01$ for a dB increase in *SNR*). A lower *SNR* (i.e., a larger contribution of road traffic noise) was more likely to evoke a high annoyance response.

TABLE IV. Results for collinearity between independent variables. Note that variance inflation factor (VIF) > 10 is highly collinear (Menard, 2002).

Variable	VIF
Sound characteristics	
SPL	*1.583*
SNR	*2.149*
View characteristics	
G	*1.758*
Sea	*1.343*
Road	*1.800*
G × Road	*2.526*
Sea × *SNR*	*1.147*
Personal Characteristics and Perception	
WDom	*1.462*

The model indicated that noise annoyance was dependent on whether sea sound was perceived by the participant as a dominant type of sound, or whether road traffic noise was perceived to be annoying. A participant who regarded sea sound as a dominant type of sound was about 0.6 times as likely to evoke a high noise annoyance response as those who did not regard sea sound as a dominant type of sound (*CI*, 0.477–0.741, $p < 0.01$). Further, it was 2.37 times as likely for a participant who perceived road traffic sound to be very annoying as the non-dominant counterpart (*CI*, 1.95–2.89, $p < 0.01$).

As discussed earlier, the visual cues to which a person was exposed at home were also statistically significant predictors of high annoyance responses. The size of moderation effect due to views from homes depended on the percentages of sea, mountain greenery and/or roads within the view. Road views and mountain greenery views were found to produce negative annoyance moderation effects (i.e., coefficient value of $Road = 0.008$) despite their sizes of effect were small. The odds increased marginally by a factor of 1.01 per one percentage point increase in road views (*CI*, 1.00–1.01, $p < 0.05$). Similarly, mountain greenery at a close distance to the viewer was found to be 1.01 times as likely to evoke a high noise annoyance response per one percentage point increase in greenery views (*CI*, 1.00–1.01, $p < 0.001$).

In the case where a two-lane road was placed between viewers and mountain greenery, a net positive annoyance moderation effect would be produced. It was 0.703 times as likely for dwellers to evoke a high annoyance response if they were exposed to a view containing mountain greenery and road when compared with those exposed to a view without them (i.e., $G \times Road$; *CI*, 0.514–0.928, $p < 0.05$).

On the contrary, sea views would produce a modest positive noise annoyance moderation effect (i.e., coefficient value of $Sea = -0.005$). The odds increased by a factor of 0.995 when the proportion of visible sea increased by one percentage point (*CI*, 0.990–0.999, $p < 0.05$ for a percentage point of sea view increase). The moderation effect was found to be the strongest (i.e., coefficient value of $Sea \times SNR = -0.575$) when sea sound was 3 dB lower than road traffic noise (i.e., $SNR = -3$) in the scenario with a 60% sea view. Such scenario was 0.563 times as likely to evoke a high noise annoyance response when compared with those without a 60% sea view at $SNR = -3$ (*CI*, 0.323–0.981, $p < 0.05$).

TABLE V. Description of the coded variables in the model.

Variables	Description	Unit
Sound characteristics		
SPL	Total sound pressure level	1 dBA
SNR	Signal to noise ratio between sea and road traffic sound	1 dBA
View characteristics		
G	Percentage of greenery in a view from the window	%
Sea	Percentage of the sea in a view from the window	%
Road	Percentage of the 2-lane road in a view from the window	%
G × Road	Interaction term between view of greenery and view of road from the window. Coded as "1" if there is an interaction effect, otherwise "0"	
Sea × *SNR*	Interaction term between sea view and *SNR* from the window. Coded as "1" if there is a 60% sea view and $SNR = -3$, otherwise "0"	
Personal characteristics and perception		
WDom	Sound dominance ratings assigned by participants (0–10); Coded as "0" if participants perceived traffic sound to be dominant or no dominant sound (i.e. sound dominance rating ≥ 5); "1" if participants perceived sea sound to be dominant (i.e. sound dominance rating < 5)	
NTS	Coded as "1" if the participant perceived road traffic sound to be annoyed (i.e. annoyance-pleasantness ratings < -3 for the sum of ratings of all the single traffic sound clips), otherwise "0"	

B. Tradeoffs between factors

Apart from the odds of individual factors, the formulated multivariate model can also help determine the trade-off ratios implicitly assigned by the participants at a given specific probability value of evoking a high annoyance response. The trade-off ratio between two contributing factors can be determined by the ratio of their coefficient values shown in Table VI. For example, a 60% sea view was roughly equivalent to 1.0 dB reduction in the total *SPL* (i.e., coefficient value of 1% sea view/coefficient value of 1 dB *SPL* $\times$ $60 = 0.005/0.384 \times 60$). A 30% mountain greenery view at an intermediate distance (i.e., *Scene G*) was, by contrast, equivalent to about 0.5 dB increase in the total *SPL* (i.e., $0.010/0.384 \times 30 - 0.370$). A 60% road view was equivalent to 1.5 dB increase in total *SPL* (i.e., $0.008/0.384 \times 60$). There was an equivalent reduction in 0.2 dB in total *SPL* (i.e., 0.082/0.384) per dB increase in difference between road traffic sound and sea sound (i.e., *SNR*). The scenario containing a 60% sea view with road traffic sound level 3 dB higher than sea sound level (i.e., $SNR = -3$) implied an equivalent 1.5 dB reduction in total *SPL* (i.e., 0.575/0.384).

TABLE VI. Estimated coefficient values and odds ratios for the variables in the ordered logit model.

McFadden's ρ^2	0.266		
Variable	Coefficient (β)	Standard error	Odds ratio (CI 95%)
Sound characteristics			
SPL	0.384[a]	*(0.015)*	1.47 (1.42–1.51)
SNR	−0.082[a]	*(0.013)*	0.921 (0.897–0.945)
View characteristics			
G	0.010[a]	*(0.003)*	1.01 (1.00–1.01)
Sea	−0.005[b]	*(0.002)*	0.995 (0.990–0.999)
Road	0.008[b]	*(0.003)*	1.01 (1.00–1.01)
G × Road	−0.370[b]	*(0.151)*	0.690 (0.514–0.928)
Sea × *SNR*	−0.575[b]	*(0.283)*	0.563 (0.323–0.981)
Personal characteristics and perception			
WDom	−0.520[a]	*(0.113)*	0.595 (0.477–0.741)
NTS	0.864[a]	*(0.101)*	2.37 (1.95–2.89)
Cut points 1	21.434	*(0.927)*	N/A
Cut points 2	26.010	*(1.00)*	N/A

[a] p-value ≤ 0.001.
[b] p-value ≤ 0.05.

IV. DISCUSSIONS AND CONCLUSION

To the best of our knowledge, this study is one of the pioneering studies that successfully formulated a multivariate model to quantify the effects on noise-induced annoyance due to neighborhood settings containing different composition of environmental features as well as different combinations of sea sound and road traffic sound. There are a number of observations drawn from this study that can provide valuable insights into the effects of composite visual scenes and combined sound exposure on noise annoyance.

First, it was revealed that the presence of greenery view might not always produce positive noise annoyance moderation effect as reported in many earlier studies (Anderson *et al.*, 1984; Dzhambov and Dimitrova, 2015). Results in this study demonstrated that mountain greenery views increased the probability of evoking a high annoyance response. The probability increased with the percentage of mountain greenery in a view (i.e., $60\% > 30\% > 0\%$ greenery view). If a two-lane road was placed between viewers and mountain greenery, the net probability of evoking a high noise annoyance response was reduced by 0.03 for a 30% road view plus 30% greenery view, and by 0.04 for a 30% road view plus 60% greenery view), but increased by 0.01 for a 60% road view (i.e., 60% road view + 30% greenery view) when compared with those scenarios containing greenery but without the road (see the interaction term "$G \times Road$"). The observation for greenery is different from the findings associated with waterscapes that a water space located close-by had a stronger ability to improve acoustic comfort than the one located far away (Ren and Kang, 2015). Upon close examination, the negative moderation effect of views dominated by mountain greenery was attributed to the presence of dense or nearly impervious vegetation at a close distance from dwellings. With impervious or sufficiently dense mountain greenery located in such a close distance, poor visibility becomes a concern for the perception of security. In such a situation, the restorative effect was expected to reverse, as more nature would lead to the prospects of more danger (Herzog and Chernick, 2000) and threats to safety (Chiang *et al.*, 2014). The extent of blockage of the field of vision reduced with a larger separation distance between greenery and dwellers, suggesting that the effect of spatial openness was likely to outweigh the effect of visual connection to greenery when the dense mountain greenery was located close-by. The findings implied that people would enjoy an restorative experience only if they perceived nature as unthreatening (Herzog and Chernick, 2000; Van den Berg *et al.*, 2014). Thus, it is reasonable to conclude that the noise annoyance moderation capability of greenery should not depend solely on its proportion within a view. Other factors associated with the spatial openness of a view should also be taken into account. In the case when the spatial openness of a view is seriously restricted by greenery, the probability of evoking a high annoyance response increases.

Second, the present study is one of the few studies that provides valuable information regarding the relationships between acoustic perception, SNR and visual landscapes. With the aid of the model, it is possible to determine and compare the trade-off ratios between any two variables implicitly assigned by the participants at a specific probability value of a high annoyance response. The model benefits planners and strategists by providing a set of trade-off ratios across visual and acoustical variables, and especially from *SNR* in settings of combined sound sources. In addition, quantifying the moderation effects on noise annoyance by converting the percentages of view composition of natural and built features into equivalent decibel units enables the majority of the public to have easier understandings of the sensory relations in both descriptive and evaluative terms.

Third, some manipulations involving the use of visual and acoustical properties of the sea were found to be able to moderate high noise annoyance responses caused by road traffic sounds. A 60% sea view could yield a 1.0 dB equivalent reduction in total *SPL*. This was comparable to that achieved by having sea sound at a level 5 dB higher than road traffic sound (i.e., $SNR = 5$). Furthermore, 1.5 dB additional equivalent reduction could be achieved by having a 60% sea view together with road traffic sound being 3 dB higher than sea sound (i.e., $SNR = -3$) apart from those achieved by implementing them in isolation. Meanwhile, 1.4 dB equivalent reduction in total *SPL* would be achieved if an individual perceived sea sound as a dominant type of sound. Further investigations are needed to explore the situations that will make a person perceive sea sound as a dominant type of sound.

Fourth, the total annoyance model based on coefficients for each independent sound source in the total dose has been proven to give satisfactory account for short-term annoyance induced by transportation noise (Gille *et al.*, 2016). Using the mean total *SPL* as the basis for the logit model is appropriate for examining the relative effects of road traffic sound and sea sound as a combined sound source rather than in isolation on noise annoyance response. If the variable "total *SPL*" was broken down into one independent variable for road traffic sound and the other for sea sound, the regression model could only account for the annoyance due to that specific sound source. A model using partial coefficients would not facilitate the assessment of the roles of *SNR* and *SPL* in rendering sea sound as an effective masker of road traffic noise for the moderation of total noise annoyance. Our findings are consistent with the empirical evidence that the ability of water sound masking unwanted noise of similar *SPL* of the two combined sources moderates annoyance due to traffic noise (Jeon *et al.*, 2010; Leung *et al.*, 2017).

Finally, audio-visual interaction effects were found to exist in the scenarios where $SNR = -3$ and Sea = 60%. This result suggests that, apart from the acoustic condition of having water sound around 3 dB below road traffic sound for an enhancement effect in urban soundscape as reported in other sound preference studies (Galbrun and Ali, 2013; Jeon *et al.*, 2010; You *et al.*, 2010), there is an additional condition that the perceived sea view should account for 60% of the scene composition. Thus, simultaneous monitoring of both signal-to-noise ratio and visual scene composition is necessary for moderating high annoyance responses.

Nonetheless, this study is not without a number of limitations on the applicability of the model. First, the applicability of the findings are within the confines of the neighborhood views containing the three types of environmental features under investigation, namely, mountain greenery, sea, and road. Second, the independent variables of mountain greenery, sea, and road views are discrete rather than continuous; it is assumed that there were no subtle changes in effects around each discrete percentage point. Third, acoustical quality of the stimuli was only described in terms of mean sound pressure level and signal-to-noise levels without considering other sound properties such as frequency and temporal content. Fourth, the interactions between two types of sound and visual scenes have not been fully explored due to the limitations of the efficiency design and limited number of response data. Fifth, the findings are only applicable to mountain greenery located at a close and an intermediate distance from the viewer because more distanced greenery may give different results. Sixth, personal factors are not included in the model. The two variables that are capable of nesting participants' subjective judgements in the context of personality traits are noise sensitivity and health status. However, statistical results suggest that distribution and significance of the self-reported data are less than promising for noise sensitivity and health status to become explanatory variables at the second level (see Table II).

Instead of applying multi-level regression analysis, the energy-based acoustical indices and psychometric ratings were fitted at the first level of the model because of the simplicity of the exposure-response relationship as a strategy of quantifying short-term noise annoyance and the primary consideration of the predictor variables being at the stimulus level. Finally, as participants in our experiments are between 18 and 29 years old, the collected data do not purport to be applicable to the population other than the age group examined. A larger scale study on the subject is invariably merited. Despite the limitations, the findings in this study should provide valuable insights into the relationships between noise annoyance and the audio-visual composition of environmental attributes contained in views across the natural and urban realms.

ACKNOWLEDGMENTS

The authors would like to thank the Research Grant Council in Hong Kong for the funding support through the General Research Grants Nos. 15215515 and 512112.

Anderson, L. M., Mulligan, B. E., and Goodman, L. S. (**1984**). "Effects of vegetation on human response to sound," J. Arboricult. **10**, 45–49.

Axelsson, Ö., Nilsson, M. E., Hellström, B., and Lundén, P. (**2014**). "A field experiment on the impact of sounds from a jet-and-basin fountain on soundscape quality in an urban park," Landsc. Urban Plan. **123**, 49–60.

Babisch, W., Beule, B., Schust, M., Kersten, N., and Ising, H. (**2005**). "Traffic noise and risk of myocardial infarction," Epidemiology **16**, 33–40.

Belsley, D., Kuh, E., and Welch, R. (**1980**). *Regression Diagnostics: Identifying Influential Data and Sources of Collinearity* (Wiley, New York, NY).

Björk, J., Ardö, J., Stroh, E., Lövkvist, H., Ostergren, P.-O., and Albin, M. (**2006**). "Road traffic noise in southern Sweden and its relation to annoyance, disturbance of daily activities and health," Scand. J. Work Environ. Health **32**, 392–401.

Brown, A. L. (**2012**). "A review of progress in soundscapes and an approach to soundscape planning," Int. J. Acoust. Vib. **17**, 73–81.

Can, A., Rademaker, M., Van Renterghem, T., Mishra, V., Van Poppel, M., Touhafi, A., Theunis, J., De Baets, B., and Botteldooren, D. (**2011**). "Correlation analysis of noise and ultrafine particle counts in a street canyon," Sci. Total Environ. **409**, 564–572.

Chiang, Y. C., Li, D., and Jane, H. A. (**2014**). "Influence of visibility and situational threats on forest trail evaluations," Landsc. Urban Plan. **125**, 166–173.

De Coensel, B., Bockstael, A., Dekoninck, L., Botteldooren, D., Schulte-Fortkamp, B., Kang, J., and Nilsson, M. E. (**2010**). "The soundscape approach for early stage urban planning: A case study," in *Proceedings of the 39th International Congress and Exposition on Noise Control Engineering (INTERNOISE)*, pp. 1–10.

Dzhambov, A. M., and Dimitrova, D. D. (**2015**). "Green spaces and environmental noise perception," Urban Forest. Urban Green. **14**, 1000–1008.

Erber, N. P. (**1975**). "Auditory-visual perception of speech," J. Speech Hear. Disord. **40**, 481–492.

Fastl, H. (**2005**). "Psycho-acoustics and sound quality," in *Communication Acoustics*, edited by Blauert, J. (Springer, Berlin), pp. 139–162.

Galbrun, L., and Ali, T. T. (**2012**). "Perceptual assessment of water sounds for road traffic noise masking," in *Acoustics 2012*, April, Société Française d'Acoustique, Nantes, France.

Galbrun, L., and Ali, T. T. (**2013**). "Acoustical and perceptual assessment of water sounds and their use over road traffic noise," J. Acoust. Soc. Am. **133**, 227–237.

Galbrun, L., and Calarco, F. M. A. (**2014**). "Audio-visual interaction and perceptual assessment of water features used over road traffic noise," J. Acoust. Soc. Am. **136**, 2609–2620.

Gidlöf-Gunnarsson, A., Öhrström, E., and Ögren, M. (**2007**). "Noise annoyance and restoration in different courtyard settings: Laboratory experiments on audio-visual interactions," in *Proceedings of Inter Noise*, Istanbul, Turkey.

Gidlöf-Gunnarsson, A., and Öhrström, E. (**2007**). "Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas," Landsc. Urban Plan. **83**, 115–126.

Gidlöf-Gunnarsson, A., and Ohrström, E. (**2010**). "Attractive 'quiet' courtyards: A potential modifier of urban residents' responses to road traffic noise?," Int. J. Environ. Res. Public Health **7**, 3359–3375.

Gille, L., Marquis-Favre, C., and Morel, J. (**2016**). "Testing of the European Union exposure-response relationships and annoyance equivalents model for annoyance due to transportation noises: The need of revised exposure-response relationships and annoyance equivalents model," Environ. Int. **94**, 83–94.

Hamilton, L. C. (**2006**). *Statistics with STATA: Version 9* (Thomson-Brooks/Cole, Belmont, CA).

Herzog, T. R., and Chernick, K. K. (**2000**). "Tranquility and danger in urban and natural settings," J. Environ. Psychol. **20**, 29–39.

Hong, J. Y., and Jeon, J. Y. (**2014**). "The effects of audio–visual factors on perceptions of environmental noise barrier performance," Landsc. Urban Plan. **125**, 28–37.

Jeon, J. Y., Lee, P. J., Hong, J. Y., and Cabrera, D. (**2011a**). "Non-auditory factors affecting urban soundscape evaluation," J. Acoust. Soc. Am. **130**, 3761–3770.

Jeon, J. Y., Lee, P. J., You, J., and Kang, J. (**2010**). "Perceptual assessment of quality of urban soundscapes with combined noise sources and water sounds," J. Acoust. Soc. Am. **127**, 1357–1366.

Jeon, J. Y., Lee, P. J., You, J., and Kang, J. (**2012**). "Acoustical characteristics of water sounds for soundscape enhancement in urban open spaces," J. Acoust. Soc. Am. **131**, 2101–2109.

Jeon, J. Y., You, J., Jeong, C. Il, Kim, S. Y., and Jho, M. J. (**2011b**). "Varying the spectral envelope of air-conditioning sounds to enhance indoor acoustic comfort," Build. Environ. **46**, 739–746.

King, E. A., Murphy, E., and McNabola, A. (**2009**). "Reducing pedestrian exposure to environmental pollutants: A combined noise exposure and air quality analysis approach," Transp. Res. Part D: Transp. Environ. **14**, 309–316.

Klæboe, R., Kolbenstvedt, M., Clench-Aas, J., and Bartonova, A. (**2000**). "Oslo traffic study—Part 1: An integrated approach to assess the combined effects of noise and air pollution on annoyance," Atmos. Environ. **34**, 4727–4736.

Kleinbaum, D. G., and Klein, M. (**2010**). *Logistic Regression, Statistics for Biology and Health* (Springer, New York).

Korfali, S. I., and Massoud, M. (**2003**). "Assessment of community noise problem in greater Beirut area, Lebanon," Environ. Monitor. Assess. **84**, 203–218.

Leung, T. M., Xu, J. M., Chau, C. K., Tang, S. K., and Pun-Cheng, L. S. C. (**2017**). "The effects of neighborhood views containing multiple environmental features on road traffic noise perception at dwellings," J. Acoust. Soc. Am. **141**, 2399–2407.

Li, H. N., Chau, C. K., and Tang, S. K. (**2010**). "Can surrounding greenery reduce noise annoyance at home?," Sci. Total Environ. **408**, 4376–4384.

Li, Z. (**2006**). "A new life cycle impact assessment approach for buildings," Build. Environ. **41**, 1414–1422.

Lindvall, T., and Radford, E. P. (**1973**). "Measurement of annoyance due to exposure to environmental factors: The fourth Karolinska Institute symposium on environmental health," Environ. Res. **6**, 1–36.

Maffei, L., Masullo, M., Aletta, F., and Di Gabriele, M. (**2013**). "The influence of visual characteristics of barriers on railway noise perception," Sci. Total Environ. **445-446**, 41–47.

McFadden, D. (**1973**). "Conditional logit analysis of qualitative choice behavior," Front. Econom. **1**, 105–142.

Menard, S. (**2002**). *Applied Logistic Regression Analysis*, 2nd ed. (Sage, Thousand Oaks, CA).

Nilsson, M. E., Alvarsson, J., Rådsten-Ekman, M., and Bolin, K. (**2010**). "Auditory masking of wanted and unwanted sounds in a city park," Noise Control Eng. J. **58**, 524–531.

NIST/SEMATECH (**2013**). "e-Handbook of Statistical Methods," http://www.itl.nist.gov/div898/handbook/ (Last viewed 15 October 2018).

Pedersen, E., and Larsman, P. (**2008**). "The impact of visual factors on noise annoyance among people living in the vicinity of wind turbines," J. Environ. Psychol. **28**, 379–389.

Pheasant, R., Horoshenkov, K., Watts, G., and Barrett, B. (**2008**). "The acoustic and visual factors influencing the construction of tranquil space in urban and rural environments tranquil spaces-quiet places?," J. Acoust. Soc. Am. **123**, 1446–1457.

Pheasant, R. J., Fisher, M. N., Watts, G. R., Whitaker, D. J., and Horoshenkov, K. V. (**2010**). “The importance of auditory-visual interaction in the construction of ‘tranquil space,’ ” J. Environ. Psychol. **30**, 501–509.

Preis, A., Kociński, J., Hafke-Dys, H., and Wrzosek, M. (**2015**). “Audio-visual interactions in environment assessment,” Sci. Total Environ. **523**, 191–200.

Ren, X., and Kang, J. (**2015**). “Effects of the visual landscape factors of an ecological waterscape on acoustic comfort,” Appl. Acoust. **96**, 171–179.

Sato, T., Yano, T., Björkman, M., and Rylander, R. (**1999**). “Road traffic noise annoyance in relation to average noise level, number of events and maximum noise level,” J. Sound Vib. **223**, 775–784.

Schultz, T. J. (**1978**). “Synthesis of social surveys on noise annoyance,” J. Acoust. Soc. Am. **64**, 377–405.

Sun, K., De Coensel, B., Echevarria Sanchez, G. M., Van Renterghem, T., and Botteldooren, D. (**2018**). “Effect of interaction between attention focusing capability and visual factors on road traffic noise annoyance,” Appl. Acoust. **134**, 16–24.

Szychowska, M., Hafke-Dys, H., Preis, A., Kociński, J., and Kleka, P. (**2018**). “The influence of audio-visual interactions on the annoyance ratings for wind turbines,” Appl. Acoust. **129**, 190–203.

Tam, K. C., Tang, S. K., and Lau, S. K. (**2012**). “On the recovery of moving source characteristics using time-frequency approach,” Appl. Acoust. **73**, 366–378.

Torija, A. J., Ruiz, D. P., Alba-Fernandez, V., and Ramos-Ridao, Á. (**2012**). “Noticed sound events management as a tool for inclusion in the action plans against noise in medium-sized cities,” Landsc. Urban Plan. **104**, 148–156.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., and Zelson, M. (**1991**). “Stress recovery during exposure to natural and urban environments,” J. Environ. Psychol. **11**, 201–230.

Van den Berg, A. E., Jorgensen, A., and Wilson, E. R. (**2014**). “Evaluating restoration in urban green spaces: Does setting type make a difference?,” Landsc. Urban Plan. **127**, 173–181.

Van Renterghem, T., and Botteldooren, D. (**2016**). “View on outdoor vegetation reduces noise annoyance for dwellers near busy roads,” Landsc. Urban Plan. **148**, 203–215.

Watts, G. R., Pheasant, R. J., Horoshenkov, K. V., and Ragonesi, L. (**2009**). “Measurement and subjective assessment of water generated sounds,” Acta Acust. Acust. **95**, 1032–1039.

Willich, S. N., Wegscheider, K., Stallmann, M., and Keil, T. (**2006**). “Noise burden and the risk of myocardial infarction,” Eur. Heart J. **27**, 276–282.

You, J., Lee, P. J., and Jeon, J. Y. (**2010**). “Evaluating water sounds to improve the soundscape of urban areas affected by traffic noise,” Noise Control Eng. J. **58**, 477–483.

Zhang, M., and Kang, J. (**2007**). “Towards the evaluation, description, and creation of soundscapes in urban open spaces,” Environ. Plan. B: Plan. Des. **34**, 68–86.

Zimmer, K., Ghani, J., and Ellermeier, W. (**2008**). “The role of task interference and exposure duration in judging noise annoyance,” J. Sound Vib. **311**, 1039–1051.