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NOISE ANNOYANCE REDUCTION BY GREEN WINDOW VIEW : THE EFFECT OF GREEN QUALITY

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ABSTRACT

There is convincing real-life evidence that seeing outdoor vegetation through the windows of one's dwelling is able to mitigate negative health effects due to exposure to environmental noise, in particular for noise annoyance. However, design guidelines to maximally benefit from this positive audio-visual interaction are currently lacking, but are mandatory when this idea is to be brought to the urban sound planning arena. In a previous virtual reality experiment, it was found that the optimum "RGB greenness" in the window pane of a dwelling is near 30%. In this follow-up study, vegetation quantity was fixed near this optimum, but green quality varied, on the dimensions biodiversity, colorfulness, and maintenance degree. Similar to the green quantity study, a living room was mimicked overlooking a vegetated central reservation along an inner city ring road at high noise exposure levels. Preliminary analysis showed that higher colorfulness and biodiversity of the green belt not only increased the aesthetic quality perceived by the participants, but also tended to reduce the self-reported noise annoyance.

Keywords: *noise annoyance, road traffic noise, environmental noise perception, audio-visual interactions, urban greening.*

1. INTRODUCTION

In many real-life urban situations such as inner city ring roads, the applicable measures to reduce the exposure to environmental noise are scarce. Such roads need a sufficient traffic throughput, meaning that significant vehicle speed reduction or a heavy traffic ban cannot be simply imposed. Screening by walls or berms, on the other hand, would be visually too intruding or too much land-taking. Notwithstanding the resulting high exposure to road traffic noise, such zones are often densely inhabited.

Instead of aiming at decibel reduction, noise perception improvement could be an appealing alternative. In this respect, noise annoyance could be targeted, a main health effect due to exposure to environmental noise. In many regions worldwide, noise annoyance is an important environmental policy indicator.

There is convincing real-life evidence that seeing outdoor vegetation through the windows of one's dwelling is able to reduce noise annoyance. Li et al. [1], e.g., showed that visible outdoor greenery reduces self-reported noise annoyance for residents of high-rise buildings. The category "a lot of greenery, parks and gardens" lead to a 2-point shift towards less annoyance (on an eleven-point scale) when compared to "no greenery". Along the highly noise-exposed inner-city ring road of Ghent (Belgium), outdoor vegetation as seen from the living room showed to be a strong predictor of self-reported noise annoyance. No view on vegetation resulted in a 34% chance of being at least moderately annoyed by road traffic noise, while this chance reduced to only 8% for respondents having extensive vegetation views [2]. Leung et al. [3] found that the probability of high annoyance when viewing noise walls was 26%, while with vision on greenery this percentage reduced to only 5%. In a nation-wide noise annoyance survey performed in Switzerland [4], complemented with spatial green analysis at each address point, it was found

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that neighborhood green lead to a 6 dB "equivalent noise reduction" when analyzing noise annoyance from road traffic noise sources. Although these studies clearly showed the positive effect of vegetation views in fully ecologically valid contexts, they cannot be directly used to derive urban greening design guidelines.

A first follow-up controlled virtual reality study showed that there is an optimal green quantity (more precisely window RGB greenness) near 30-35% to reduce self-reported noise annoyance [5]. This minimum, however, was not very pronounced. In this paper, a second follow-up study is described, aiming at assessing the impact of green quality on noise annoyance.

2. METHODOLOGY

2.1 Virtual Reality environment

The immersive virtual environment was a living room at the first floor of a terraced house, overlooking a 2 times 2 lane road. The 3D modelling was performed with Autodesk Revit, while Twinmotion was used for the rendering (see Fig. 1).

Figure 1. Virtual reality living room with view towards the green belt on the central reservation of a city ring road.

The vegetation was located along a wide central reservation. Defining green quality is not obvious; based on our understanding of related literature, this was performed along the dimensions biodiversity, colorfulness and maintenance degree. The five greening scenarios are depicted in Fig. 2. Scenario 5 scores highest on biodiversity, scenario 4 is the most colorful one while scenario 3 the best maintained (closely followed by scenario 1). Scenario 5, in contrast, is the least maintained. The green quantity was in all scenarios between 30% and 40%, so near the minimum as found in the first virtual reality study [5].

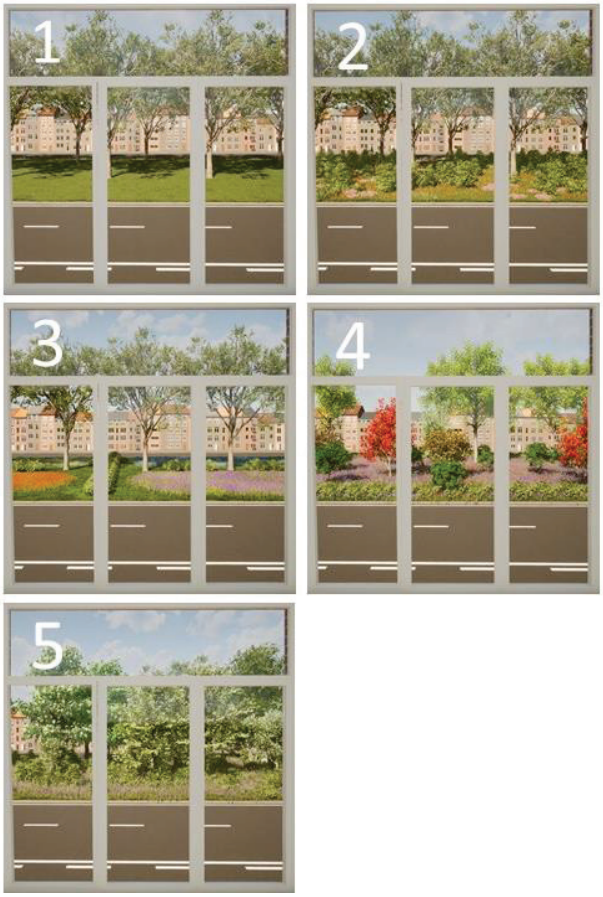

Figure 2. Vegetation scenarios as seen through the window of the virtual living room used in the audio-visual perception experiment analyzing the impact of green quality.

2.2 Sound Reproduction

Binaural recordings were made inside a real-life dwelling on which the modeled VR environment was based. A head-and-torso simulator (HATS) was positioned (frontal view) at close distance from the window which was partly open. The equivalent sound pressure level, averaged over both microphones, was equal to 67 dBA. Although the participants could look around in the virtual living room, their position was fixed near the window. To simplify the development of the auditive environment, directional sound was not considered. This is consistent with the fact that

individual road vehicles could not be identified and that the sound recordings were made during periods of busy but non-congested traffic.

2.3 Test panel

Sixty-two persons participated in the virtual reality experiment. To ensure people were looking through the window most of the time, they were asked to count the number of cars in a particular color. Participants were exposed to each of the 5 vegetation scenarios (see Fig. 2, but in randomized order) for each time 5 minutes, after which they answered a few questions, among which a standard noise annoyance question (on a scale from 1 to 11, where 11 denotes the highest annoyance). The subjects were also asked to rate the esthetic quality of the scenes (on a scale from 1 to 5, where 5 denotes the most beautiful green belt).

3. RESULTS AND DISCUSSION

The data was analyzed by means of an artificial neural network (ann) to catch potentially complex and non-linear relations between the variables involved. In addition, there is no need for a priori assumptions on the distributions, a mixture of data types can be easily handled, and input parameters may be (strongly) correlated. To have an indication of the impact of (randomly) choosing a training and test set during the ann model development, multiple models were constructed, where the final outcome is the average of all models. This approach also allows visualizing confidence intervals on the predictions.

Figure 3 shows the predicted noise annoyance (which is essentially an interpolation on the data) for the 5 green belt scenarios. All other (personal) variables involved were set to their mean values (over the test panel) while evaluating the ann model.

The results show that green quality is relevant when aiming at minimizing noise annoyance through window views. Best effects are seen for either biodiverse and/or colorful vegetation. Both quality dimensions are strongly related, and within the modelling uncertainty, no distinction can be made. The best maintained green belt (scenario 3) scores somewhat less.

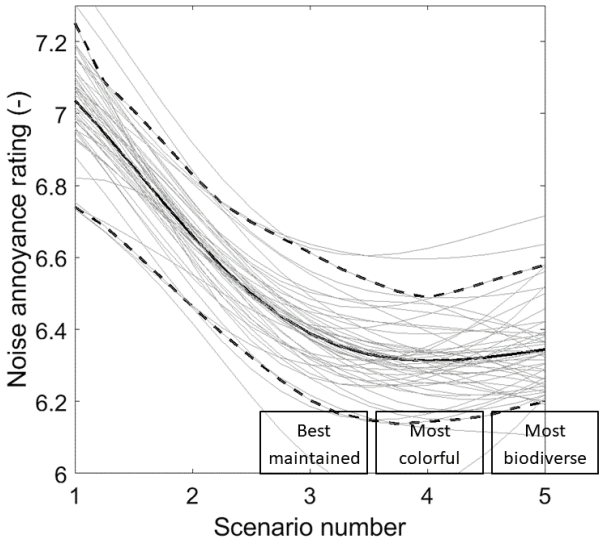

Figure 3. Modeled (absolute) noise annoyance rating vs scenario number (full line). The dashed lines indicate 90% confidence intervals on repeated model developments. The thin lines show the individual models on which the means and confidence intervals are based.

A second ann model (see Fig. 4) was constructed where the rated esthetic value by each participant (after being exposed to a specific scenario, in random order) was directly used as an input instead of scenario number. It is easily seen that the higher is the esthetic value, the lower the noise annoyance. The variation between the minimum and maximum annoyance rating is now much higher than in Fig. 3 which suggests that esthetic value is the driving factor behind the observed noise annoyance mitigation. Indeed, scientific literature on the effect of vegetation on people (in general) stipulates that concepts such as preference, esthetic value and even perceived stress reduction potential are all intertwined. This is consistent with the hypothesized main mechanism why green vision for human noise annoyance reduction works, as discussed in detail in the meta-analysis in Ref. [6].

Overall, the effect of visual outdoor green in the virtual reality settings is less pronounced than in the real-life noise annoyance surveys discussed in the introduction of this paper. The limited exposure time (which was only 5 minutes for each scenario in the lab setting) could be a main reason for this, contrasting with the (long-term) noise annoyance assessed at the dwelling, probably spanning multiple years.

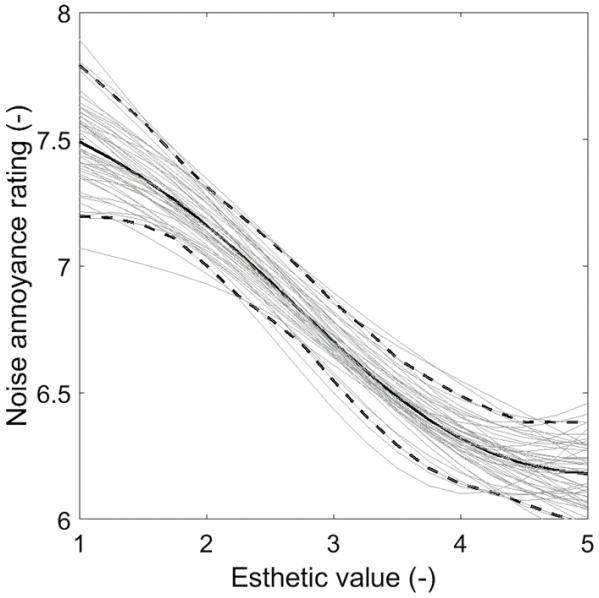

Figure 4. Modeled (absolute) noise annoyance rating vs rated esthetic value (full line). The dashed lines indicate 90% confidence intervals on repeated model developments. The thin lines show the individual models on which the means and confidence intervals are based.

4. CONCLUSIONS

The virtual reality study discussed in this work shows that the quality of vegetation infrastructure, and more precisely colorfulness and biodiversity, are relevant in view of self-reported noise annoyance reduction by green window view. The data further suggests that esthetic quality is a main driving factor in this respect. Not only green quantity should therefore be considered in urban green planning, but also quality. In this way, noise perception improvement can be a valid additional ecosystem service, fully in line with the current need for increased (urban) biodiversity.

5. REFERENCES

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