Landscape and Urban Planning 148 (2016) 203–215

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research paper

View on outdoor vegetation reduces noise annoyance for dwellers near busy roads

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HIGHLIGHTS

- View on vegetation through the living room window strongly reduces noise annoyance.
- Neighborhood vegetation or indoor plants are not sufficient to reduce annoyance.
- This perceptional measure is applicable to highly noise exposed dwellers along roads.

ARTICLE INFO

Article history:
Received 12 June 2015
Received in revised form 30 October 2015
Accepted 29 December 2015

Keywords:
Road traffic noise
Noise annoyance
Vegetation
Audio–visual interactions

ABSTRACT

The effect of outdoor vegetation, as seen from the living room's window facing an inner-city ring road, on the self-reported noise annoyance, was studied. Face-to-face surveys were taken at 105 participants at their homes in the city of Ghent (Belgium). The living room window, facing the road, was in all cases highly exposed to road traffic noise and characterized by Lden levels between 65 and 80 dBA, as taken from the official European Environmental Noise Directive's city road traffic noise map. All houses were selected to have a pronounced front-back level difference to rule out this effect. The self-reported extent to which vegetation is visible through the living room window was shown to be a strong and statistically significant predictor of the self-reported noise annoyance. The complete absence of view on vegetation results in a 34% chance of being at least moderately annoyed by noise, while this chance reduced to 8% for respondents answering to have a very pronounced vegetation view, notwithstanding median Lden levels of 73 dBA at the street-facing facade of the dwelling. Real vision on outdoor vegetation was shown to be essential - living room (indoor) plants and the mere presence of vegetation in the neighborhood is insufficient. Road traffic noise facade insulation, measured in-situ at each dwelling, could not be linked to the self-reported noise annoyance.

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1. Introduction

Along major arterial roads and city ring roads, the noise levels to which dwellers are exposed can be very high, leading to serious health risks (Fritschi, Brown, Kim, Schwela, & Kephalopoulos, 2011). As the basic function of such roads is providing sufficient traffic throughput, this leads to inevitably high noise levels. In case of optimal urban environmental planning, dwellers should not appear there. However, in many countries, mainly due to city expansion, such zones become inhabited to an increasing extent.

The traditional measures to deal with road traffic noise problems, more precisely source level reduction (quieter engines, tire optimization, low-noise pavements, ...) (Sandberg & Ejsmont, 2002), achieving noise reduction during propagation between source and receiver (Kotzen & English, 2009; Van Renterghem et al., 2015) (noise walls, earth mounds, exploiting ground-related effects, ...), and providing sufficient acoustical façade insulation, all have their merits. But clearly, there are many issues with these for the specific application along city ring roads: there is often a lack of available space for propagation related measures or these might be visually intrusive, and the technological improvement with relation to the noise emission of individual vehicles and road coverings is a steady but slow process. In addition, low-noise pavements typically need maintenance, regular replacement and only reduce rolling noise, making this often a less attractive solution. Even façade insulation is only part of the solution: people open windows resulting in an almost complete loss of insulation (Jean, 2009). This means that additional approaches are needed to com-

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http://dx.doi.org/10.1016/j.landurbplan.2015.12.018
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plement these traditional measures to improve the noise climate at such highly exposed dwellings.

An approach that has been successfully applied is providing dwellers with a quiet side, either by building and street design (e.g. ensuring connected building rows (Gidlöf-Gunnarsson, Öhrström, & Forssén, 2012) and by traffic management (Salomons et al., 2009)). Essential in this respect is a pronounced front-back façade level difference (END, 2002), compensating for the exposure at the loud side (Öhrstrom, Skanberg, Svensson, & Gidlöf-Gunnarsson, 2006). Clearly, some limits have to be set regarding the maximum level at the shielded façade as discussed by Öhrstrom et al. (2006). The presence of such a non-directly exposed façade was shown to significantly reduce the self-reported noise annoyance and self-reported sleep disturbance based on surveys in different European countries (Bodin, Björk, Ardö, & Albin, 2015; de Kluizenaar, Salomons, & Janssen, 2011; Gidlöf-Gunnarsson et al., 2012; Gidlöf-Gunnarsson & Öhrström, 2010; Öhrstrom et al., 2006; Van Renterghem & Botteldooren, 2012).

In general, the human perception of noise is strongly influenced by the visual scenery (see e.g. Fastl, 2004). Also for the specific case when vegetation is involved, positive effects have been reported. Viollon, Lavandier, & Drake (2002) showed that artificial sounds like road traffic noise are perceived less stressful and less unpleasant when the visual setting was less urban or greener. Attractiveness of courtyards, e.g. linked to the presence of vegetation, was found to be an important modifier when studying the aforementioned quiet side effect (Bodin et al., 2015; Gidlöf-Gunnarsson & Öhrström, 2007). Li, Chau, & Tang (2010) held surveys indicating that visible greenery is able to reduce noise annoyance for residents of high-rise buildings overlooking urban parks and wetlands. Visible natural features were shown to be relevant predictors of tranquility (Pheasant, Horoshenkov, Watts, & Barrett, 2008; Watts, Pheasant, & Horoshenkov, 2011). In another study, it was reported that landscape plants provide excess noise attenuation through the subjects' emotional processing based on analysis of electroencephalograms (Yang, Bao, Zhu & Yang, 2011). Aylor & Marks (1976) and Aylor (1977) concluded that as long as the source of sound can be seen, reduction in the visibility of the source, amongst others by vegetation, is accompanied by a reduction in apparent loudness. However, when vegetation fully visually screens the source there is a reversed effect namely an increase in noisiness, the latter consistent with findings by Watts, Chinn, & Godfrey (1999). Zhang, Shi, & Di (2003) reported that hedges that make passing vehicles invisible resulted in significantly less noise annoyance, and that such improvements are even more pronounced at higher noise levels. Vegetation on noise walls not only improved the overall environmental quality, but also enhanced the perceived noise attenuation performance (Hong & Jeon, 2014).

In addition to the potential of improving the perceived noise environment, there is an extended evidence base that a natural and green urban scenery is beneficial for general human health (De Vries, Verheij, Groenewegen, & Spreeuwenberg, 2003; Kaplan & Kaplan, 1989; Thompson, 2011; Thompson, Roe, Aspinall, Mitchell, Clow, & Miller, 2012; Tzoulas, Korpela, Venn, Yli-Pelkonen, Kaźmierczak, Niemela, & James, 2007; Ulrich, 1984; Velarde, Fry, & Tveit, 2007).

The main aim of this study is to see how the self-reported amount of visible vegetation through the living room window influences the dweller's self-reported noise annoyance. Many studies aiming at elucidating the audio-visual interactions are typically well controlled but rather artificial in their setup by using projections on screens in laboratories and/or by offering (very) short acoustic stimuli (e.g. Hong & Jeon, 2013; Hong & Jeon, 2014; Joynt & Kang, 2010; Preis, Kociński, Hafke-Dys, & Wrzosek, 2015; Viollon et al., 2002; Watts et al., 1999; Yang, Bao, & Zhu, 2011). In such experiments, soundscape characteristics like noisiness, pleasantness, stressfulness, comfort, harmony and others are then assessed. The focus in the current study is on the residents' experiences in their ordinary living environments, ensuring ecological validity and allowing to assess (long-term) self-reported noise annoyance. Noise annoyance is an important noise policy indicator, and one of the health-endpoints of environmental noise as identified by Fritschi et al. (2011). Furthermore, the focus is here on the effect of the mere presence of vegetation in a zone highly exposed to road traffic noise and not necessarily vegetation as a means of hiding the noise source or in relation to traditional noise walls (Aylor, 1977; Aylor & Marks, 1976; Hong & Jeon, 2014; Joynt & Kang, 2010; Watts et al., 1999; Zhang et al., 2003).

2. Methodology

2.1. Participant selection

Participants were selected along different sections of a highly noise-exposed inner city ring road in Ghent, Belgium, characterized by either an abundance of vegetation (street trees, parks bordering the road, vegetation on the central reservation, etc.) or a lack of vegetation. Such sufficiently contrasting parts of the ring road were selected in advance based on aerial photographs.

Dwellings directly bordered the ring road and were part of closed-row building blocks with enclosed backyards and should therefore have a similar and pronounced front-back level difference. Corner houses were not selected. Given the high road traffic noise levels at the front façade, it can reasonably be assumed that the ring road dominates the soundscape at the shielded façade as well.

Participants were directly contacted, without prior announcement, by knocking on doors. The survey was announced as general research on the living environment. The minimum age for respondents was 18 years. Before starting the survey, the number of years living at the dwelling was asked for and it was checked that the participants were living at least 1 year at their current location. It was ensured by the interviewer that the dwelling had a living room window facing the ring road. A single interviewer performed all 105 face-to-face questionnaires. The surveys were taken during summer in a two week's period. Multiple participants were allowed per dwelling, but interviewed separately. No informed consent was asked from the respondents.

2.2. Noise exposure assessment

2.2.1. Most exposed façade level L_{den}

The noise exposure at the most exposed façade was extracted from the road traffic noise map approved by the Flemish regional government for the agglomeration of Ghent, which has been reported to the European Commission in the framework of the Environmental Noise Directive (END, 2002). Such strategic noise maps predict long-term yearly-averaged noise indicators. For the current study, L_{day} (i.e. the equivalent sound pressure level during daytime, from 7.00 h until 19.00 h) and L_{den} (i.e. the equivalent sound pressure level over a 24-hour period, including penalties for the evening and night period) were considered. The front-door position of the dwelling was taken as a reference point, and the average of the noise levels within 7.5 m was calculated since sound pressure levels could vary along longer façades.

Although often concerns are raised related to the accuracy of such strategic noise maps, levels near busy roads, as those considered in the current study, are reasonably accurate since noise levels are strongly source driven there. Only large deviations from the actual traffic intensity or composition would lead to significant errors in the predictions. For less trafficked roads or at shielded

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