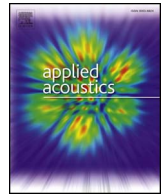




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# Effect of interaction between attention focusing capability and visual factors on road traffic noise annoyance



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## ABSTRACT

In recent decades, noise annoyance has been investigated thoroughly as one of the most prominent effects of traffic noise. Still, the influence of visual factors on sound perception is not completely understood. Audiovisual attention focusing and gating are expected to play a role at the perceptual stage. This would also imply the existence of inter-person differences in exposure-effect relationships beyond known factors such as noise sensitivity. To explore these hypotheses, an experiment was designed that combines a newly designed test on audiovisual attention focusing capabilities with a noise annoyance experiment conducted in a mockup living room. The noise annoyance experiment used 16 audiovisual stimuli, which are a combination of 4 window-view video sceneries and 4 sound fragments, to investigate the relative importance of sound source visibility and green elements visibility. In this setting, it was found that (1) sound source visibility, as a functional parameter of the visual setting, has more impact on self-reported noise annoyance than the green element's visibility which describes the quality of the visual; (2) self-reported noise sensitivity remains the strongest personal factor, yet persons being easily distracted by visual elements report significantly lower noise annoyance at the same exposure level; (3) two significant interactions were observed in the prediction of self-reported noise annoyance: (a) noise sensitivity interacts with sound source visibility; (b) vision dominance, as a personal factor, interacts with the visibility of green elements. The interaction between these factors provides additional evidence to support the role of audiovisual attention in the emergence of noise annoyance.

## 1. Introduction

In recent decades, the relationship between noise exposure and annoyance, especially in and around the dwelling, has been explored in depth [1,2]. Hence, noise annoyance has now been recognized by the World Health Organization as the strongest and best proven effect of environmental noise on people. For the European Union's noise indicator,  $L_{den}$ , exposure effect relationships have been derived [3]. It has also been shown that noise annoyance could be an indicator for effects of noise on health and well-being [4–6]. The determinants of annoyance were investigated in related studies leading to complex models [7,8]. Epidemiological research has indeed shown that not only the average sound level influences annoyance, but also personal factors modify the exposure effect relationship (such as age, gender, education and noise sensitivity, as well as other environmental factors [9–11]). In particular, subjective noise sensitivity was shown to be a very stable personality trait which is determined both by inheritance and experience [12–16].

In environmental noise surveys, the effect of visual elements such as the view from the window on long-term noise annoyance have been addressed before [17–20], yet less frequently than other contextual factors. Audiovisual interactions in combination with noise annoyance in and around the dwelling is a multifaceted effect that is not easy to grasp. In experimental work related to urban environments, the congruence between visual and sound information was strongly affecting the appraisal of the sonic environment, in terms of visual influence [21]. Although congruence may also play a role in occurrence of annoyance in and around the dwelling [22], more basic aspects of the audiovisual experience have been suggested, such as visibility of sound source [23]. Some studies pointed out that seeing the sound source would increase subjective annoyance [24], others found that visually screened traffic was perceived as more noisy [25,26]. In addition, the general quality of the visual setting and more particularly, the visibility of green elements was shown to have a direct influence. Visually attractive and green noise barriers tend to be more efficient in reducing noise annoyance [27]. Recent research [28] has nevertheless confirmed

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the complexity of the audiovisual interaction: in a lab experiment, adding visual information to a listening experiment tended to reduce annoyance if the sound source was believed to have a positive influence, while annoyance increased for mechanical sound sources.

Psychophysical knowledge may help understanding the complex influence of visual information on perceived noise annoyance in and around the dwelling. Prior research has shown that noticing sounds can be regarded as a precursor for noise annoyance [29]. In this view, sounds that attract more attention would more likely cause annoyance. Audiovisual stimuli, which are irrelevant for the tasks a person is involved in, may capture involuntary attention, a process where sensory modalities interact at different levels in the brain [30]. This could lead to an increase in annoyance for visible sources. In addition, individual differences in the capability of focusing attention has recently been shown to affect the cocktail party effect [31]. Distractibility may be a personality trait that can be defined also in the healthy population [32]. Hence, it seems useful to study whether distractibility could be a personal factor affecting the influence of the visual scene on noise annoyance or even the emergence of noise annoyance itself.

It should be noted, however, that occasional attention saccades to environmental factors not only cause increased noticing and therefore possible annoyance. Attention restoration theory predicts that such attention switches may enhance restoration and therefore would not be appraised as annoying [33,34]. A better understanding of audiovisual interactions in perception of the environment may lead to better urban planning and soundscape design [35].

In this article, an experimental study is described that aims at confirming the hypothesis on the mechanisms underlying the effect of the view from the window on noise annoyance. In addition, the experiment aims at identifying subjective noise sensitivity and distractibility as personal factors influencing this effect. To be able to go beyond questionnaires for assessing personal factors, we opted for a lab study using well controlled stimuli. Assessing noise annoyance in an ecologically valid way in an experimental setup is rather difficult as the main hidden factor under investigation, i.e. non-voluntary attention, is replaced by focused attention in a listening experiment. For this reason, two specific requirements were introduced in the experimental design. Firstly, the exposure time for each stimulus was 10 min and participants were instructed to engage in some light activity during the experiment in order not to focus on the sound. Earlier studies [36,37] have shown that this protocol is valid. Secondly, since the target of this study is the effect of the view from the window, direct comparison between different visual stimuli is avoided by showing the visual stimulus in a natural setting, a mockup window, and by presenting the different visual stimuli on different days. The additional distractibility experiment is conducted at the very end not to reveal the focus on visual information.

## 2. Methodology

### 2.1. Overview

The first part of this study is a road traffic noise annoyance experiment conducted in conditions that should resemble the everyday living context as closely as possible. Participants were exposed to 16 audiovisual stimuli (Fig. 1) during 4 separate experimental days in the same mockup living room. At each experimental day, the view from the window was fixed and the audio fragments varied. The participants were led to believe this experiment was about rating the perceived annoyance of 16 environmental sound conditions in a living room. Each audiovisual stimulus was played for 10 min, in order to give participants enough time to engage in some light activity and to adapt to the living room environment. After the presentation of each audiovisual stimulus, they were asked to rate their perceived noise annoyance during the past 10 min on an 11-point scale (from 'Not at all' (0) to 'Very much' (10) annoyed) [38].

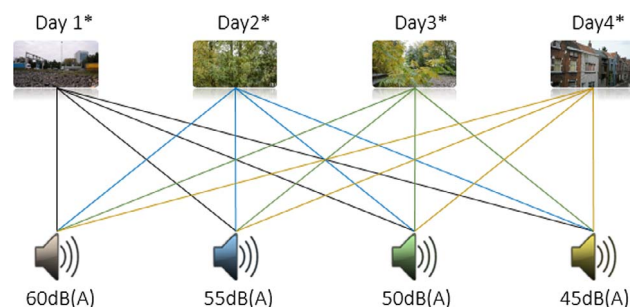


Fig. 1. 16 audiovisual stimuli (combination of 4 sound fragments and 4 window-view sceneries). (\*The order of experimental days was randomized.)

Since detecting the effects of visual factors on sound perception was the objective of this study, all other factors were carefully controlled in order to eliminate their impact on sound perception as much as possible. For example, during each experimental day, participants were asked to sit in the same seat in the mockup living room, which gave them the same perspective to all scenes. It was also assured that the room setup, the lighting, and the room ventilation remained unchanged. The acoustic playback level was controlled by measuring the sound level in the center of the room. Participants were also asked to refrain from drinking alcohol or unusual amounts of coffee or taking medical drugs before the experiment. In addition, it was asked not to listen to loud music while waiting to participate in the experiment.

The design of the experiment assumes that the auditory memory of participants was erased in between experimental days. However, there may still be a degree of habituation to the experimental setup. Therefore the order of presentation of the 4 visual settings during 4 days was randomized between participants.

The second part of the experiment was only conducted the fourth day, after the regular test was completed. It consisted of a listening task focused on detecting deviant auditory scenes. This was to avoid impact on the subsequent days. The second part also included the short version of the noise sensitivity questionnaire proposed by Weinstein [39].

### 2.2. Mockup living room

The mockup living room was arranged as shown in Fig. 2. A 60-in. television screen, projecting window-view videos, was fixed in a specially-made cabinet integrating it in the wall and making it resemble a window. Two loudspeakers were hidden in the cabinet to make the sound appear to come from the window. Note that the loudspeakers visible in Fig. 2a were not used in this experiment. The control room is positioned in the corner, separated from the living room by a large thick curtain. A subwoofer is also positioned next to the control room, which ensures that low frequency sound is reproduced realistically.

As shown in Fig. 2a, three sitting positions were marked in this room. Participants were suggested only to sit in these preselected seats, which gives them certain perspectives to the mock-up window (obviously, they are not being told that this was the reason).

### 2.3. Audiovisual stimuli

#### 2.3.1. Window-view video sceneries

The four videos contained a mixture of different natural and man-made landscape elements. Four screenshots of the videos (all taken near the city of Ghent, Belgium) are shown in Fig. 3. Scene (a) provides an open view of highway traffic and contains very few green elements; (b) allows vision on some parts of the highway through the woods; (c) contains a totally green visual setting; and (d) shows a row of houses along a non-busy street, hiding a highway from sight. The sound source was completely visible in scenery (a) and partly visible in scenery (b), while in (c) and (d) no sound source was visible. On the other hand,

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