Effects of Sound Source Visibility on Sound Perception in Living Room Environment

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ABSTRACT

Due to urban sprawl and rural urbanization, an increasing number of dwellings and offices are subjected to high levels of traffic noise, which might disturb people's daily life and activities, ultimately leading to noise annoyance. Although the relation between sound exposure and noise annoyance has been investigated thoroughly during the last decades, the influence of visual factors on sound perception is not completely understood. In this paper, the effects of sound source visibility on sound perception in living room environment are studied. For this purpose, 4 window-sight video sceneries, which contain a mixture of different nature and man-made landscape elements are combined with different sound levels and presented to the participants in the experiment in a mockup living room using a surround system and a large television screen. To explore individual differences in attention focusing, a series of scenarios, in which either the audio or visual parts of the videos are subtly altered are used. Results of the experiment are used to investigate the mechanisms explaining the influence of sound source visibility on audiovisual perception.

Keywords: sound perception, living room, sound source visibility
I-INCE Classification of Subjects Number(s): 02.6

1. INTRODUCTION

Based on the EEA Report: Urban sprawl in Europe – the ignored challenge (1), urban sprawl has accompanied the growth of urban areas across Europe over the past 50 years. Countries or regions with economic activity and high population density such as Belgium, The Netherlands, southern and western Germany, northern Italy and the Paris region are enjoying the most visible impacts of urban sprawl. By 2050, about 70% of the World's population will be living in cities (2). This leads to a continuously increasing number of dwellings and offices being subjected to high levels of traffic noise, which ultimately has a large impact on human perception of one's living environment.

In the last decade, the relationship between sound exposure and annoyance has been explored in depth, as well as the impact of noise on human health, on sleeping disturbance and on human behavior in general (3, 4, 5, 6). According to earlier studies, non-acoustic factors are important modifiers for sound perception, such as social, landscape and behavioral factors (7, 8). Though it is often found that visual elements interact with sound perception (9), still, the underlying mechanisms are not completely understood.

This study focuses on the effects of sound source visibility and the visibility of green elements on sound perception and resulting annoyance in conditions that resemble the everyday living context as closely as possible. In particular, the objective of the study is to investigate how people's subconscious reaction to visual stimuli influences their perception of the sonic environment and to quantify the noise reduction that would lead to the same impact. For this purpose, a listening experiment is designed, in which participants are asked to perform an evaluation of the effect of the sound in a living room while being kept in the dark about the changes in view through a mockup window. In Section 2, the methodology of the experiment is explained in detail; in Section 3, some preliminary results are discussed.

2. METHODOLOGY

Participants are asked to come to a mockup living room for this experiment four times in total. Each time they come, four indoor sound environments are played during 10 minutes while keeping the view through the window constant. After the presentation of each indoor sound environment, a questionnaire is administered to the participants. Because the objective of this study is to detect the effects of visual factors on sound perception, all other factors are being controlled in order to eliminate their impact on sound perception. Firstly, all four scenes presented on one day contain the same video, and the same kind of traffic noise, but at different levels corresponding to different window insulations. Participants are asked to participate in four separate days, in order to erase their acoustical memory of the audio. In fact they are led to believe that they will be experiencing four different sounds each time. In reality the sound fragments are exactly the same and only the view from the window changes. Secondly, every time when participants come, they are asked to sit in the same seat in the mockup living room, which gives them the same perspective to each scene. Furthermore, the same questionnaire is used each time, and the questionnaire is kept short and intuitive.

2.1 Mockup living room

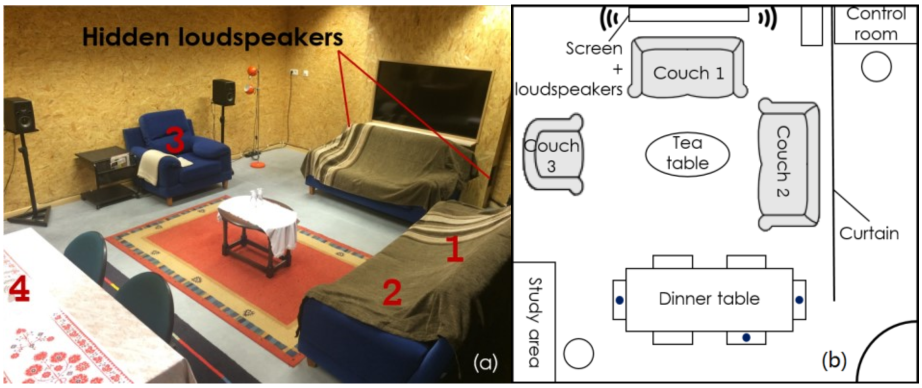

Figure 1 – Layout of the mockup living room: (a) photograph; (b) schematic drawing (not to scale).

A mockup living room used for this experiment is arranged as shown in Fig.1. A 60-inch television screen and two hidden loudspeakers, which are used to project window-sight videos and to play back two-channel audio, are fixed in a specially-made cabinet integrating it in the wall and making it resemble more a window. The control room is positioned in the corner, isolated 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 can be seen from Fig.1(a), two additional loudspeakers are positioned at each side of couch 3, which are not being used for audio playback in the current experiment.

As shown in Fig.1(a), four sitting positons are marked in this room. Seat 1 and 2 are in coach 2, coach 3 is seat 3 and seat 4 is on the dinner table not directly facing the mock-up window. Participants are 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 is the reason). This experiment can thus host four participants at a time, and they should keep sitting in the same seat during the complete experiment. In practice, there is the possibility that some participants may miss their turn, hence they will be merged into other groups to catch the next round of window-sight scenery. Two side seats on the dinner table and the other seat next to seat 4, as marked with dark dots in Fig.1(b), are considered as backup seats to ensure that in such case, there is a maximum similarity with their initial seats.

2.2 Audio-visual stimuli

One window view and four sound environments are presented in random order (see below) to the participants each experimental day. During 4 different days, different window views are projected while the same sound environments are presented. These audio-visual scenes are constructed by mixing all combinations of 4 videos and 4 audio fragments. The videos contain a mixture of different nature and man-made landscape elements. They are constructed to reproduce four different but typical scenes that one might see from one's living room window, in case it would be facing a busy road. Each audio-visual scene lasts for 10 minutes, in order to give participants enough time to engage in some light activity and adapt this living room environment. Experiments using shorter fragments may result in an evaluation of loudness rather than an evaluation of annoyance as attention focus will be very strongly on the sound. Longer exposure time could be beneficiary yet it would extend the total experiment too long and make participants unhappy about the duration of the experiment itself.

2.2.1 Window-sight video's

Four screenshots of the video's (all taken in Ghent, Belgium) are shown in Fig.2. Scene (a) is the total open view of highway traffic and contains very few green elements; (b) shows some parts of the highway traffic through the woods; (c) contains a totally green view and even some close shot of trees and branches, behind which it is assumed that there's busy traffic, although this can not be seen; and (d) shows a series of rather traditional Belgian dwellings, along a tranquil street but presumably hiding a highway from sight.

Figure 2 – Four window-sight sceneries

The sound source is completely visible in scenery (a) and partly visible in scenery (b), while in (c) and (d) no sound source is visible. On the other hand, scenery (b) and (c) contain dominant nature elements, whereas scenery (a) and (d) contain more man-made elements.

These four visual scenes show various possibilities of having a living room window facing a busy road, both directly and indirectly. In addition, the visual elements within each scene are clearly different.

2.2.2 Audio fragments

Four audio fragments with different sound level are created by simulating the effect of a change in window isolation. The original traffic noise audio fragment was recorded during the video recording at the location of scene (a)(see Fig.2) with a B-field microphone, in a four-channel B-format. This audio recording was then transformed into two-channel format using VVMic (Visual Virtual Microphone) 3.4. According to the work of Antonio and Diogo (10), three frequency attenuation curves out of six were selected to represent single glazed window, double glazed window and triple glazed window (specific choices: 'single layer 8mm', 'double 8+4, d=10mm', 'triple 8+4+4, d1=100, d2=50'). The frequency attenuation curves were applied to the original audio recording using Sony Soundforge. Fig.3 shows the insulation curves for three types of glazed windows.

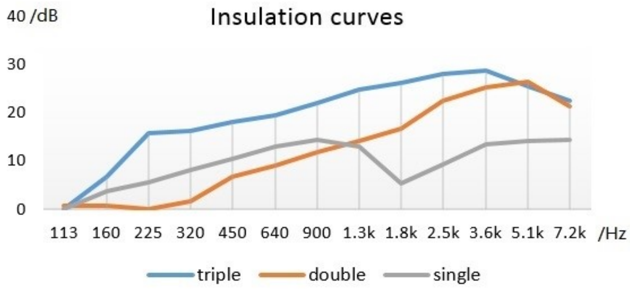

Figure 3 – Frequency attenuation (insulation curve after calculation).

By fixing the volume of the audio card of the playback PC, the media player software and the amplifier of the loudspeakers, the overall presentation sound level of the original audio fragment is settled at 60dB(A). This roughly represents the open window situation. The overall presentation sound level for the single, double, and triple glazed window is fixed at 55dB(A), 50dB(A) and 45dB(A) respectively, by adjusting the overall gain/loss in the audio fragment. Participants in the experiment are being told that sounds correspond to four different window insulations. At each experiment day, the same audio fragments are presented, but the participants are told that they are evaluating sounds corresponding to different window insulation. It is assumed that this method of presentation ensures that it does not direct a participant's attention to differences in the view from the window. As the difference between the sounds is in fact not the target of the investigation, the above procedure for generating the different sound excerpt only needs to suggest ecological validity so calibration for the room response for example is not essential.

2.3 Course of the experiment

Since each participant experiences 4 different audio-visual scenes at each experiment day, the order of presentation is important, for both the visual and audio fragments. There are A_4^4=24 possibilities for the order of video presentation over the four experiment days, and an equal number of 24 possibilities for the order of audio fragment presentation each experimental day. To prevent a sharp contrast in level of subsequent audio fragments, such as a jump from 60dB(A) (original recording) to 45dB(A) (triple glazed window), the maximum change in sound level between subsequent fragments was limited to 10 dB(A). This reduces the number of possible of sound presentation orders to 12, as shown in Table 1. The sound order is then applied to the video's ordered randomly between experimental days, as shown in Table 2, by adhering to the following rules: each scenery should be coupled two times with all 12 sound orders, and over all experiment days, all four scenes should have a different audio fragment order. This randomization ensures that all possibilities are covered, and is expected to eliminate any impact of order of presentation on the results of the experiment.

Table 1 – Sound order randomization.

sound order	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
	original	original	original	original	single	single	double	double	triple	triple	triple	triple
	single	single	double	double	triple	original	triple	original	single	single	double	double
	double	triple	triple	single	double	double	single	single	double	original	original	single
	triple	double	single	triple	original	triple	original	triple	original	double	single	original

Table 2 – Scenery order randomization combined with sound order
(eg, 'a2' stands for scenery (a) in Fig.2 combined with sound order 2 in Table 1).

scenery order	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Day1	a2	a5	a1	a4	a8	a3	b5	b1	b3	b6	b10	b12
Day2	b11	b7	c11	c5	d4	d10	c4	c9	d12	d1	a9	a5
Day3	c8	d9	d12	b2	b11	c1	d8	a3	a2	c4	c4	d3
Day4	d6	c3	b10	d1	c2	b6	a1	d2	c9	a12	d6	c7
scenery order	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Day1	c1	c5	c11	c3	c10	c6	d10	d11	d9	d8	d7	d3
Day2	d5	d11	a10	a12	b3	b7	a6	a4	b4	b9	c6	c8
Day3	a7	b8	b12	d7	d2	a11	b11	c10	c12	a11	a10	b4
Day4	b2	a6	d5	b8	a9	d4	c2	b5	a8	c7	b9	a7

At the start of the experiment, participants are told that the experiment is designed to study their disturbance by traffic noise from the window in a living room environment. All they have to do is to relax and be as if they were in their own living room. They can read a book, browse a magazine, have some drink, play with their phones to some extent, or even to chat with the other participants. This prevents that participants would focus their attention too much on listening to the sound.

At each experiment day they experience four living room environments, consisting of the same view from the window but combined with the four sound fragments, each lasting 10 minutes. There is a one-minute break between each exposure, during which every participant is asked a single question: 'Thinking about the last 10 minutes staying in this living room, which number from 0 to 10 best shows how much you are annoyed or not annoyed by the traffic noise?'. At the end of the complete experiment, after four days, a more elaborate questionnaire survey is presented to all participants to collect some personal information and individual personality preferences.

2.4 Attention focusing experiment

An additional audiovisual attention focusing experiment is conducted at the end of the 4-th day of the above described experiment. This experiment explores individual differences in audiovisual attention focusing. A series of scenarios, in which either the audio or visual parts of an audio-visual stimulus is altered in a subtly way is used. Four audiovisual scenarios are designed. For each scenario a congruent and subtle attention attraction object is added to the visual scene or not. The matching attention attracting sound is added to the sound track or not. This ecologically valid alternative to basic psychological stimuli is intended to investigate whether a person's visual attention mechanism dominates auditory attention.

Table 3 – Visual and auditory context for each of the scenario's used in the attention focusing experiment together with congruent visual attention attracting object (VAO) and matching auditory attention attracting object (AAO).

No.	a	b	c	d
Scenario	airport terminal	student restaurant	city park	airport runway
Visual context	terminal window view to parking apron	student restaurant at sitting position	a bunch of chicken in the park	terminal window view to airport runway
Auditory context	broadcasting, people talking, aircraft engine	people talking, eating, forks and plates	chicken crowing and walking on fallen leaves	airport outside sound, wind, shuttlebus passing
VAO	shuttlebus passing	tapping finger	walking pigeon	departing aircraft
AAO	shuttlebus sound	finger tapping sound	pigeon call, walking on leaves	aircraft departing sound
Duration	0:30	0:30	1:00	1:00

Table 4 – Six items of each scenarios

	item No.	format	content
Section 1	1	audio file	background sound + attention attracting sound
	2	audio file	background sound
	3	audio file	background sound + attention attracting sound
Section 2	4	video file	background view+ trick object; background sound + trick sound
	5	video file	background view + trick object; background sound
	6	video file	background view; background sound + trick sound

Table 3 describes the context and the visual object (VAO) that could attract attention and a corresponding sound (AAO) in each scenario. Audio-visual fragments of each of the scenarios will be presented at the conference. Two sets of three items are constructed based on these elements for each scenario (Table 4). A classical odd stimulus detection is used to assess the ability of participants to detect the auditory attention attracting object. Participants are asked to first listen to item 1, 2 and 3 of one scenario, and then answer the question: 'Which of the three items sounds most different from the other two?'. This step is to test the participants' pure hearing sensitiveness since there is a correct answer (item 2) in each scenario. Afterwards, participants are asked to watch item 4, 5 and 6 of one scenario, and they receive the same task as before: to select which of three items sounds most different from the other two. Since item 4 and 5 are the same from the visual perspective, whereas items 4 and 6 hold the same audio, the correct answer of this section should be item 5. But this becomes more tricky because of the influence of the subtly altered visual. Participants are guided through section 1 of all scenario's and subsequently through all sections 2. Also, the order of scenario presentation, the order of items in each section, and the order of the correct answer is randomized.

3. RESULTS

At the moment of the submission of Inter-Noise proceedings paper, the experiment had not been completed, but based on some initial runs of the experiment, certain results can already be foreseen. Firstly, among all four sceneries, scenery (a) easily attracts more of participants' attention by giving the most visual access to the moving sound source, whereas scene (b), (c) and (d) attract relatively low attention. Since scene (b) allows a partial view on the sound source, some participants may focus their attention on this, in particular during the high level noise. Secondly, in an older pilot for this experiment using a more basic mock-up of a living room, a monotonously increasing exposure effect relationship was found for annoyance as a function of sound level, as expected. But although participants were not made aware of the different view from the window, this view had a significant effect on this exposure effect relationship. The attractiveness of the visual scene was not as carefully selected in this pilot study, which may explain why the effect of visibility of the source and visibility of nature could not be disentangled. So, although it is often mentioned that 'green' elements (trees, woods and grass) significantly contribute to a reduction of noise annoyance at home, scenes (b) and (c) may not be the least annoying scene under all sound environments.

An important factor in understanding the mechanisms leading to noise annoyance and how vision plays a role is attention. The combination of the first and second part of this experiment will allow to uncover whether a stronger dominance of vision in the environmental perception leads to a stronger influence of the view from the window on noise annoyance.

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