Determination of the context related sound level in an urban public place by using a sound-masking procedure

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Introduction

In an urban environment, a multitude of sounds from cars, motorcycles, bicycles, talking people on the terraces, sound from church's bell, foaming fountain, singing birds and many others, affect soundscape. A person often becomes aware of the presence of a particular sound source if it is related to the instantaneous mental activity, or if the sound has some very remarkable feature. Once someone's attention is focused to an individual sound in a mixture, it becomes possible to qualitatively estimate its sound pressure level. Since the dynamic range of sounds occurring in daily situations is very large, very often weak sounds are masked by louder ones. However, the severeness of masking of a particular sound of interest (from here on referred to as the "signal" sound), by the other sounds in a mixture (from here on referred to as the "masking" sound), is not only determined by its relative loudness, i.e. the difference in overall "signal" sound level and in masking due to suitable frequency spectum. People are able to exploit particular spectral and temporal features of weak signal sounds to detect their presence and nature in the presence of a louder background if they understand the meaning or context of the sound signal. Boubezari and Coelho (2008) have made some steps to unravel and quantify this ability, by performing listening tests where first the threshold of people hearing a signal in white noise was determined by presenting the signal at decreasing levels till it was not heard anymore. The authors found that their result to be consistent with experiments of Zwicker & Schaft (1965), i.e. a complex sound is totally masked by a white noise equal to the level of its loudest frequency component. The sound level (SPL) of that white noise was referred to as the 'size' of the sound (Boubezari and Coelho, 2008). Following a similar but nevertheless distinct strategy, here we present the results of listening tests for which signal sounds have been mixed with a masking sound consisting of other sounds and random noise, with the goal of determining the detection threshold of different signals in different acoustic contexts. In all our experiments we have worked with binaural stimuli.

Sound sample preparation and listening tests

The soundscape mimicked in the listening tests was the one of the "Grote Markt", the main square of the city of Leuven in Belgium. The square is surrounded by a historical town hall, St. Pieter's church, several restaurants and apartment buildings. Due to a variety of sound sources and socio-cultural activities on this square on different days and in seasons in the year, the soundscapes occurring on this site are quite interesting. The overall most typical sounds occurring on the site are definitely human voices, human steps, bicycles, church bells and busses passing by 10 times per hour during working days. During the past years several changes were made in this square, mainly related to a reduction of its accessibility by cars for reasons of functionality, noise and safety. Nowadays, the square is considered as a pedestrian zone where only city buses are allowed to enter.

In order to make the soundscapes presented in the listening tests by headphones realistic, a hybrid combination of anechoically recorded sounds (footsteps, saxophone, talking people and restaurant sound (e.g. from cutlery impacts) convolved with the binaural room impulse response (BRIR) of the acoustic location for appropriate source and receiver positions, and in situ recorded sounds (traffic and singing birds) were prepared. A 3D computer model of Grote Markt was based on measured dimensions of the square in situ by using a laser distance meter. A simplified virtual model was constructed in Odeon9.2®. Grote Markt has an irregular shape of roughly 120 x 32 m^2 size. For the sake of making acoustical simulations, a part of the streets that terminate on this square were included in the model, resulting in a total calculation domain of about 240 x 140 m surface (Figure 1). Sound absorption and scattering coefficients of the surrounding buildings and ground surfaces were estimated based on visual inspection. In order to make the presented soundscape more realistic, the talking people were simulated by mixing sound coming from different positions on the square (respective BRIRs simulated at different source positions), while subsequent footstep sounds were simulated from a respective steadily moving source position with 70 cm step length in between).

The listening tests were realized in a silent anechoic room with background noise less than 30dB(A) in order to eliminate the possible influence of unwanted sound sources. Samples of different compositions, with footsteps (L_{Aeq}=45dB), distant saxophone music (L_{Aeq}=50dB), traffic (L_{Aeq}=54dB), talking people (L_{Aeq}=54dB) and singing birds (L_{Aeq}=45dB) as signal sounds presented at real life sound pressure level, mixed with a variable level of white noise, or pink noise (both generated in CoolEdit®), were presented by open headphones of listening unit (Head acoustics®) to 12 normal hearing people, 22 to 35 years old. The noise level was varied randomly in pre-programmed steps, such that a wide range of signal to noise ratios were achieved, from the signal sound being fully masked to the signal sound being clearly audible. For every sample, the test person was asked whether he could hear or not a particular sound.

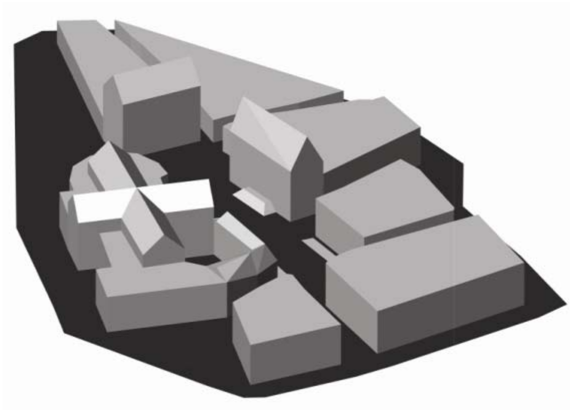

Figure 1: 3D model of Grote Markt, Leuven, Belgium

For the sake of compensating for guessing by the test persons, also some samples with signal sound absent were presented. In the next section, the results of listening test are expressed as the percentage of the times that the 12 persons on average could hear (or not hear) a sound signal of interest. All variations of noise level and type of noise, were examined for two categories of cases: in the first category, the signal of interest was mixed with (a variable level of) noise only, while in the second category, the other signals mentioned above were also mixed in together with the signal of interest and the noise.

Results and discussion

The results of the listening tests are graphically depicted for different combinations of signals and type of noise, in the presence of additional sounds (filled squares) or without additional sounds (empty squares). Example of the result presentation is given in the figure 2 and 3 that show the result for saxophone. A quick inspection of the variation within the two latter categories learns, that the spectral and temporal nature of the signal sound, as well as the type of masking sound are quite crucial for detecting its presence.

In all circumstances, the musical sound of the saxophone and singing birds abruptly change with the level of the noise. Both types of sounds are detected even in very high masking sound levels probably thanks to clear tonal components. From the five signal sounds (talking people, saxophone, birds, traffic and footsteps), the sound of saxophone has been the easiest to detect in the individual as well as in a mixed signal sound.

The detection of footsteps has been almost as easy as saxophone, most probably due to an impulsive character of the signal, e.g. sound of a short duration and high intensity.

To detect a presence of talking people was slightly easier in experiments where speech was not mixed with the other environmental sounds.

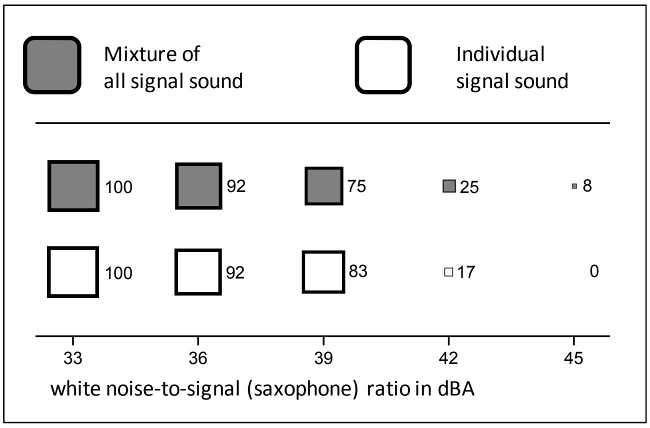

Figure 2: Example of the listening test result for saxophone as a signal sound and white noise as masking noise sound.

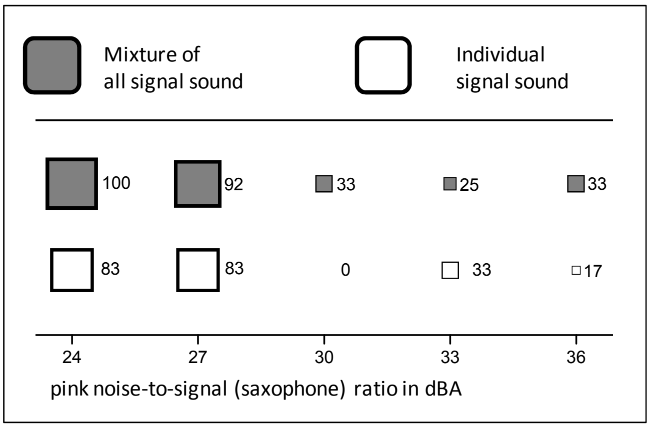

Figure 3: Example of the listening test result for saxophone as a signal sound and pink noise as masking noise sound.

Traffic noise (signal without clearly passing-by vehicles) was the most difficult to detect in both masking sounds (white and pink) as well as in both individual and mixed signal, due to its stationary character and flat spectrum, most similar to masking sounds.

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