DEVELOPMENT OF A SOUND MASKING SYSTEM FOR ROAD CONSTRUCTION NOISE

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1. INTRODUCTION

A large proportion of Montreal' highway network was built during the 60'. Today, many overpasses need major renovation. To avoid traffic jams, the road works are made mostly at night while the highway can be closed. A fairly large numbers of highways are located in densely populated areas and inhabitants living near by are complaining about the noise related to the construction works. The main objective of this project was to examine the effectiveness and feasibility of a noise masking technique used to reduce the population's annoyance related to emerging construction noises. The current research is a replication of Leroux et al. (2004).

The overpass Roi-René above the Metropolitain highway (A-40) has been crumbled down and rebuilt during the summer of 2004. The project was divided into three phases. The *first phase* measured the level of emerging noises at different distances from the construction sites. Surveys were also carried out among inhabitants to obtain their opinion and perception before and during the road construction. The *second phase* led to the evaluation, in laboratory, of the perception of the noise emerging from the construction site Subjects were asked to comment individually on the disturbing dimension of the noise generated by the construction work, presented against 12 different background noises designed to reduce the annoyance. Focus groups were also organized to get a closer look at the relation between psychoacoustics dimensions and emotions. A *third phase* examined, directly within the affected areas, how a system broadcasting various background noises selected from the second phase, was able to reduce the annoyance expressed by the inhabitants. This paper provides the results of the first two phases.

2. METHOD

2.1 Environmental analysis and survey

A sound level meter (Larson-Davis model LD 824) was used to measure the level of ambient noise before and during the construction noise in the residential neighbourhood ($L_{Aeq\text{-}15m}$). Samples of noise were recorded at 17 different locations onto a digital audio tape (Sony MZ-R55). In parallel, one hundred residents were asked to provide a rating of the level of annoyance at night, under two conditions: (1) while the highway was open to regular traffic at night and, (2) when it was closed for refection purposes.

2.2 Listening sessions and focus groups

Three groups of 20 subjects took part in the laboratory experiment: (1) young normal adults, (2) adult residents from the neighbourhood where the field work was conducted, and (3) adults that were matched to the subjects in group 2 except that they did not reside in the neighbourhood. The subjects were tested individually during three test sessions. They were seated in a quiet room (Hoeg et al., 1997) and they were instructed to rate the level of masking efficacy (using a 100 point scale arranged along five adjectives) of complex signals that were presented to them thru loudspeakers positioned in front of them. An adapted version of SEAQ (CRC, 2003) was used to present the signals and to record the responses. During the first session the subjects rated 12 different background noises that were played in isolation. During the following test session the subjects rated the same 12 background noises, presented simultaneously with a recording of the construction noise. Each masking signal was presented at a S/N ratio of + 5 dB. Finally, the subjects were asked to rate their emotional feelings when listening to the background noises. Six scales (7 point each) were used to assess the pleasantness, relaxing, restfulness, soothing and happiness dimensions.

Six (3 resident and 3 non-resident) focus groups were organized with each six subjects. The subjects were first asked to listen to series of artificial sounds manipulated according to 1) frequency, 2) amplitude modulation and 3) frequency/amplitude dimensions. The sound were obtained from a white noise digitally filtered using the above mentioned dimension. Subjects were then asked to rate the pleasantness (7 point scale) and provide a general appreciation of each sound using their own words. A discussion was then conducted asking subjects to provide their opinion about the best/worst sound for relaxing, sleeping, concentration and subjective stress response.

3. RESULTS

3.1 Environmental analysis and survey

The ambient noise measured during normal night operation of the A-40 highway show levels of noise varying from 65.2 to 68.9 dBA at the closet street to 50.2 to 53.4 dBA for farther away row of houses. The level of ambient noise when the highway is closed varies at the same locations from 55.5 to 50.5 dBA. The noises generated by the construction itself are intermittent and the most frequent ones seem to be vehicle reverse alarms and jack hammers.

The responses revealed that the level of annoyance was greater when A-40 was closed than when it was open to regular traffic (see Figure 1). These responses were obtained even though the overall noise level was 10 dB lower when the highway was closed for refectory work. The residents identified the reverse alarm signals and the noise of the jack hammers as being the most annoying components of the noise they perceived.

3.2 Listening sessions and focus groups

The data were submitted to a Friedman rank sum technique (Mack & Skillings, 1980). The analysis made it possible to identify the masking noises that were the least annoying (i.e., most pleasant) and the more efficient for the participants. The ranking obtained for each of the 12 masking sounds are provided in Table 1. The results revealed that the four least annoying and more efficient maskers were: (1) continuous large waterfall, (2) babbling brook, (3) ocean waves and (4) sea. When looking at the subjects' emotional responses provided by Table 2, the ocean waves sound received the more positive emotional responses for all of four studied dimensions. As a basis of comparison the underwater bubbles sound evoked the more negative emotional responses.

The focus groups provided identification of desirable (least annoying) acoustic components in terms of frequency and amplitude modulation. As expected a low frequency spectrum was less annoying than a high frequency content. However, there is a lower boundary where low frequency evoked negative emotions such as fear. The mean for the most desirable frequency content is around 1754 Hz. For the amplitude modulation, a fast modulation was perceived as highly annoying while a slow modulation was less annoying. Again, a low boundary was found, a very slow modulation evoked exasperation and irritation. The mean for the most desirable amplitude modulation is around 2.8 Hz.

4. DISCUSSION

Many investigators have reported that indices of equivalent noise level. (i.e., L_{eq}) do not provide accurate predictions of annoyance for intermittent noise sources. The results of the present investigation are consistent with this observation. The study of the acoustic characteristics of masking signals that reduce the level of annoyance revealed optima for frequency content and amplitude modulation. Moreover, the non acoustic load/meaning characteristics of sounds seemed to be even more important to the receivers than acoustic factors.

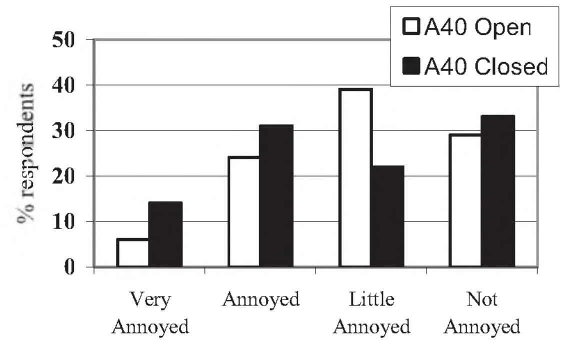

Figure 1: Level of annoyance

Table 1: Friedman's rank analysis for pleasantness and masking efficacy

Masking signals	Rank
Continuous large waterfalls	8,93
Babbling brook	8,84
Ocean waves	8,54
Sea	7,88
Heavy rain	7,23
Rainfall in traffic noise of low density	6,43
Heavy rain with reverberation	5,49
Whispering leaves	5,30
Heart beats	5,12
Frogs in a pond	5,04
Cat purr	5,02
Underwater bubbles	4,18

Table 2: Emotional subjective appreciation

Masking signals	Relax	Restful	Sooth	Happy
Ocean waves	5.55	5,42	5.48	5.40
Babbling brook	5.50	5.32	5.48	5.38
Waterfalls	5.45	5.30	5.50	5.12
Sea	4.77	4.98	5.05	4.97
Heavy rain	4.60	4.22	4.43	4.15
Underwater bubbles	*2.53*	*2.63*	*2.68*	*2.67*

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