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## **A STUDY OF PLEASANTNESS AND ANNOYANCE IN SIMULATED SOUNDSCAPES**

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### **ABSTRACT**

An experimental study has been conducted in the Acoustic Technology Department of the Technical University of Denmark. Audio-visual simulations of a park and an urban square were attempted; a series of listening tests were carried out. The subjects were asked to qualify the soundscape in terms of both annoyance and pleasantness. Two sources were taken into account: Street Traffic Sound and Fountain Sound. The annoyance study concentrates in each source separately, whereas the pleasantness analysis focuses in combination of both sources. Figures of street traffic sound and water sound versus annoyance are presented. Furthermore, four different street traffic sound levels were used, whereas fountain sound level was varied. In all the presentations, birds sound has been included in order to make the acoustic environment more realistic. The pleasantness of different combinations of street traffic sound and fountain sound is illustrated.

The results show that the accuracy of the simulation is a decisive factor in order to have reliable results; on the other hand, even a simple model can be sufficient to demonstrate the tendency of the test subjects' preferences.

## 1 INTRODUCTION

The concept of Soundscape was first introduced by R. Murray Schafer during the 70's [1]. The fact that the sound of a particular locality can -like the architecture, customs and dress- express the community's identity to the extent that settlements can be recognized and characterized by their soundscapes, was the centre of attention for Shafer and his colleagues [2], [3]. Since that time, the consideration of soundscape is constantly gaining ground in the process of designing outdoor public spaces and not only. The concept of sustainable development, which is widely spread in modern building/designing philosophy, has increased the awareness of the importance of acoustically balanced environments.

The response of every person is influenced by a large number of different factors: physical (i.e. sound pressure level), psychological (i.e. natural or man-made sound), and social factors, make the soundscapes a rather complex system [4]. In the present study, a series of listening test were carried out with the use of simple audio-visual simulations. The test subjects were asked to evaluate the soundscape in terms of both annoyance and pleasantness.

## 2 GENERAL INFORMATION OF THE EXPERIMENT

Three different stimuli were used in the experiment: Street Traffic Sound (STS), Fountain Sound (FS) and Birds Sound (BS). Trying to create a more realistic stereo-sonic environment, as well as to avoid masking among signals [5], a virtual room was created with the use of ODEON, and the sources were located at different positions. It should be mentioned that the chosen positions agree with the location of the sound sources on the projected photographs.

A simple analogue system composed of 3 CD players, attenuators and mixer was used. Each signal was calibrated measuring a  $Leq(A)$  over an integration period of 1 minute. After, the mixed stereo signal was presented to the test subjects via headphones. Ten test subjects (8 male and 2 female) from 23 to 30 years old, took part in the listening tests. To avoid any kind of bias, the instructions were given in paper form to the test subjects. Pure tone audiometry was conducted in the frequency range 125 - 8000 Hz, in order to ensure normal hearing in both ears.

## 3 EVALUATION OF ANNOYANCE OF INDIVIDUAL SOUND SOURCES

The first listening test was focused in the evaluation of sounds at different levels, in terms of annoyance. Two sources were taken into account: Street Traffic Sound (STS), and Fountain Sound (FS). Each source was presented separately. The test subjects were exposed to the stimuli, while a picture related with the sound source was projected. Each presentation had a duration of one minute in both STS and FS. The presentation of the levels was random and the range was different for each source; for the STS the range varied from 40 to 80 dBA, in steps of 5 dBA; thus, 9 presentations of STS. For the FS, the covered range was between 50 and 95 dBA, in steps of 5 dBA as well; hence, 10 presentations of FS. The mentioned level values are  $LeqA$  (1 minute). The test persons were asked to answer the question: “**How annoying do you find the sound?**” whereas the possible answers were: **NA**: Not Annoying, **SA**: Slightly Annoying, **MA**: Moderately Annoying, **HA**: Highly Annoying and **EA**: Extremely Annoying.

### 3.1 Results and Discussion

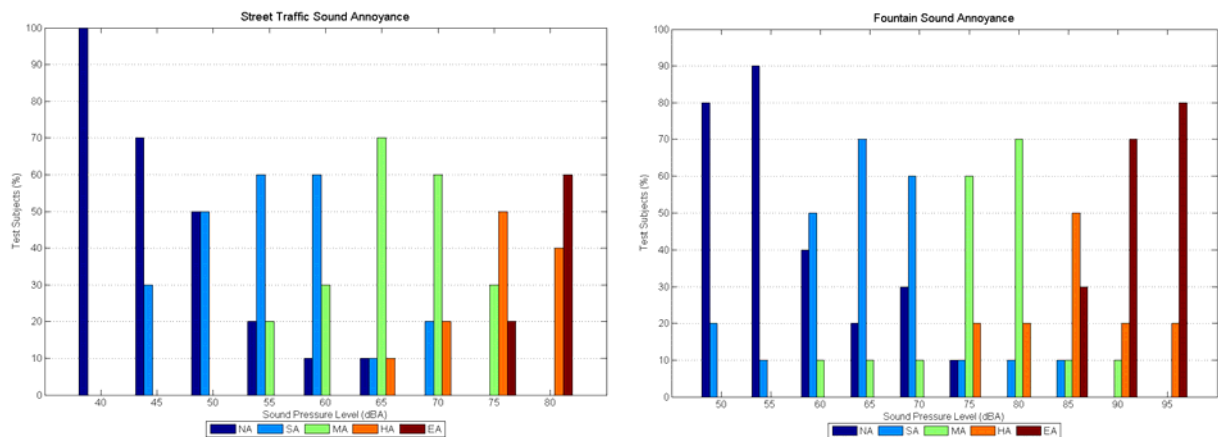


Fig. 1. Evaluation of annoyance for different levels of STS (left) and FS (right). The levels on the x axis are Leq (A)-1 min.

As expected, at low levels (40-45 dBA) the STS is not considered annoying, while most of the people characterize STS at high levels (75-80 dBA) as very annoying. The 50 dBA level seems to be a turning point, as it can be seen in the graph, since 50% of the subjects find STS slightly annoying, while the rest find it not annoying. Another interesting observation is that from 70 dBA and above, STS is definitely a source of annoyance (i.e. 0% has answered NA), while from 55 to 65 dBA, the results lie in a range from NA to HA; this fact probably reflects what the test subjects are used to experience in their everyday life. Looking at the distribution of the answers of the test subjects for each level, it is possible to correlate the discrete points of the rating scale with a level range (or, ideally, a level). Following this way of thinking, for STS, NA is defined as 40 to 45 dBA, SA as 55 to 60 dBA, MA as 65 dBA, HA as 75 dBA and EA as 80 dBA. Furthermore, it is interesting to notice that 65 dBA seems to be an important point, since the majority of the test group defines this level as the middle point (MA) of the discrete scale.

In the case of FS, the expected ratings were given by the majority of the test group for the extreme values of the scale (i.e. NA for 50-55 dBA and EA for 90-95 dBA). The turning point where FS becomes slightly annoying for 50% of the test subjects seems to be at 60 dBA (10 dBA higher than the value obtained for STS). FS starts to be definitely considered as a noise source from 80 dBA and above. Furthermore, by correlating the levels with the distribution of ratings like before: NA corresponds to 50-55 dBA, SA to 65-70 dBA, MA to 75-80 dBA, HA to 85 dBA and EA to 90 dBA. The middle point (MA) of the rating scale for the FS is at 80 dBA. In addition, if the results are evaluated in terms of majority, it is clear that in order for the FS to produce the same annoyance as STS, its level must be 10 to 15 dBA higher than the level of STS.

## 4 EVALUATION OF PLEASANTNESS OF DIFFERENT SOUNDSCAPES

In the second part of the listening tests, an attempt of evaluating different simulated soundscapes in terms of pleasantness was made. The test subjects were exposed to different soundscapes, while a picture showing a landscape was projected. Three sound sources were

combined for this part: STS, FS and BS. Four different STS levels were chosen: 40, 50, 60 and 70 dBA, whereas FS was introduced in three different levels for each level of STS ( $\pm 5$  dBA). The level of BS was kept constant at 50 dBA for all the STS-FS combinations. Furthermore, the test subjects were asked to imagine that they are in a specific condition described by a given scenario; **Scenario 1**: You have just left from work. It has been a very busy day and your mind is full of thoughts. You decide to sit on a bench and try to clear your mind and relax. **Scenario 2**: It is Saturday and you have completely nothing to do. You decide to go out for a walk. The day is beautiful so you decide to sit on a bench and enjoy.

After letting the test subject read the scenario, 12 combinations of the sound sources were played, with duration of one minute each. In order to analyze the effect of the picture in each scenario, four combinations were repeated with a different photograph projected. After the end of each presentation, the test subject was asked to answer the question: **“Taking into consideration the given scenario, how pleasant do you find these conditions?”**. The test subjects had to answer this question by putting a mark on a 10cm pleasantness scale with no end stops. The sequence of descriptive words used in the scale was: “Very Unpleasant”, “Unpleasant”, “Slightly Unpleasant”, “Satisfactorily Pleasant” and “Very Pleasant”.

#### 4.1 Results and Discussion

At first, neither the scenario nor the projected picture had a considerable effect in the evaluation of the pleasantness for the test subjects. Due to the distribution (not shown here) of the individual answers for each specific soundscape, a detailed quantitative comparison of the data sets could lead to plasmatic conclusions. Nevertheless, it is possible to qualitatively assess the data since the results for each combination agree for both scenarios and the trends of the subjective evaluations are obvious. Therefore, the data sets obtained from each test person were averaged (for each combination) and Fig. 2 was obtained using the new data set.

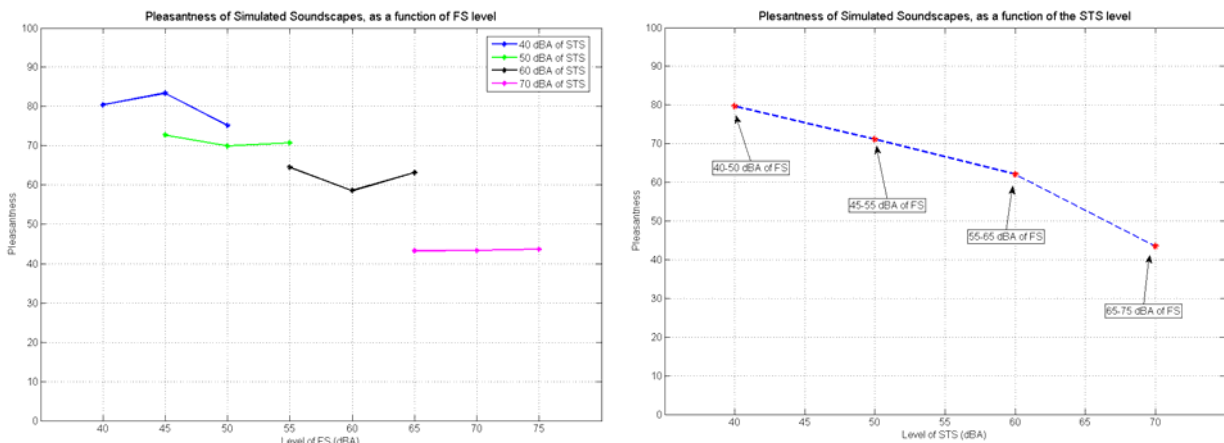


Fig. 2. (Left)-> Pleasantness evaluation of simulated soundscapes, as a function of the level of FS. Each color corresponds to a specific level (dBA) of STS. (Right)-> Pleasantness evaluation, as a function of the level of STS. The purpose of the dashed line is to emphasize the trend that pleasantness follows when STS increases. For both figures, the values on the x axis are  $LeqA$  (1 min) and the 0 point on the y axis corresponds to “Very Unpleasant”, while 100 corresponds to “Very Pleasant”.

It can be seen (Fig. 2 left), that for the same level of STS pleasantness does not depend on the level of FS. In other words, FS seems to behave as a neutral sound source in terms of pleasantness, which is apparently determined by the level of STS. One might argue that pleasantness depends on the overall level rather than the level of STS; however, the fact that FS was found “Not annoying” even at quite high levels (Fig. 1), can be regarded as an indication that STS defines in a great extent the pleasantness of the soundscape. Therefore, as pleasantness is independent of the level of FS, the mean value of the three pleasantness ratings for every STS level is obtained and presented in Fig. 2 Right.

For low to moderate STS levels pleasantness seems to decrease following an approximately constant stepsize of 10 pleasantness units per 10 dBA of STS; only at the highest levels, when STS increases from 60 to 70 dBA, a decrease of nearly 20 pleasantness units is observed. This probably shows that the test subjects' internal criterion of pleasantness has a constant value, when the levels are in a range that they consider realistic/usual. In an attempt to express the obtained data from both listening tests in terms of percentage of test persons, the following considerations have been made: (1) **“Evaluation of Annoyance of Individual Sound Sources”**: When the test subjects rated an STS level as MA, HA or EA on the annoyance scale, the corresponding level was considered to be “Annoying”. In that way, it was possible to obtain a percentage of “Annoyed” people, for every STS level (see Fig. 3 Left); (2) **“Evaluation of Pleasantness of Different Soundscapes”**: When the test subjects' ratings were in the interval from 70 to 100 on the pleasantness scale, the corresponding combination was considered to be “Pleasant”. The number of combinations rated as “Pleasant”, was then calculated for each STS level; in that way, it was possible to obtain a percentage of “Pleased” people, for every STS level (see Fig. 3 Right).

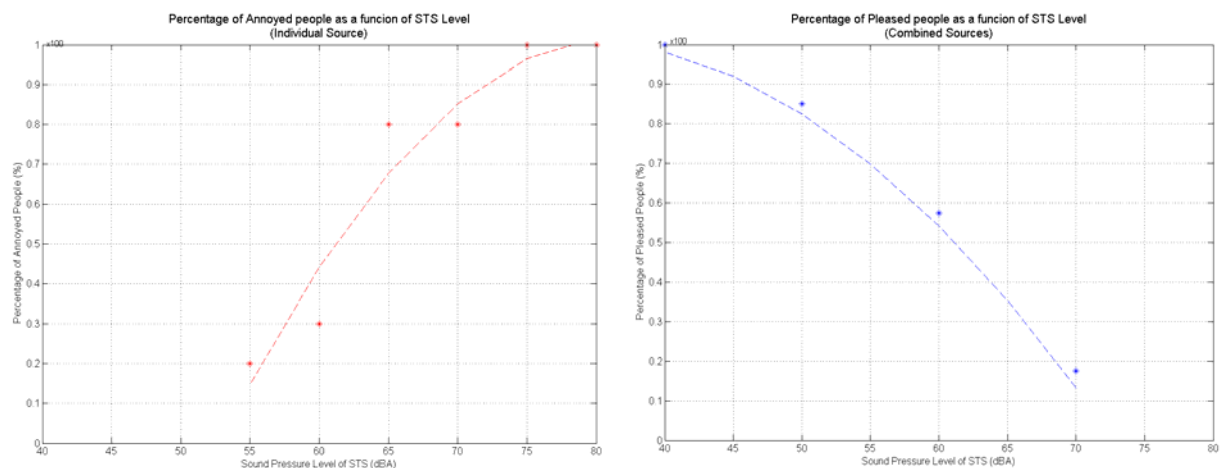


Fig. 3. (Left)-> Percentage of annoyed people as a function of STS level. (Right)-> Percentage of pleased people as a function of STS level. The points indicate the percentage of people that find the soundscapes annoying or pleasant respectively. The purpose of the dashed line in both graphs is to emphasize the trend that this percentage follows when STS increases; it is NOT a fitting attempt.

Looking at Fig. 3 Left, it is clear that when the level of the STS increases, the percentage of annoyed people increases. For a 10 dBA increase of the level of STS (55 to 65 dBA), the percentage of annoyed people jumps from 20 to 80%. On the other hand, looking at Fig. 3 Right, when the level of STS increases from 50 to 70 dBA, the percentage of pleased people reduces from 85% to 18%, approximately. A steeper slope would be expected, for the same level range, if STS was presented individually, meaning that the existence of FS and BS improves the soundscape, in terms of pleasantness. However, this expectation can only be based on simple observation of the figures, and not on direct comparison; for comparing directly it must be assumed that the terms “Annoyance” and “Pleasantness” are absolutely opposite, which is not completely true [6].

## 5 CONCLUSIONS AND SUGGESTIONS

Regarding the annoyance study, apart from the expected observations, it was interesting to see that in order for the FS to produce the same annoyance as STS, its level must be 10 to 15 dBA higher than the level of STS. In relation to the pleasantness study, the results but also the comments of the test subjects showed that it is not possible to investigate so many parameters at the same time; the effect of the pictures, scenarios and pleasantness evaluation, could be topics of 3 separate studies. Nevertheless, the expected reduction of pleasantness with increasing STS level was clearly observed. It was also observed that FS seems to behave as a neutral sound source in terms of pleasantness, which is determined by the level of STS, but it acts (together with BS) in a positive way by keeping almost 20% of the test subjects pleased with the soundscape, even at high levels of STS. However, further research should be conducted in order to find the relation of pleasantness of soundscapes and the overall level.

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