SYMPOSIUM REPORT

Memory effects in loudness scaling of traffic noise —How overall loudness of short-term and long-term sounds depends on memory—

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The influence of cognitive factors such as attention, short-term, and long-term memory on overall loudness of non-steady state sound has not yet been systematically investigated. In this paper, preliminary experimental results are presented, showing how loudness scalings of non-steady state traffic noise depend on memory.

Keywords: Non-steady state sound, Traffic noise, Overall loudness, Implicit memory, Sensory memory

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1. INTRODUCTION

Only very little is known about cognitive processes underlying the temporal integration of loudness of long-term non-steady state sounds. While basic psychoacoustics and auditory physiology have become prospering fields yielding good results, the study of cognitive effects in sound evaluation is still at its very beginning. What are the constituents of overall loudness? Are they based on information stored in sensory memory or on categorical codes kept in nonsensory forms of memory?

There is some plausibility that overall loudness of long-term non-steady state sounds does not reflect a perceptual integration process but depends on memory. There is, however, no well-founded theory or model that considers memory effects on overall loudness, nor does there exist systematic research on memory effects on loudness evaluation of long-term non-steady state sounds. The experiments reported here should be considered as a pilot study in this field.

The question behind the following study is whether loudness scaling of long-term noise can be predicted by averaged loudness scalings of short-term noise intervals enclosed in the respective long-term noise.

2. METHOD

2.1 Description of the Noise Scene

The stimulus we used was a 20 minute lasting traffic noise scene near a village on a main road at a gated level crossing. The scene consisted mainly of road traffic noise and some railway noise. The background noise consisted of moderate wind noise, rustling leaves, occasional birdsongs, and other sounds associated with the rural area and the proximity of the small village.11

The noise scene was recorded with artificial-head technique and played back with head phones in a sound proof room. Sound pressure level was calibrated by measuring a calibration tone with an artificial ear. The mean energy level of the 20 minute noise was $L_{eq} = 76.3 \text{ dB}$.

2.2 Subjects, Experimental Conditions, and Design of the Study

Altogether 48 subjects participated in the study. The subjects were students and co-workers of normal hearing of the University of Oldenburg, aged between 21 and 51 years. Each subject was first exposed to the whole — not interrupted — noise,
instructed just to listen to the noise and to imagine the scene. After the sound had been fully presented, the subjects were requested to judge the overall loudness of the whole 20 minute lasting sound. For the second trial, subjects were randomly assigned to one of 5 experimental conditions. Under each condition the noise was interrupted by 5 s pauses, that is under condition (1) it was interrupted every 7.5 s, under condition (2) every 15 s, under condition (3) every 30 s, under condition (4) every 60 s, and under condition (5) every 120 s. Thus, the whole noise consists of ten 120 s intervals, each 120 s interval of two 60 s intervals, four 30 s intervals, and so on. In other words, each shorter period was systematically enclosed in longer periods. In each pause the subjects had to judge the loudness of the respective preceding 7.5 s, 15 s and so on noise interval. Under each condition between 8 to 12 subjects participated in the study.

It is important to note that overall loudness judgement on the whole noise is independent of loudness scalings of short-term sounds enclosed in that.

2.3 The Scaling Method
We used the technique of category subdivision scaling. The scale has five verbally distinguished categories. Additionally, each category is divided into 10 graduations. Thus, a 50-point scale results: 1-10 ("very quiet"), 11-20 ("quiet"), 21-30 ("medium"), 31-40 ("loud"), and 41-50 ("very loud").

3. RESULTS

Figure 1 shows the arithmetically averaged loudness scalings of the 30 s interval condition as an example. The standard deviations of the individual loudness judgements are in a reasonable range of around 5 scale points. One can see that the mean overall judgement (dotted horizontal line) is certainly higher than the mean loudness judgements on the 30 s intervals.

Figure 2 shows on the one hand that the correlation between 20 minute overall loudness and the various short-term overall loudness scalings is low ($r = 0.30$), and on the other hand that on the average the 20 minute overall loudness is slightly but significantly higher than the average of loudness scalings of all short-term sounds (as we could expect from Fig. 1): $t = 3.64, df = 47; p = .007$. That means, most (but not all) subjects evaluate the whole noise scene, in terms of an overall judgement, louder than the mean loudness scalings of involved short-term intervals would predict. The latter result fits findings of Namba and Kuwano as well as of Fastl.

While listening to the whole noise in the first experimental run, the subjects were not instructed to focus the attention on loudness. We assume, therefore, that overall loudness of long-term noise is determined by implicit memory, i.e., unintentionally stored information. It is known that conspicuous perceptions are good candidates for implicit memory. Thus, it might be reasonable to assume that very loud impressions have a stronger influence on
subjective evaluation of past acoustical events than the soft impressions do. This might be the reason why overall loudness is usually (i.e. for the majority of people) found to be slightly higher than the average of all intentionally made loudness judgements during the time course of the whole noise.

We assume that the overall loudness of the 20 minute sound is based on categorical forms of memory, i.e. events which can be easily remembered due to their high loudness, and therefore dominate the general impression of the sound. But what is about the 120 second sound periods? Such sound periods are short in comparison to the 20 minute period, but long compared to the 7.5 s intervals. Each 120 s interval encloses sixteen 7.5 s sections. Can the 120 second overall loudness judgement be predicted by the average of the involved 7.5 second judgements? In Figure 3 we can see that the correlation between the mean loudness judgements of the ten 120 second intervals and the averaged loudness of the enclosed 7.5 s sections is very low ($r = .17$). However, if we do not average all sixteen 7.5 s loudness judgements, but only the last four, i.e. the last 30 seconds of the 120 s interval, after which the judgement is made, then the correlation will be much higher ($r = .83$; see Fig. 4). We yielded similar results in the 15 s noise interval condition. The correlation between the loudness scalings on the 120 s intervals and the 15 s intervals based on the average of all 8 intervals was $r = .27$, but based on the last 2 sections the correlation increased up to $r = .90$.

That means, the loudness of the 120 s-intervals is strongly influenced by the last loudness impressions.

4. CONCLUSIONS

The overall loudness scaling of very long-term non-steady state sounds is slightly higher than the average of involved short-term loudness impressions. The loudness of non-steady state noise up to the duration of 2 minutes (in our study) seems to be strongly influenced by perceptual features stored in sensory memory. If the duration of non-steady state sounds exceeds several minutes (in our study 20 minutes) then the overall loudness judgement does not seem to be based on information kept in the sensory store. In that case, the overall loudness judgement is assumed to depend on nonsensory forms of memory. Moreover, it seems to be influenced by implicit memory factors based on conspicuous auditory impressions. We need, however, much more experiments to understand the memory effects in loudness scaling of long-term and short-term noise. To understand such effects is of theoretical interest for perceptual and cognitive psychology, as well as of practical interest for psychological evaluation of acoustic environments.

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REFERENCES


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