Memory Effects in Sound Evaluation.

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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. Only very little is known about cognitive processes underlying the temporal integration of loudness of non-steady state sounds. However, there is a need to account for attention and memory processes when the overall loudness of non-steady state sounds is of particular interest. (We prefer the more neutral term *overall loudness* instaed of *perceived average loudness*, because the latter insinuates an underlying averaging or integration process, which has not yet been proved.) Though research on overall loudness has been considerably pushed by Namba and Kuwano from Osaka University [e.g. 1], as well as by Fastl [e.g. 2] from the Technical University of Munich - the pioneers in the field of subjective evaluation of non-steady state sounds -, the influence of cognitive factors such as selective attention, short-term, and long-term memory on overall loudness has not yet been systematically investigated.

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 are numerous studies on sensory memory. Many of them show evidence for a very brief sensory store. After holding in this store for some hundreds of milliseconds, stimuli are partially transformed into categorical codes. According to Cowan [3], however, sensory memory should be seen on the one hand as composed of a kind of afterimage, and on the other hand as a sensory storage keeping perceptual features for 10 to 20 seconds. The decay of the sensory memory is exponential. (But there is no exact data on the half-life parameters of sensory memory.)

There is some plausibility that overall loudness of non-steady state sounds 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 first question behind the following study is whether or not overall loudness scalings of non-steady state noise depend on the duration of the sound. The second question is whether loudness scalings of long-term noise can be predicted by loudness scalings of short-term noise enclosed in the respective long-term noise.

Method

Description of the noise scene

The stimulus we used was a 20-minute lasting 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 railway section involved in this study was very busy and included all types of trains, regional trains, Inter-city trains and freight trains as well. 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 [4].

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 conditions

This noise was presented under 5 conditions: It was interrupted by a 5s-pause every 7.5 s,15 s, 30 s, 60 s, and every 120 s as well. In each pause the subjects had to judge the loudness of the respective preceding 7.5s-, 15s- and so on noise interval.

Thus, the whole noise consists of ten 120s-intervals, each 120s-interval of two 60s-intervals, four 30s-intervals, and so on. In other words: Each shorter period was systematically involved in longer periods.

The scaling method

We used the technique of category subdivision scaling. This technique was introduced by Heller into the field of audiometry, which shall be used here as a technique for subjective noise evaluation. In contrast to the usual type of category scales, the categories here are finely graduated, allowing for differentiation within each category. The scale has five verbally distinguished categories: very quiet, quiet, medium, loud and very loud. Additionally, each category is divided into 10 graduations. Thus, a 50-point scale results. The advantage of this procedure over other category scales, usually comprising 5, 7 or 9 categories, is the combination of assigning the loudness in everyday terms and the direct scaling of the transitions between the categories.

Subjects and procedure

All subjects were students of normal hearing of the University of Oldenburg. Each subject was first exposed to the whole – not interrupted – noise. His/her task was only to listen to the noise and to imagine the scene. (The subjects were not instructed to attend to the loudness!). After the sound had been fully presented, the subjects were requested to judge the overall loudness by use of the category subdivision scale. For the second trial, subjects were randomly assigned to one of the 5 conditions listed above, and were instructed to judge the loudness of noise intervals according to the respective condition, i.e. every 7.5 s, every 15 s and so on. Under each condition between 8 to 12 subjects participated in the study. The design of the study was completely randomized.

Data analysis and results

Under each condition, individual loudness scalings on each interval were arithmetically averaged. Do loudness scalings depend on interval length? We found intervals longer than 15 s to be judged as softer. The reason for that remains to be subject of further investigations. In Figure 1, examples of mean loudness scalings relating to A-weighted Leq is shown. We found no significant differences between 30s-intervals and 60s-intervals or 120s-intervals. Neither did we find systematic differences between 7.5s-intervals and 15s-intervals (not shown in Fig. 1).

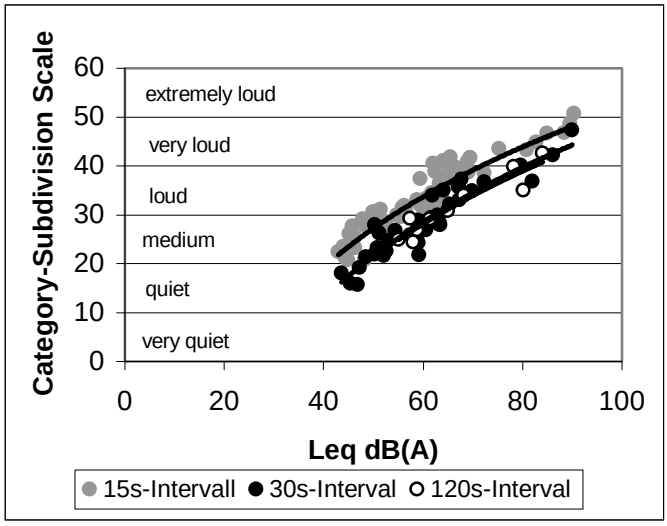

Fig. 1. Loudness scalings of 15-s-intervals compared with loudness scalings of 30s-intervals and 120-s-intervals as well.

Can loudness judgements on longer intervals be predicted by loudness scalings on the shorter intervals involved in the longer ones? We calculated the individual arithmetic means of the loudness scalings on all respective intervals and correlated them with the respective individual overall judgments. We did not only calculate individual arithmetic means of loudness scalings of short-term sounds over the whole time (see Fig. 2), but also over the last 2 minutes (see Fig. 3).

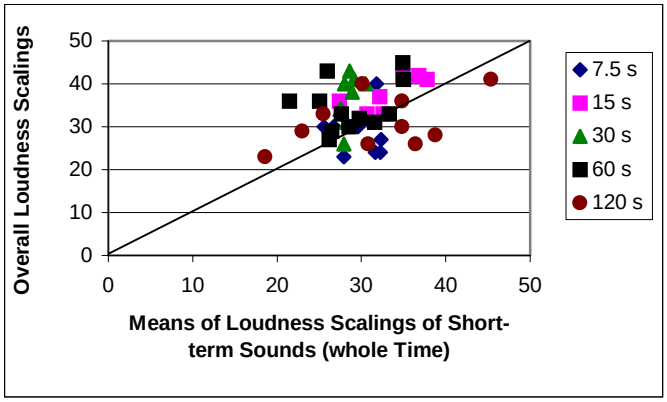

Fig. 2. Overall loudness scalings compared with corresponding means of involved short-term intervals over the whole time. The markers symbolize individuals.

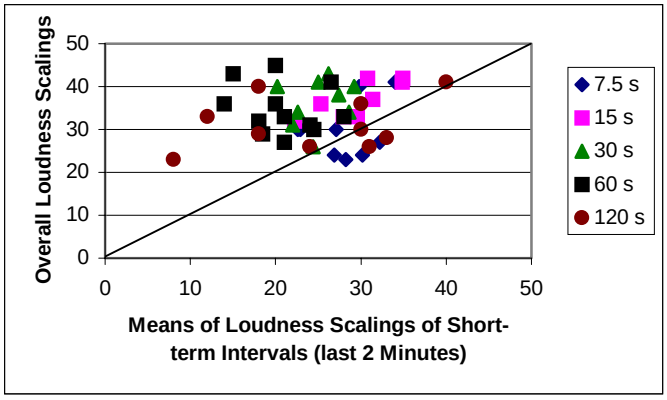

Fig.3 . Overall loudness scalings compared with corresponding means of involved short-term intervals over the last 2 minutes. The markers symbolize individuals.

Figure 2 shows that overall loudness is slightly higher than the average of loudness scalings of all short-term sounds. As we can see in Fig. 3, in the last 2 minutes of the noise the loudness was rather low compared to the overall loudness. That means, the overall loudness is not influenced at all by the last loudness impressions. Thus, the overall loudness scaling must be based on long-term memory codes. It is important to note that overall loudness judgements and loudness scalings of short-term sounds are independent. While listening to the noise, the subjects were not instructed to focus the attention on loudness. We assume, therefore, that overall loudness is determined by implicit memory, i.e., unintentionally stored information [5]. 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 found to be slightly higher than the average of all loudness impressions during the time course of the whole noise [cf. Fig. 2; see also studies of Namba and Kuwano, and Fastl as well).

We also correlated individual loudness scalings of short-term sounds involved into the 120s-sounds with the respective individual overall judgments on 120s-intervals. We did not only calculate individual arithmetic means over the whole time, but also over the last 60s, the last 30s, and the very last judgement as well. The coefficients of determination r^2 serve as rough indicators for the quality of regressions. Here we have a clear-cut effect of both, the length of intervals as well as the time which has passed between the 120s-judgements and the respective single judgements. The longer the subdivisional intervals and the less time has passed, the better the quality of regression. That means, the loudness of the 120s-interval is strongly influenced by the last loudness impressions.

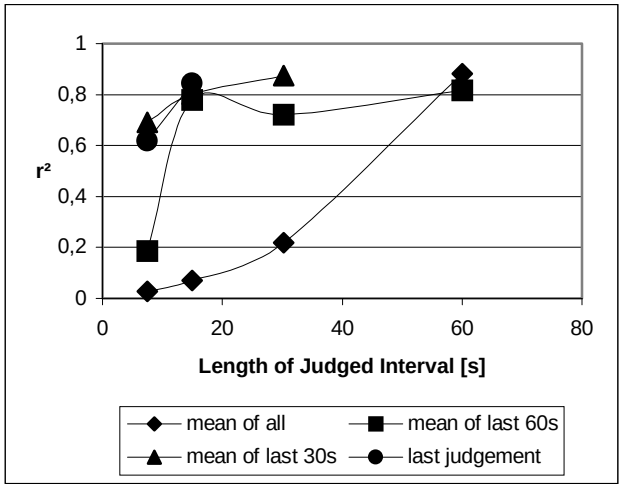

Fig. 4. Can the variance of overall judgement on the 120s.-intervals be explained by arithmetic means of loudness judgements on shorter intervals involved into the 120s-interval? Rhombuses indicate r^2 of regression equations based on mean loudness scalings over all involved segments related to the respective interval length. Squares show the same, however based on last half of the 120s-periods, etc.

Discussion and Conclusions

The overall loudness scaling of long-term non-steady state sounds is slightly higher than the average of involved short-term loudness impressions. This result fits such of Namba and Kuwano, and Fastl as well. 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 seems not to be based on information kept in the sensory store. In that case, overall loudness judgement is assumed to depend on nonsensory forms of memory. Moreover, it seems to be influenced by implicit memory factors.

References

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