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# COMPARISON OF SUBJECTIVE AND PHYSICAL EVALUATION OF TENNIS-NOISE

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## INTRODUCTION

In Europe, tennis courts are often built near houses. Therefore, in Europe, tennis together with soccer belongs to the most important sports for an investigation of recreation noise evaluation [1]. The residents near such sport grounds bemoan most of all the impulse- and information-contents of these noises. Tennis-shots with the racket and the ball contacts with the ground cause the high impulse content of tennis court noises. Furthermore, many conversations, shouts and expressions of disappointment lead to a high information content. Further noise sources are the access road to the parking lots, the sliding of the players on the sand, the hitting of the ball on the wire fence etc. [2]

In order to assess the noise burden it is useful to evaluate the immissions through physical measures adequate to our noise senses. In the practice of noise evaluation in Europe, today measuring procedures with the “Taktmaximalpegel” $L_{AFTmax}$ as measure are being used. For the “Taktmaximalpegel” each 5 seconds time interval is counted with the maximum-level $L_{AFmax}$ within these 5 seconds measuring time.

The impulse contents of tennis noise led in the past to enormous problems for the evaluation of measuring results. In expert opinions that have been used by justice courts in disagreement cases as expert witness comments, the level fluctuation was interpreted as scaring cause and therefore insufficiently described merely by sound pressure levels. Certainly the “Taktmaximalpegel”-procedure used in the Federal Republic of Germany leads because of the time sequences of the tennis-shots-impulses to an extremely high “impulse penalty” and so by comparing the measured values determined with this procedure and the immission target values to a quite strict evaluation. Some influences on the subjective noise sense such as for example the tennis shot-rate are not included in the evaluation by the “Taktmaximal”-procedure. At normal conditions, a tennis shot follows every two seconds. Therefore, a game at only one court – usually the court next to the immission place – already leads to a high sound pressure level in most time intervals. More sound impulses from another court do not lead to an increase of this sound pressure [2].

## PSYCHOACOUSTICAL EXPERIMENTS

Psychoacoustical experiments were performed to investigate single dependencies of the loudness and the annoyance of noises with impulse content.

Tennis sounds were recorded in a Tennis-court-park at a quiet surrounding according to the rules of the TA-Lärm (3 meters away, 1.2 meters high). The recording equipment were composed of a recording-microphone with pre-amplifier, an amplifier, and a DAT-Recorder. The sounds were recorded in one-channel on DA-Tapes with no frequency weighting.

Single tennis-shots were extracted from these recordings with the help of the Triple-DAT software. First the loudness and the annoyance of these sounds alone were evaluated (as emission sounds) using the psychoacoustical method of magnitude estimation without anchor sound. The maximum sound pressure level $L_{Fmax}$ of the "loud" tennis-shot was measured as 58.4 dB and that of the "soft" tennis-shot 52.2 dB (see also Table 1).

| | "loud" | "soft" |
|---|---|---|
| $L_{Fmax}$ in dB | 58.4 | 52.2 |
| $L_{AF}$ in dB(A) | 54.8 | 46.1 |

*Table 1: Maximum sound pressure level $L_{Fmax}$ in dB and A-weighted sound pressure level $L_{AFmax}$ in dB(A) for the "loud" (left row) and the "soft" (right row) tennis shot.*

For the analysis of the influences of loudness and rate of tennis shots on the loudness and the annoyance evaluation, scenarios were composed with the same tennis-shots as above. The duration of these scenarios was five minutes, the tennis-shots were statistically varied within these five minutes. "Soft" road noises with an energy equivalent sound pressure level $L_{eq}$ of about 35 dB(A) were presented within the five minutes to simulate a real environment. This "soft" road noise was recorded at a terrace of an apartment in a quiet surrounding.

The scenarios were presented diotically by a DAT-tape recorder via an electrodynamic headphone (Beyer DT 48) with free-field equalization [3] in a sound proof booth.

Eight subjects aged between 22 years and 30 years with normal hearing abilities took part in the experiment. Every single scenario was presented to each subject separately. The subjects were informed by a written experiment-instruction and asked to listen very attentively. After the presentation they had to fill in a questionnaire answering questions about their perceived loudness or annoyance. They were reminded to consider a linear representation of the scale of the possible loudness- as well as annoyance-values to the number scale. That means that a number with a double value corresponds to a presentation perceived double as loud or annoying. In addition, during the psychoacoustical experiments regarding the annoyance, the subject had to read from a book [4] and imagine the following situation: "You are sitting on your desk and want to read a book. From the window you can hear recreation sounds". The psychoacoustical annoyance does not take into account non-acoustical factors on the annoyance perception such as the attitude against the noise-source, the own mood etc. [5]

## SUBJECTIVE EVALUATION OF SINGLE TENNIS SHOTS

In a first experiment, in two separate sessions the loudness or the annoyance of the tennis shots used was assessed by a method of magnitude estimation without anchor sound. The different tennis-shots were presented each five times in different sequence. Only the last four evaluations were entered in the calculations. In a pause of two seconds between two tennis-shots, the subjects had to give a number which represents according to their sensation either the loudness or the annoyance. As an example, these results are given for the "loud" or the "soft" tennis-shot. The evaluations of each subject were normalized to the median of the "loud" tennis-shot. The median and interquartiles of the values obtained this way are displayed in figure 1 for the "loud" or the "soft" tennis-shot.

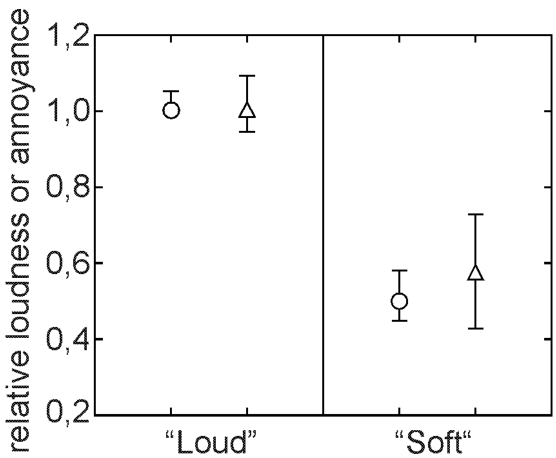


*Fig. 1: Subjective evaluation of the “loud” (left) or the “soft” (right) tennis-shot with respect to loudness (circles) or annoyance (triangles). Results normalized with respect to the median of the “loud” tennis-shots.*

The results displayed in figure 1 reveal that most tennis-shots are evaluated with respect to loudness or annoyance in a similar manner. The “soft” tennis-shot produces approximately half the loudness or annoyance in comparison to the “loud” tennis-shot. Even with evaluations of annoyance in the lab, both intra- and interindividual differences are larger for annoyance evaluations than for loudness evaluations.

## SUBJECTIVE EVALUATION OF SIX SCENARIOS

Six different scenarios were evaluated with respect to global loudness and psychoacoustic annoyance. On the one hand, the dependence on the number of shots (events) per minute and on the other hand the influences of the loudness of a tennis-shot at constant shot-rate were evaluated. Figure 2 shows the results for the variation of the shot-rate which was varied from 30 over 50 to 70 tennis-shots per minute. 30 tennis-shots per minute are typical for *one* tennis-court. 50 or 70 shots per minute are achieved with several neighboring tennis-courts.

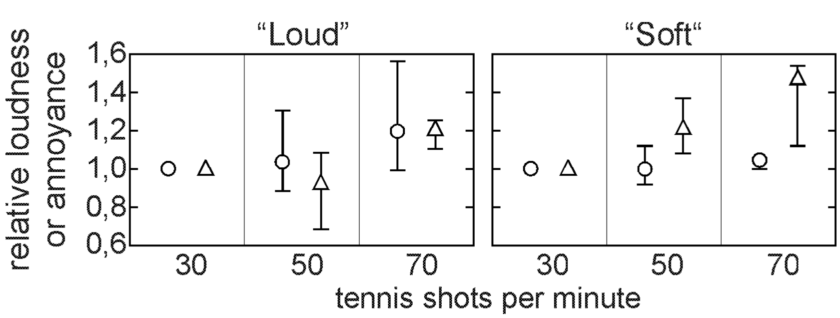


*Fig. 2: Subjective evaluation of global loudness (circles) or annoyance (triangles) for 30 (left), 50 (middle), and 70 (right) tennis-shots per minute. “Loud” tennis-shots (left panel) and “soft” tennis-shots (right panel). Normalized relative to the scenario with 30 tennis-shots per minute (left).*

The results displayed in figure 2 reveal that loudness and annoyance are rather similar for the "loud" tennis-shots. For shot-rates of 70 shots per minute, the evaluation of loudness and annoyance increases by about 20%. With "soft" tennis-shots, data for global loudness show almost no influence of the shot-rate. However, the scenario with 50 shots per minute produces about 20%, and the scenario with 70 shots per minute about 40% more annoyance than the scenario with 30 shots per minute.
Figure 3 shows the results for constant shot-rate but different loudness of the tennis-shots.

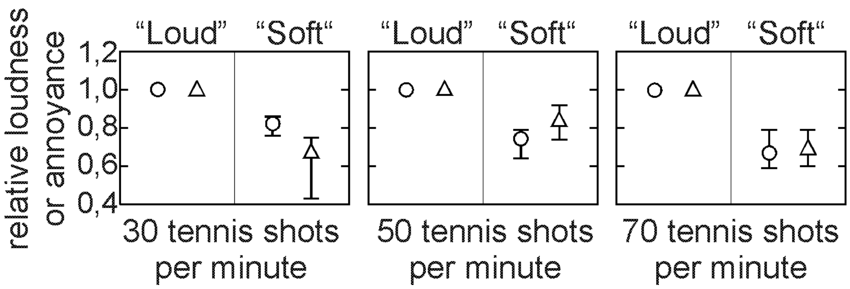


*Fig. 3: Subjective evaluation of global loudness (circles) or annoyance (triangles) for the scenarios with "loud" (left) and "soft" (right) tennis-shots. The shot-rate is 30 (left), 50 (middle), and 70 (right) tennis-shots per minute.*

For all shot-rates evaluated, the differences in loudness or annoyance between "loud" or "soft" tennis noise are more or less the same. Scenarios which include "soft" tennis-shots are evaluated by about 20 - 30% softer or less annoying in comparison to the scenarios which include "loud"-shots. In comparison to the differences for single tennis-shots, the differences for tennis-noise immissions are somewhat smaller.

## COMPARISON OF SUBJECTIVE EVALUATION WITH PHYSICALLY MEASURED DATA

For the comparison of the psychoacoustic data with physical measurements, the loudness according to DIN 45 631 [6] with calculation of percentile loudnesses, the $L_{eq}$, and the "Taktmaximalpegel" $L_{AFTmax}$ which in Germany is prescribed for these noises, were used (table 2).

| | Loud30 | Loud50 | Loud70 | Soft30 | Soft50 | Soft70 |
|---|---|---|---|---|---|---|
| $N_1$ in sone | 4.5 | 4.9 | 5.0 | 3.1 | 3.3 | 3.4 |
| $L_{eq}$ in dB(A) | 42.4 | 44.8 | 46.2 | 36.4 | 37.7 | 38.7 |
| $L_{AFTmax}$ in dB(A) | 54.8 | 54.8 | 54.8 | 46.1 | 46.1 | 46.1 |

*Table 2: Percentile loudness $N_1$, $L_{eq}$, and $L_{AFTmax}$ of the six scenarios.*

Data displayed in figure 4 enable a comparison for the six scenarios between subjective evaluations and physical measurements. All data were normalized relative to the scenario with 30 "loud" tennis-shots per minute.

The dependence on the shot-rate – because of the addition of the energies of the single shots – is reflected in the $L_{eq}$ which shows a high rank correlation to the psychoacoustic data; however, quantitative differences are substantially overestimated. By applying the $L_{eq}$ concept it is not possible to simulate the influence of shot-rate or loudness of the tennis-shots.

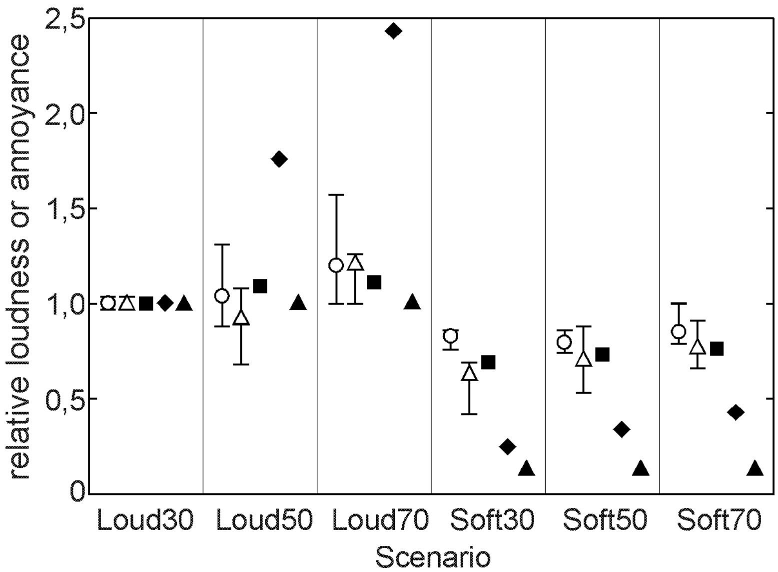


*Fig. 4: Subjective evaluation of loudness (unfilled circles) or annoyance (unfilled triangles) for six scenarios in comparison to percentile loudness $N_1$ (filled squares), $L_{eq}$ (filled rhombs), or "Taktmaximalpegel" (filled triangles). All data normalized relative to the scenario "loud" 30 (left).*

The "Taktmaximalpegel" does *not* reflect the dependence on the tennis-shot-rate, since from 30 tennis-shots per minute always at least one shot occurs within the five second period. In addition, the dependence on the loudness of the tennis-shots is overestimated. In contrast, the percentile loudness $N_1$ which is close to the loudness maxima can account for the psychoacoustic evaluation: qualitative differences caused by an increase in shot-rate as well as the quantitative magnitudes of the differences between different scenarios are reproduced in line with features of the human hearing system.

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