Difference limen for early lateral energy fraction and late lateral level

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Abstract

Spatial impression is considered an important aspect of a listening experience in concert halls. Since the early 1980s it is understood that lateral sound incidence at a listener's position strongly relates to this impression. Recently, it has been shown that parameters seizing spatial impression vary from one listening position to another. The question if and how these variations are perceived by the listener is not entirely clarified. In order to add to the understanding of acoustic perception in concert halls, listening tests were carried out. With the aim to use real room impulse responses (RIR), comprehensive measurements were conducted in four concert halls in Germany. Following the listening tests, an extensive statistic analysis has been calculated with the results of the psychometric survey.

Introduction

There are eight subjective descriptors (clarity, reverberance, intimacy, source broadening, listener envelopment, loudness, brilliance, and warmth) that are used fairly often in order to describe the perceived acoustics in concert halls. In the last few decades the aspects of spatial impression, namely Apparent Source Width (ASW) and Listener Envelopment (LEV), have enjoyed tremendous attention by the acoustic community.

Recent research by de Vries [1] indicates that small changes in the microphone position result in a notable change of the parameters quantifying the perception. The answer to the question if such changes are perceivable is aggravated by findings of Cox [2], who identified the difference limen (DL) for ASW in synthetic sound fields to lie below the extent of these variations, and the direct observation that a listening impression in concert halls doesn't change when moving from one seat to the adjacent one. The goal to clarify these aspects can only be achieved by considering the DL for aspects of spatial impression as it is perceived in <u>real</u> sound fields.

Methodology

In order to merge the benefits of a laboratory environment and a genuine sound reproduction, a combination of dummy head measurements and a two loudspeaker cross-talk cancellation (CTC) playback was used to determine the just noticeable difference of ASW and LEV. As it is essential to not only measure RIRs with a dummy head but to also characterise the sound field with objective measures, measurements were also conducted with an omni directional microphone and a figure-of-eight pattern microphone. These results were used to calculate LF and LG as the accepted correlates to ASW and LEV.

In order to cover the largest possible domain of values, two strategies were pursued: firstly measurements were conducted in concert halls with different room geometries and secondly a large number of microphone positions were covered. The binaural RIR were convolved with a short piece of anechoic music. This way the only difference between two audio samples is the sound field at the respective measurement position. The "excitation" is identical for all recordings. In a listening test volunteers are asked to compare two sound fields. Their answers form the basis of statistical analysis from which the DL and a confidence level can be derived.

Implementation

Measurement Equipment

Official frame in terms of room acoustical measurements is the ISO 3382 standard. The settings of this norm, however, cannot not be considered sufficient when having auralisation purposes in mind. Hence the frequency range of interest was extended. A digitally equalised three-way dodecahedron loudspeaker developed at the ITA Aachen is the appropriate sound source to cope with these challenges. Besides the ITA dummy head microphone and a B&K 4190-microphone, two figure-of-eight pattern microphones were used as part of the eight channel measurement equipment. This was regarded important to assure the accuracy of the measured parameters.

Measurements were made possible in the new Gewandhaus in Leipzig, the newly opened Konzerthaus Dortmund, Cologne Philharmonic Hall and Brussels Hall of the Eurogress in Aachen. This way, two trapezium-shaped halls, a fan-shaped hall and a rectangular-shaped hall were part of the survey. Due to the quality of the equipment and a sophisticated measurement procedure, 16 coherent averages turned out to be sufficient to measure RIRs with a SNR of at least 70 dB at about 100 listening/measurement positions in each concert hall. This was done in two measurement sessions of 8 hours each. For a detailed overview of the equipment please read our ICA2004 contribution [3].

Test Design

The audio samples used in the listening tests need to be chosen with special care as their effects are known to be manifold. The anechoic piece of music that was convolved with the binaural impulse responses had a length of almost 14 s and included a solo trumpet playing staccato and legato parts as well as final notes followed by silence. These frame settings give the subject the chance to develop a sensation of ASW as well as LEV and not exhaust it by too long a sample. All audio samples were adjusted to the same dB(A) level in order to minimise the effects of loudness.

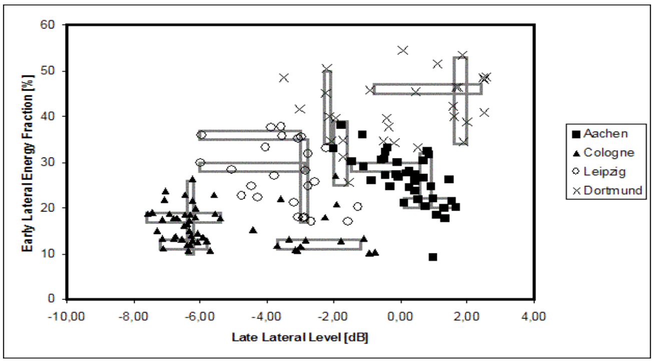

Figure 1: Distribution of LF vs. LG for listening positions in the four concert halls (the bars denote to the regions from which the samples for the listening test were taken from).

The listening test was designed as a pair comparison. Each pair consisted of two samples which were successively played to the subject and separated by silence and a heralding sound.

Figure 1 shows those measurement results in the four concert halls in respect of LF and LG, whose accuracy has been determined to be very high. Two different tests were designed to survey ASW without LEV. Hence pairs in the tests are recruited from the regions indicated by the rectangles in Figure 1. In order to further reduce the effects of other influences, pairs were only formed from samples recorded in the same concert hall. With the goal to have the same test progression for all subjects, they could only listen to the pair once and then had to determine - depending on the test - which sample inhered the larger sensation of ASW or LEV. For a detailed description of the psychometric testing please read our RADS2004 contribution [4].

Results

1. Sensor accuracy

Sensory precision is a well-known and unfortunately still unsolved problem of figure-of-eight pattern microphones. A double-diaphragm microphone and an intensity probe were used to quantify the sound fields. General problems that were found include a mismatch of the sensitivity lobes, a frequency dependent directional sensitivity pattern and a lack in assembly precision. These weak points were found for both commercially available and self built microphones.

2. Variation within a single seat

It is important to determine if the single number parameters sufficiently describe the sound fields as they were measured with the dummy head. This question has to be seen in the light of the findings of de Vries: If the fluctuations of the parameter are too large, it cannot be said that they accurately describe the samples used in the listening tests.

$$\sigma^2 \approx 0{,}045\mu \qquad (1)$$

Equation (1) shows the approximate relation of the fluctuations' standard deviation σ^2 in regard to the arithmetic mean μ of LF-measurements taken in 5cm steps within a single seat on the main parquet. Such measurements were taken in Cologne, Dortmund and Leipzig.

3. Apparent Source Width

The pairs that were used in the listening test were grouped into sequences which had an anchor value in common. These sequences can be seen in the rectangles in Figure 1. In order to calculate the DL the psignifit toolbox by Wichmann [5] was used. The dots in Figure 2 mark the performance of the subjects in respect to the stimulus difference. The psychometric function is drawn on the basis of a maximum likelihood estimation. Although results as they are displayed in Figure 2 seem plausible at first glance, analysis of the statistic significance suggests that the model underlying the depicted outcome is 87% unlikely to describe the results of the listening tests.

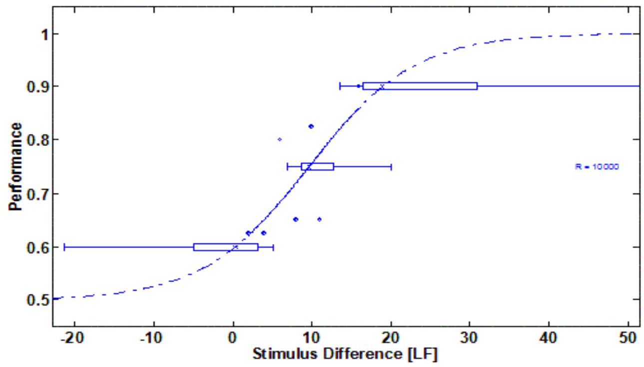

Figure 2: Psychometric function fitting the data of the "Anchor 10" sequence.

Other sequences had a similar level of statistic significance or were rejected with a 95% certainty.

4. Listener Envelopment

The results of the LEV test do not facilitate the drawing of a simple conclusion. Some single answers, however, show such statistic significance that they cannot be considered a coincidental outcome of the listening tests. Detailed analysis of these pairs indicated that they differed most in their clarity index. Although subjects were asked to judge LEV they judged C_{80} instead.

Conclusion

A few aspects in room acoustics need further discussion. Measurement of LF or LG is by no means a matter of course, as microphones still lack in precision. The results of the listening tests are not unanimous. A large difference in clarity seems to influence the LEV perception. The concept of considering LEV and ASW as a single perceptual dimension needs revision. Although the general approach used in this study is correct, further research needs to be done.

References

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