

## Notes on Performing and Playing Back Binaural Measurements

For a correct sound analysis and judgment, it is important to perform both the recording and the playback properly. This Application Note points out possible sources of error and explains what should be taken care of when recording and playing back sound files.

### Artificial Head Recordings

For a realistic judgment of sounds, it is by no means sufficient to regard only the A-weighted level curve or a spectrogram. The analyzer called “human hearing” must be involved in the judgment, too. However, simply playing back a microphone recording is often not sufficient to judge a sound. Only with artificial head measurement technology, is an acoustics engineer able to record and play back a sound in the same way as if the listener was present in the original sound field. Human hearing is capable of recognizing different directions of sound incidence and identifying different sound sources, and furthermore it has a very fine resolution in both time and frequency domain. Artificial head measurement technology with transfer characteristics comparable to those of human hearing allows an expansion of conventional measurement technology by including human hearing as a measurement instrument [1].

Of course, often a sound can also be listened to and judged directly at the time of occurrence. However, in many situations this is not possible for technical or organizational reasons; for example if several people are to judge the same sound from the driver’s seat. Furthermore, recording a signal has the advantage that, in addition to analyzing the sound with the human ear, the sound data can also be subjected to computer-based measurement and analysis. This combination of analyzing, i.e. “seeing” the sound and hearing it optimizes sound diagnostics and facilitates sound optimization.

Using the equalization interfaces, it is possible to analyze artificial head recordings in a way that is compatible with conventional measurement technology. This requires that the interface matching the type of sound field is used for the recording. Artificial head measurement systems from HEAD acoustics provide three equalization types: Equalization for the standardized sound fields (free field and diffuse field) and an equalization affecting only the direction-independent components of the sound. This equalization type is called “Independent of Direction (ID)” [2] and is suitable, for example, for the interior of vehicles, where neither a diffuse field nor a free field exists.

Besides selecting the appropriate equalization for the respective sound field, it is also necessary to choose a suitable artificial head. HEAD acoustics offers two fundamentally different groups of artificial heads. One type is only suitable for measurements in the far field<sup>1</sup>, the other group can also be used for measurements in the near field. An artificial head typically used for the usual

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<sup>1</sup> Far field: The distance  $r$  from the sound source is greater than twice the wavelength  $\lambda$  ( $r > 2\lambda$ ). Near field: The distance  $r$  from the sound source is smaller than twice the wavelength  $\lambda$  ( $r < 2\lambda$ ).

tasks in the NVH area (i.e. far field measurements) cannot be used for measurements in the near field.

Several publications in the past describe a method for checking the measurement and playback chain by placing a headphone on an NVH artificial head. An artificial head recording is then played back via the headphone and recorded again with the head. However, this method is not suitable, because the deviations that can occur in a comparison between the “headphone / artificial head” recording and the original artificial head recording can be caused not only by a wrong playback, but also by the fact that a typical NVH artificial head is not suitable for near field recordings. The headphone enclosing the ears of the artificial head modify the acoustic impedance, so the recording can be distorted under certain conditions. Such a measurement setup can only be used for comparative measurements, but not for determining absolute values. For exact near field measurements, HEAD acoustics offers a special artificial head, which can be used, for example, for measurements of headphones and telephone terminal equipment. When using an artificial head for the measurement of headphones, special care must also be taken regarding the positioning of the headphone. Since it is difficult to place the headphone in exactly the same position for each measurement, it is necessary to make several measurements, repositioning the headphone each time. The results can then be averaged.

## Playback of Sound Recordings

For the playback of artificial head recordings, HEAD acoustics offers a suitable playback system, which optimally matches the artificial head systems. A matched playback chain is the best guarantee for a correct playback. But even if the playback is performed correctly regarding the technical aspects, a number of environmental factors, the listener’s expectations or the playback order can have an undesired effect on the judgment. The engineer listening to the sounds or the experimenter conducting a listening test should know and take care of the following aspects in his work in order to obtain a valid judgment of the sounds.

- The context of the playback can have a considerable influence on the judgment of a sound. This can have several reasons:

- The acoustic characteristics of the recording location differ from those of the playback location:

An inexperienced subject who listens to an artificial head recording for the first time can be made insecure by a discrepancy between the acoustic conditions of the test room and those of the room that is heard. For example, if the subject is sitting in a large room with reverberant walls, he or she expects sounds with a certain degree of reverberation. Sounds recorded in an anechoic room do not fulfill the subject’s expectations in this case and are therefore judged differently. A wrong judgment can best be avoided if the recording and playback locations have similar acoustic characteristics, or otherwise by means of a training phase prior to the actual listening test.

- The test environment does not fit the sound:

Some publications describe tests where sounds were presented both at the location of origin (e.g. in a vehicle cabin) and in a listening room. The comparison of the results of the two test series exhibit considerable differences in some areas. These differences were not caused by a technically incorrect playback, but by the listeners’ different expectations due to the respective environment. Noise from the

interior of a vehicle is perceived as “very loud” by many subjects when played back in a quiet room. The same noise, played back in a vehicle cabin, is perceived as less loud by many subjects. Just like matching acoustic characteristics, a suitable environment causes an appropriate expectation of the listener and thus a realistic judgment of the sound. For the playback of vehicle interior noise, HEAD acoustics has developed the SoundCar, where vehicle interior noise can be listened to and judged in a real vehicle cabin. In certain cases, an appropriate environment can also be created by a suitable visualization. e.g. using a still image, a movie or an animated scenery on a monitor. A careful selection of the images is important, as they have an influence on the judgment [3], [4].

- Vibrations affect the perception of sound:  
If airborne and structure-borne sound occur at the same time, e.g. in the interior noise of a vehicle, the structure-borne sound can influence the judgment of the airborne sound [5]. In the SoundCar, the steering wheel and the driver’s seat can be caused to vibrate by means of shakers, allowing an adequate playback of the structure-borne sound. This makes the playback of noise even more realistic. The additional presentation of vibrations can lead to either a better or a worse judgment of the sound [6]. In many cases, this depends on whether or not the vibrations are perceived as “matching” the sound.
- The judgment situation is unrealistic:  
In every-day life, sounds are often perceived subliminally along the way. In a vehicle, the driver concentrates on driving and on the other traffic participants. He is unable to focus his attention on the noise of his vehicle only. Nevertheless, an inappropriate sound or an unusual change of the soundscape is perceived immediately. In a listening test, where the subject concentrates on the sound only, the sound is often judged differently than in the real situation [7]. A simple and evident example for this kind of distorted judgment is a recording of an acceleration noise in the interior of a vehicle. When listening to such a sound in a laboratory, many subjects react with fear, as they have no control over the acceleration they are hearing. With the H3S (HEAD 3D Sound Simulation System), HEAD acoustics offers a software solution, which, in combination with the required hardware, allows a subject to “drive” a vehicle as usual while hearing the sounds to be judged. This puts the subject in control of the driving situation and thus also of the acoustic feedback. That way, the distortion of judgment can be minimized. Other types of sounds can also involve the risk of inappropriate judgment due to a separation from the original context (e.g. road traffic noise or aircraft noise). In such cases, it is necessary to allow a judgment of the sound in an appropriate context. In examinations of traffic noise, for example, there is the possibility to have subjects judge the sounds in a familiar environment, such as in their home.
- The playback via headphones alone may not be sufficient in the low-frequency area. In this case, the headphone playback must be supplemented by a subwoofer. In this setup, not only the headphone signal is equalized via a PEQ (Programmable Equalizer), but also the subwoofer via a separate PEQ unit. Using the PEQs, the headphone and the subwoofer can be adapted to each other. This means that the delay between the headphone signal and the subwoofer signal is compensated, the sound pressure level is calibrated and the frequency response is adapted. Since a subwoofer amplifies low frequencies in the playback, this addi-

tional signal level changes the judgment of the sounds compared to a headphone-only playback.

- The playback of sounds in an A/B comparison can influence the judgment. When a subject is presented test signals in an A/B comparison, the subject is able to identify even small changes, e.g. in the signal level, and includes them in the judgment. In reality, such direct A/B comparisons are hardly possible. For example, in reality the noise of a certain type of aircraft cannot be compared directly to the noise of another type, since it takes some time until the other plane passes by. Usually the human hearing system relies on certain patterns in sounds for identification. These patterns can be stored in long-term memory and used for the judgment. In an A/B comparison, on the other hand, it is also possible to use the sound pressure level information stored in short-term memory for the judgment. This can lead to different judgments in listening tests compared to reality [8]. This fact must be taken into account in the design of listening tests. If a listening test is meant to examine the capabilities of human hearing to detect differences in parameters like frequency or signal level, a test design with A/B comparisons is appropriate. The judgment of sound quality or annoyance due to noise, however, should normally be based on absolute impressions without a direct comparison, as only that way a realistic judgment is possible.

When conducting listening tests, it will probably not be possible to take all of the above aspects into account in all cases. However, the experimenter should be aware of these effects and consider them in the evaluation of the results. That way, distortions in the sound judgments can be interpreted and accounted for appropriately. Furthermore, it is important to point out that a subject who is influenced, for example, by an unrealistic environment, is not doing something “wrong”. The subjects’ expectations will always affect their sound judgments in a specific form, because the subjects cannot abstract from their expectations and thus cannot make uninfluenced judgments. This means that such errors cannot be “corrected” by the subject, but only by an appropriate test design.

Do you have questions for the author? Contact us at [imke.hauswirth@head-acoustics.de](mailto:imke.hauswirth@head-acoustics.de).

We look forward to your feedback!

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