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Pre-Amble

In SP1, test procedures for efficiently assessing hearing and its disorders were collected (WP2: definition of a set of auditory and cognitive impairment tests) and developed (WP1: communication performance tests) to form the Auditory Profile and the set of HearCom hearing screening tests.

The Auditory Profile (see D-2-1b, D-2-2, D-2-3, D-2-4, D-2-5) is an audiological test battery that is intended to provide a “complete” and non-redundant set of diagnostic procedures for the characterization of the major aspects of hearing deficiencies, to be used by professionals. As stated in D-2-5, it contains test procedures for assessing audibility (pure tone audiogram), loudness perception (Acalos), auditory resolution (F&T-test), speech perception (everyday sentences test, matrix sentence test, see D-1-2), binaural processing (ILD, BILD), subjectively perceived hearing impairment (Gothenburg Profile), and cognitive ability (lexical decision test). Information on different language versions of the everyday sentences test and the matrix sentence test can be found in D-1-3, D-1-7, and D-1-10.

Within SP5, WP11, the platform for professionals has been set up for dissemination of the Auditory Profile via the Internet to hearing professionals (as described in D-2-4). The target group includes researchers, audiologists, hearing aid acousticians, and ENT specialists. In addition to promoting the use of the Auditory Profile in clinics, the platform for professionals also informs professionals about the hearing screening tests and how to interpret their results.

The current deliverable is mainly a demonstrator consisting of demo versions of the AP test procedures that can be downloaded from the HearCom website. Therefore, it is closely related to D-11-7 which also describes the platform for professionals and which was written in close collaboration with WP2. For this reason, most of the contents of the current deliverable coincide with the contents of D-11-7. In order to provide a document on its own, this deliverable does not simply cite D-11-7 but reproduces much of its contents.

1 Executive Summary

The professionals section on the HearCom portal informs professionals from all fields of hearing about the outcomes of the HearCom project.

The Auditory Profile test procedures are a prominent HearCom result in the development of which many project partners were involved. The platform for professionals promotes the Auditory Profile (AP) and the respective test procedures not only within Europe but all over the world.

There are two target groups of professionals:

1. Audiology clinics and hearing centers that want to raise the current standards for clinical audiology by using the Auditory Profile in the individual treatment of hearing-impaired subjects
2. Research groups that may use the Auditory Profile to describe the auditory characteristics of their test subjects in a standardized way. Through the use of the Auditory Profile they also can profit from the extensive database of reference values that will build up in the future.

Along with descriptions of the AP philosophy and its test procedures, one of the main features of the platform for professionals is the possibility to download software demo versions and manuals of the test procedures. The webpage with the demos can be accessed using the following URL:

<http://www.hearcom.eu/prof/DiagnosingHearingLoss/AuditoryProfile/SoftwareDownloads.html>

2 Introduction

One of the central outcomes of the HearCom project is the Auditory Profile, an audiological test battery that is intended to provide a “complete” and non-redundant set of diagnostic procedures for the characterization of the major aspects of hearing deficiencies. The aim of the Auditory Profile is that it should be used as a diagnostic tool, for use in a (specialized) hearing centre or clinic or in audiological research, for a broad population of subjects with complaints about their performance in (auditory) communication tasks. The end user of the auditory profile is the professional interested in the characteristics of the hearing of a particular client/patient.

The intent of the Auditory Profile is to characterize the individual's auditory impairment profile in a comparable way across Europe, and so to extend and set standards for hearing care in Europe. In addition, some of the AP tests can help to determine the benefit from assistive devices.

One of the advantages of the Auditory Profile is that all test procedures are available as modules of a single software package (Oldenburg Measurement Applications – OMA), thus providing the same look and feel for all tests and enabling the storage and analysis of test results within one single database.

In order to promote the Auditory Profile and the test procedures that have been developed in the HearCom project, these basic ideas need to be communicated to the target group of professionals in the hearing sector. At the moment these are mainly hearing researchers, but in the future, the tests will also be of interest for audiologists, ENT clinics, hearing aid dispensers or hearing aid manufacturers. For promoting the HearCom test procedures, a section on the HearCom website for professionals is dedicated to “Screening and diagnosing hearing loss”. The two sub-sections of this page describe the HearCom screening tests and the HearCom Auditory Profile.

The section about the Auditory Profile describes the profile itself and each test procedure included in it. Additionally, the platform provides information on the Oldenburg Measurement Applications (OMA) and the software modules available for each test procedure. In that context, demo versions of most test procedures may be downloaded. If visitors to the site are interested in buying one or more of the software modules, they are directed to the HörTech webpage, where they can order research versions of the software.

Although all test procedures are generally available as software modules for OMA, some of them cannot yet be found on the web platform because the licensing conditions are not yet finally clarified with the respective owners of copyright protected audio material etc. As soon as these

matters have been settled, additional software modules will be added to the web platform.

Some of the test can – after proper calibration - also be tested in free-field conditions. However, the focus of the original Auditory Profile is a diagnostic test battery that will be conducted by headphones.

3 Web pages describing the test procedures of the Auditory Profile

The subpage “Auditory Profile” offers general information about the HearCom diagnostic test battery and provides links to detailed information about the individual diagnostic tests and the demo software downloads.

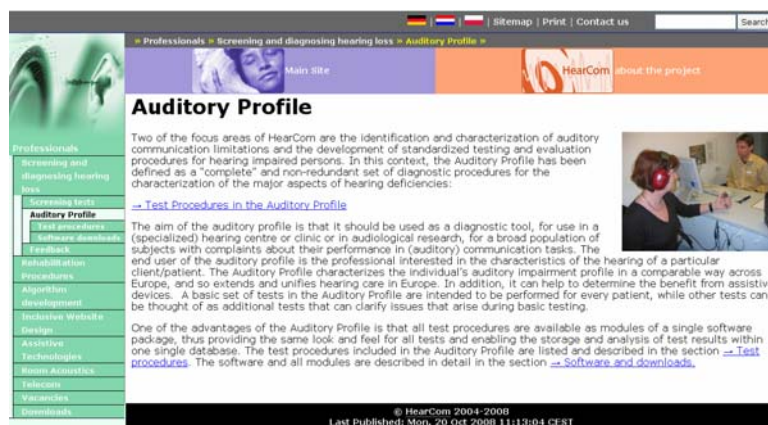


Figure 1: Page informing about the Auditory Profile and linking to more detailed information.

On the subpage “Test Procedures”, the test procedures included in the Auditory Profile are listed. Links to more detailed information are provided for each procedure.

3.1 Pure tone audiometry

The audiogram is a standard test that should be executed for every patient. It includes both air and bone conduction tests. The pure tone audiogram is a standard test that can be performed with every clinical audiometer. This procedure is not available as OMA module.

3.2 ACALOS

ACALOS (adaptive categorical loudness scaling) is a psychoacoustic measurement procedure which determines the individual subjective loudness perception. It can be applied in the following areas:

- Hearing loss diagnostics
- Measuring recruitment as a differential diagnosis for inner ear hearing loss
- Determining customization parameters for hearing aids with dynamic compression and cochlear implants
- Checking customization quality for hearing aids and cochlear implants

In loudness scaling, test signals are presented at different sound levels. The patient subjectively judges the perceived loudness of a signal using a given categorical scale including the categories “not heard”, “very soft”, “soft”, “medium”, “loud”, “very loud” and “extremely loud”. The answers given are transformed into a number between 0 (“not heard”) and 50 (“extremely loud”), and they are plotted as a function of test signal sound level. In the diagram for the hearing range as a function of frequency, equal loudness curves can be plotted for the entire frequency range.

The categorical loudness scaling software includes the following:

- Narrow-band noise with mid-range frequencies 125 Hz, 250 Hz, 500 Hz, 1 kHz, 1.5 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, 8 kHz, and 10 kHz.
- Wide-band, speech-simulating noise signals from the everyday sentences tests and the matrix sentence tests.
- User-defined, wide-band signals may be used after proper installation and calibration
- Automatic adaptive sound level regulation or defined sound level intervals / distances (individually adjustable)

ACALOS is a standard test, which means that it should be executed for every patient.

3.3 F&T-Test

The combined F&T test of Larsby and Arlinger is used for investigating auditory resolution in the frequency and the temporal domain. The F&T test is an advanced test, which will only be performed when the need arises during the diagnostic session¹.

The F&T test can be used to measure spectral and temporal resolution. Masked thresholds of tone pulses in several different noises are measured using a Békésy tracking procedure. From these thresholds the respective auditory resolutions are derived which can then be compared to reference values for young normally-hearing listeners.

3.4 Speech Perception: Everyday Sentences Test and Matrix Sentence Test

For most hearing impaired people, their hearing loss is especially manifest in noisy conditions that create especially difficult communication conditions. To obtain a realistic measure for this kind of hearing deficiency, audiologists perform speech-in-noise tests.

¹When the audiological picture emerging from the standard tests is not completely clear (e.g. an unexpectedly high SRT value given the other test results) an advanced test may provide useful additional information.

Everyday communication situations can be simulated well by using speech-in-noise tests that present whole sentences as speech signals. Such tests determine the speech reception threshold (SRT) in noise that corresponds to the signal-to-noise ratio at which 50% of the speech material is understood correctly. In addition, these tests can also be performed in quiet to estimate the perception of very soft speech.

The SRT is measured using an adaptive procedure. This means that the noise is presented at a fixed level while the level of the speech is adaptively varied: depending on the test subject's response, the speech level is either raised or lowered to increase or decrease intelligibility. This leads to a very efficient way of determining the SRT. If the test is performed in quiet, the level of the speech is varied adaptively.

The everyday sentences tests use meaningful sentences. As the patients do not have to get used to unfamiliar speech material, there is no need for initial practice. However, when performing the test repeatedly with the same patient, the patient may learn the sentences which can lead to invalid results.

The sentences of matrix tests all are composed with the same structure "Name verb numeral adjective object" (e.g. "Hannah wins twelve red tins"). Compared to everyday sentences tests, training is mandatory to accustom the subjects to the speech material (there is usually a rapid increase in performance during the first two test lists). After initial training, matrix tests can be repeated arbitrarily often with the same patient.

The assessment of speech perception is a standard test, which means that it should be executed for every patient.

3.5 Binaural Processing: ILD and BILD

Measurements where speech signal and masking noise come from different directions mimic a wider range of everyday situations than measurements with all signals coming from the same direction. Usually, the matrix sentence test is used for measuring intelligibility level-differences (ILD) and binaural intelligibility level-differences (BILD).

When using free-field presentation, these binaural parameters can only be determined in suitable rooms. A room is suited for measuring binaural parameters if the ILD measured with normal hearing subjects is larger than 6 dB and the BILD is larger than 3 dB. If the stimuli are presented via headphones using HRTFs, there is no special requirement for the room, except an acceptably low level of background noise.

3.5.1 Intelligibility level difference (ILD)

The intelligibility level difference (ILD) quantifies the benefit that a listener has from separating speech and noise sources. The ILD is the difference between the binaural SRT when speech is presented from the front and noise is presented from the side (SON90) and the binaural SRT when both speech and noise are presented from the front (SON0). Because of the benefits achieved from the head shadow effect and from binaural processing in the auditory system, the separation of speech and noise sources can lead to an improvement of the SRT. This benefit is estimated by the ILD test, and it is about 6-12 dB in normally hearing subjects.

3.5.2 Binaural intelligibility level difference (BILD)

For differentiating between the head shadow effect and binaural processing in the brain, the binaural intelligibility level difference (BILD) test can be used. The SRT in a binaural situation with SON90 presentation is compared to the SRT in the same situation but with plugging of the ear that is directed towards the noise source. Because of the benefits achieved from binaural processing, the results without the plug (binaural presentation) can be better than those with the plug (monaural presentation) by as much as 3-6 dB in normally hearing subjects. This difference is called the BILD. It is not actually measured using plugs, but because the measurement is implemented as a headphone test using head-related transfer functions, the plugging of the ear that is pointed towards the noise is achieved by switching off the headphone on that side.

Measuring the ILD and BILD is seen as an advanced test. It will only be performed when the need for it arises during the diagnostic session².

3.6 Gothenburg Profile

The Gothenburg Profile questionnaire is used to evaluate patients' subjective experiences regarding their hearing problems. The Gothenburg Profile measures experienced hearing disability and handicap. It consists of 20 items divided into two subscales. The first subscale measures experienced disability in hearing speech and sound localization. The second subscale targets the experienced handicap in social settings and the personal reactions to the experienced handicap.

The Gothenburg Profile questionnaires are available in Swedish, English, Dutch, and German.

² When the audiological picture emerging from the standard tests is not completely clear (e.g. an unexpectedly high SRT value given the other test results) an advanced test may provide useful additional information.

The Gothenburg Profile questionnaire is a standard test, which means that it should be executed for every patient.

3.7 Lexical Decision Test

As a measure of cognitive abilities related to the understanding of speech, the Auditory Profile includes a lexical-decision test. This test estimates the lexical access of subjects, which can serve as a fast way of estimating their cognitive language abilities. The task of the patient is to discriminate words from non-words. Test items are presented as text on a computer screen and subjects have to indicate the nature of the presented items by pressing the corresponding button. Both response times and correct scores are recorded and taken into account in the outcome parameter.

The lexical decision test is available in Swedish, English, Dutch, and German.

The lexical decision test is an advanced test which will only be performed when the need arises during the diagnostic session³.

³ When the audiological picture emerging from the standard tests is not completely clear (e.g. an unexpectedly high SRT value given the other test results) an advanced test may provide useful additional information.

4 Demo versions of the test procedures

For most test procedures of the Auditory Profile, modules of the Oldenburg Measurement Applications (OMA) are available. Demo versions of these modules can be downloaded from the HearCom website.

4.1 License model for the software

The OMA software is designed in a modular way. After obtaining the basic software, each test procedure can be optionally installed as an add-on module.

According to that, the OMA software license model uses a so called 'basic license' and test licenses. The 'basic license' must be purchased once and includes some basic software modules and the hardware copy protection (dongle). For each desired test, a test license can be purchased which enables the full functionality of a particular test. Note that without a test license being present, usually a demo functionality is available for each test (see below).

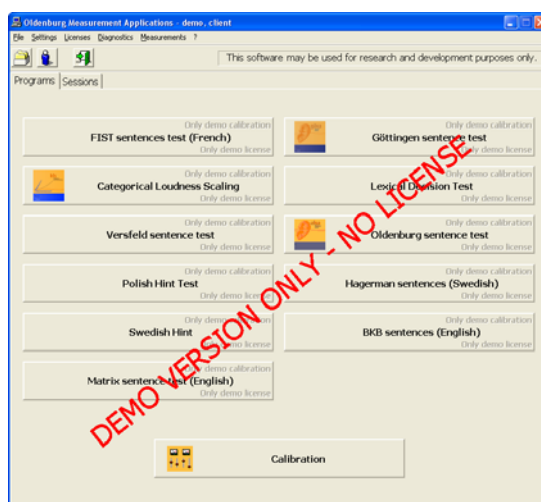


Figure 2: Screenshot of OMA with demo versions of HearCom test procedures

The software programs provided for free download on the HearCom platform for professionals are demo versions of the test procedures (there are demo versions available for all test procedures of the Auditory Profile, except for the Gothenburg Profile test which is not provided as demo due to its nature as a questionnaire with just 20 questions and without sound output). If customers want to buy one or more of the software modules, they are redirected to the HörTech webpage (www.hoertech.de) where they can find further information about how to obtain the licenses.

4.2 Restrictions of the demo versions

The demo versions of the HearCom test procedures will be described shortly in this section. All demo versions do not allow saving measurement results and display a text in large red letters across the main window of the program (see Figure 2). Printing results is disabled. Full versions and demo versions can be mixed, i.e. a customer who owns a full license of test *A* can use the demo version of test *B* with the same basic software. In headphone measurements of demo versions, all broadband stimuli (e.g. speech test materials) are presented without free-field equalisation/ compensation.

A demo calibration is shipped with OMA using 'arbitrary' calibration values. In this way the user need not calibrate the system before trying it. However, a real calibration can be done.

4.2.1 ACALOS Test

The demo version of the ACALOS test only allows for measuring loudness scaling with broadband noise or an auditory sensation field with narrow band noise at 450 Hz and 2600 Hz. It is not possible to add other individual stimuli (e.g. own noise) for loudness scaling.

4.2.2 F&T-Test

The F&T-Test is restricted in the number of turning points used during the adaptive procedure: only very few turning points are measured and the results are calculated from these few values. A corresponding warning is shown on start-up.

4.2.3 Everyday Sentences Test

The everyday sentences tests in various languages can only be performed with a standard noise. Additionally, there is only one test list with a limited number of demo sentences for each language. During sound playback, an additional sound is sporadically played back that informs the listener that the software is only a demo version.

4.2.4 Matrix Sentence Test

The matrix sentence tests in various languages can only be performed with a standard noise. Additionally, there is only one test list with a limited number of demo sentences for each language. During sound playback, an additional sound is sporadically played back that informs the listener that the software is only a demo version.

4.2.5 Gothenburg Profile Test

The well known Gothenburg Profile is a questionnaire that contains 20 text based questions without sound output. Screenshots are displayed on the HearCom website to give an impression of how the questionnaire is filled in on the computer and how the evaluation is displayed.

4.2.6 Lexical Decision Test

In the demo version of the lexical decision test, only a few trials are possible which yields a test result that is incomplete and therefore not usable.

5 Dissemination and Exploitation

Making the Auditory Profile test procedures commercially available on a single software platform is an important way of disseminating the outcomes of the HearCom project. That way, the HearCom test procedures can obtain widespread usage and so may propagate from tests only used in research to de-facto standards in audiology and ENT clinics.

The OMA research software was successfully introduced as a research platform to the market approximately 10 years ago and is already used at various universities, university clinics, research institutes and manufacturers of hearing systems, for instance. Additionally, all tests of the Auditory Profile have been used within the HearCom project by a number of project partners on that research software platform.

In parallel to the OMA research platform, HörTech has developed a software platform that is suitable for usage in CE certified products. So far, this software platform supports particular test procedures and is used in particular medical device products in Germany. Performing an audiometric measurement task usually requires a particular piece of hardware (device) that is certified for usage as medical device, and any software controlling such a device is a component or an accessory of the respective medical device. Certification of the software is thus linked to the particular device and usually only possible in cooperation with the device manufacturer. HörTech will continue to cooperate with device manufacturers in order to increase the number of supported devices and available test procedures in the future provided that the general market conditions in the addressed countries as well as the return on investment for HörTech and the device manufacturers for each specific test are assured.

The information and software for the Auditory Profile test procedures provided on the HearCom website is an essential step to spreading the modern audiological procedures developed within HearCom to a Europe-wide and possibly even worldwide community of future users in research and clinical application.

5.1 Ethical issues

The current OMA implementations of the Auditory Profile test procedures are intended for research use only. The software itself is not certified as medical device or in any other way for clinical use (see remarks concerning this issue above). Anyone using the software does this on his or her own risk and is solely responsible for any harm done when using the software.

6 Conclusions

The HearCom platform for professionals provides a comprehensive means of promoting the HearCom Auditory Profile to hearing professionals in Europe and beyond. The Auditory Profile test procedures can be downloaded as free restricted demo versions to encourage the purchase of the full versions of the software. Along with a description of the test procedures, the platform for professionals offers manuals and descriptions of how to install and use the software and how to obtain full versions.

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