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Hearing in the Communication Society

INTEGRATED PROJECT

Information Society Technologies

D-2-1b: Demo version of the preliminary test set for auditory impairments

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1 Executive Summary

This deliverable concerns the practical implication of the auditory profile that has been defined in deliverable D2.1. The auditory profile was designed in order to enable consistent characterization of individual's auditory impairment across Europe. The auditory profile can be used to determine the individual hearing deficiencies in communication and can help to determine the benefit by assistive devices. The auditory profile should include all necessary measures to describe the details of, and differences between, different hearing impairments.

To stimulate the use of the auditory profile in the diagnosis of hearing deficiencies, it is essential that the included tests are easily accessible and can be performed in a uniform way across different languages. To optimise accessibility, all tests are implemented on a common software platform. The platform chosen within the HEARCOM project is OMA: Oldenburg Measurement Applications.

The work described in this deliverable covers the implementation of all tests in the categories "Standard" and "Advanced" of the auditory profile in order to facilitate an identical test set-up in all countries for the non-speech tests and a comparable test set-up for the language-specific tests. In this deliverable the language-specific tests have been implemented in the German language. Follow-up work will deliver comparable versions in at least four languages: German, English, Swedish, and Dutch.

To facilitate the review by the reviewers and also illustrate the work to the Commission, a video has been produced that is part of this deliverable (HearCom_D2_1b.avi). The video will also be used for demonstration purposes, supporting the dissemination of information from work package WP2 and stimulating professionals in the field to start using the auditory profile in their work, following the standardized approach of HEARCOM.

The exact parameters to be used in further testing will be investigated in the multi-centre field trial. For this trial these have been described in detail in the test protocol for the multi-centre field trial. Later, they will be part of the final definition of the auditory profile and they can be fixed in the OMA programs (e.g. for clinical use) or can be left open for a more flexible application (e.g. for research purposes).

The auditory profile is relevant for the work in SP2 (Adverse Conditions), because its outcome values will define the auditory demands for the acoustical conditions required in case of hearing impairment. The work is relevant for SP3 (Rehabilitation) and SP4 (Assitive Technology), because the auditory profile indicates the deficits that need to be compensated, either by signal processing (SP3) or by alternative strategies (SP4). Finally, the implementation of these tests in OMA will have a great impact on the dissemination of the test procedures and will stimulate a broad clinical acceptance of this innovative approach to auditory testing.

2 Introduction

The demonstrator implements all „Standard" and „Advanced" tests that are defined in deliverable D-2-1 as the "preliminary auditory profile" (see D-2-1, Table 4.2, category I and II).

Table 1 shows the particular tests selected for the different tasks in the demonstrator.

Table 1: Tests selected for the demonstrator of D-2-1b

Task/test	**Category**	**Selected test/description**
1. Audibility		
Audiogram	I	Air conduction, bone conduction at standard frequencies [1]
2. Loudness		
Loudness scaling	I	Acalos measured at 0.5 kHz and 3 kHz
Loudness scaling	II	Acalos measured at more frequencies
3. Frequency-time resolution		
Combined F-T-test	II	Combined spectro-temporal resolution test (Larsby and Arlinger, 1998)
4. Speech perception		
Meaningful (open-set) sentences in quiet and in noise	I	Göttingen sentence test (German) Plomp sentence test (Dutch)
Closed-set sentence test quiet and in noise	I	Oldenburg sentence test (OlSa) in German
5. Spatial hearing		
ILD-test	I	Oldenburg sentence test with virtual acoustics
BILD-test	II	Oldenburg sentence test with virtual acoustics

[1] The standard tone audiogram procedure was not implemented in this demonstrator because each professional audiometer is shipped with standard audiometry software.

JND-azimuth test	II	Minimum audible angle test
6. Subjective judgment, communication and listening effort		
Oldenburg inventory	I	Questionnaire
Gothenburg profile	I	Questionnaire
7. Listening effort		
Effort scaling for speech in noise	I	HoerTech Effort scaling procedure
8. Cognitive abilities		
Lexical decision test	II	Lexical-decision response time
Visual SRT-test (TRT)	II	Bar-pattern text-reception test

The ‘Oldenburg Measurement Applications’ (OMA) provided by DE-HTCH were selected to be the common platform for the implementation of tests of the preliminary auditory profile.

The professional software package for audiological measurements OMA provides a multilingual user interface, shareable database and calibration, as well as support for different hardware platforms. This allows testing in different laboratories across different countries under identical conditions.

In this demonstrator, different tests provided by different partners are amalgamated to run on this platform. The tests are implemented in different programming languages, but they are invoked by OMA and share data with OMA.

Table 2 shows a list of implemented test applications with references to the chapters in this deliverable, where the particular test is described.

Table 2: Test applications that are implemented in D-2-1b

Test-Application	Chapter	Implementation[2]	Provided by
Acalos (Adaptive Categorical Loudness Scaling)	3.1	OMA	DE-HTCH, DE-HZO
Combined F-T-test	3.2	Executable, not included in the demonstrator	NL-AMC
Göttingen sentence test	3.3	OMA	DE-HTCH, DE-HZO
Plomp sentence test	3.3	OMA	DE-HTCH, DE-HZO
Oldenburg sentence test	3.3	OMA	DE-HTCH, DE-HZO
ILD & BILD (Oldenburg sentence test)	3.4	OMA	DE-HTCH, DE-HZO
Minimum audible angle	3.5	Executable	NL-AMC
Oldenburg inventory	3.6	Matlab	DE-HZO
Gothenburg profile	3.7	Matlab	DE-HZO
Effort scaling	3.8	Matlab	DE-HZO
Lexical decision test	3.9	Executable	NL-VUMC
Visual SRT test (TRT)	3.10	Executable	NL-VUMC

As with the HearCom internal tests, all procedures that will be included in the final version of the auditory profile may be implemented as native OMA measurement applications.

Fig. 1 shows the main screen of the demonstrator. Each test has been installed as an independent measurement module in the OMA platform

[2] - Matlab: implemented as MATLAB ® script, requires installed version of MATLAB ®
- Executable: implemented as standalone Microsoft Windows ® program
- OMA: implemented as native OMA measurement module

and can be started using the corresponding startup button. All relevant data (client identification, calibration data, and soundcard data) are passed to the particular test.

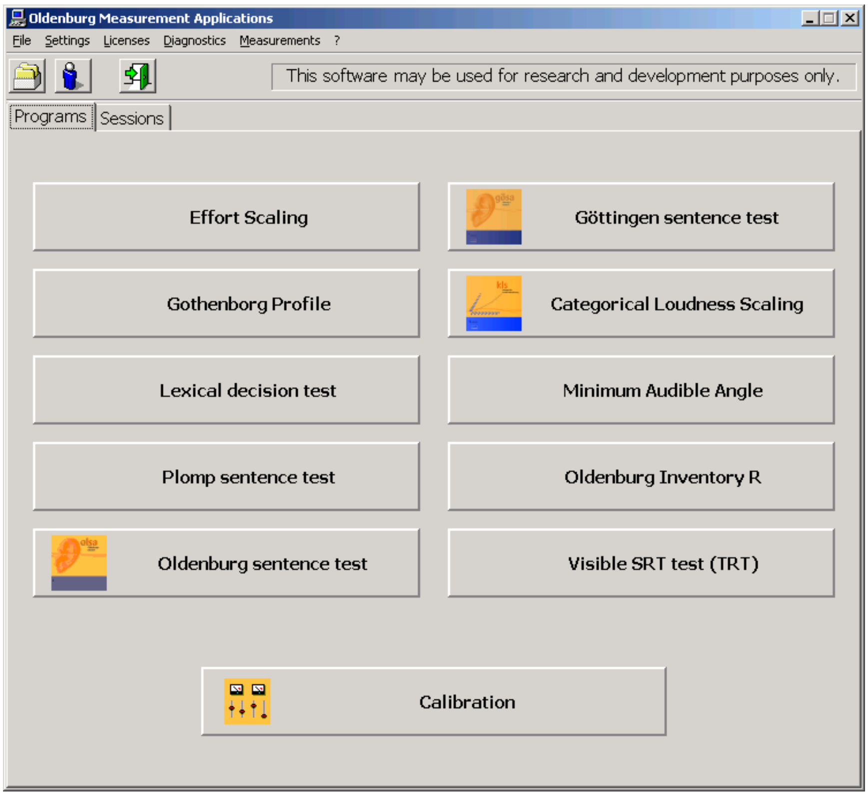


Fig. 1: Main screen of demonstrator D-2-1b

The usage of the OMA basic software package (including database handling and calibration) is described in the manuals shipped with OMA. The documentation files of the basic software package of OMA are attached to this document (see below).

'01_inst.Installation.eng.pdf':	Documentation of installation procedure
'02_tech.Technical Notes.eng.pdf':	Documentation of technical specifications
'03_start.Start_dialog.eng.pdf':	Documentation of start dialog (handling, database access…)
'04_cal_od.Calibration.eng.pdf':	Documentation of calibration
'06_faq.FAQ.eng.pdf':	Frequently asked questions

3 Test applications

In this section, the particular test applications of the auditory profile that are included in the OMA demonstrator are described. The descriptions are based on the procedures that have be chosen for further experimental work in WP2 (see deliverable D-2-1).

3.1 ACALOS

The adaptive categorical loudness scaling (Brand and Hohmann, 2002) with 1/3 octave narrowband noises (centre frequencies can be chosen from standard audiometric frequencies between 125 Hz and 10 kHz) and broadband noise (two speech shaped noises have already been included, additional signals can easily be implemented) is implemented in OMA. All signals are of 1 second duration. The stimuli (different frequency and level) are presented to the subject and the subject has to rate the subjective loudness on a categorical scale (Fig. 2) which allows to choose named categories like 'loud' or 'medium' as well as intermediate categories symbolised with bars of different lengths.

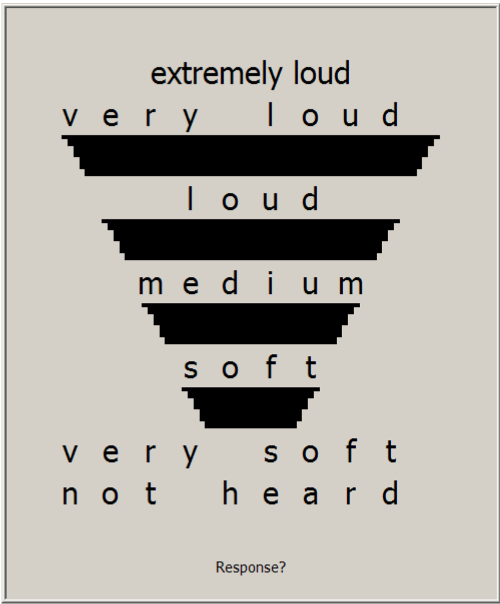


Fig. 2: ACALOS response screen for the subject

The presentation levels of the stimuli are adaptively chosen during the measurement in a way that the stimuli are neither presented at levels exceeding category 'extremely loud' or undershooting category 'not heard'. Per measurement signal, about 20 stimuli are presented to cover the entire loudness growth function. The number of presentations can slightly vary according to consistency of responses.

Fig. 3 shows an example of the measurement screen active during the ACALOS measurement. This screen is not shown to the listener; it is only shown to the experimenter to control the measurement. The individual loudness ratings of the presented stimulus are shown (red circles for right ear) as well as the reference loudness function of the stimulus for normal-hearing listeners (gray area).

For further details of the ACALOS procedure within OMA (like parameter settings), please refer to the manuals given as Appendix to this deliverable (05_kls.Categorical_loudness_scaling.eng.pdf).

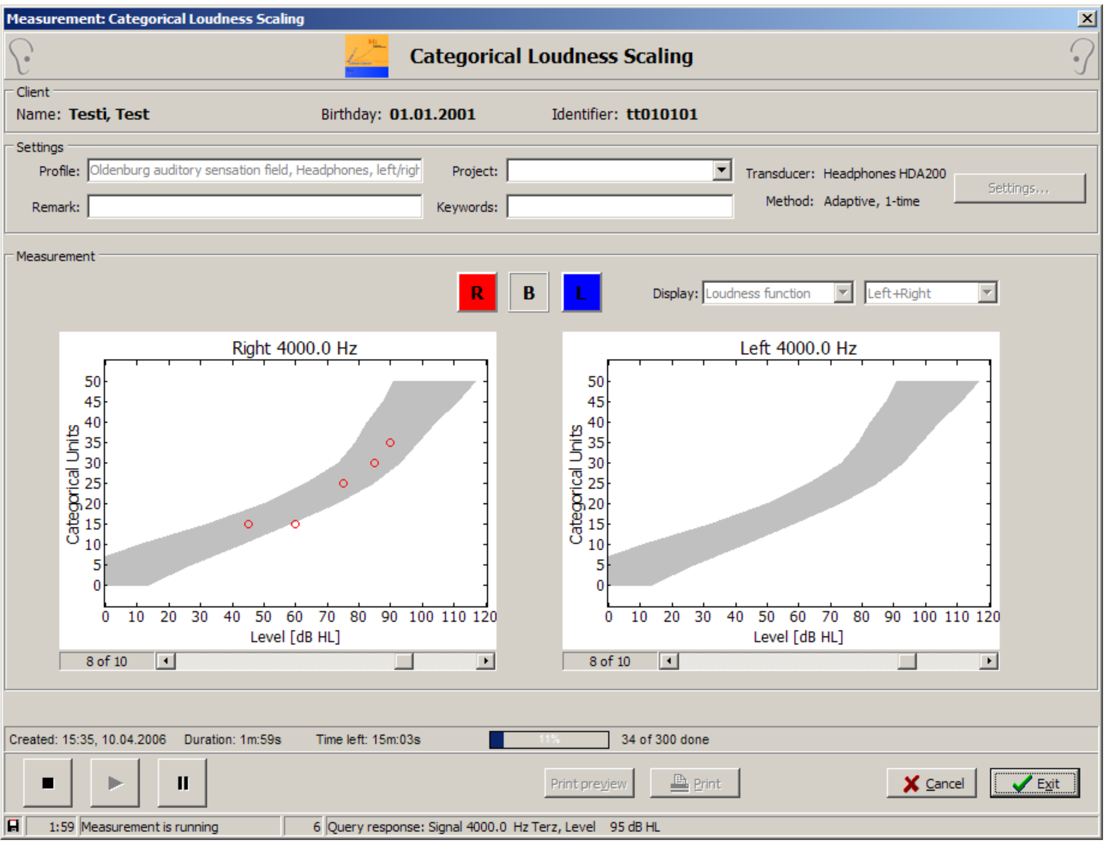


Fig. 3: Example of measurement screen of ACALOS measurement implemented in OMA during the measurement (unfinished measurement)

3.2 Combined F-T-test

To measure spectral and temporal resolution, a combined spectro-temporal resolution test (Larsby and Arlinger, 1998) will be implemented in OMA. This F-T-test is missing in the demonstrator, but will be implemented in OMA before the beginning of the multi-centre study. Currently, an executable is running at AMC-NL.

In this test, masked thresholds of tone pulses in four different noises are measured using a Békésy tracking technique. Noises are 1) continuous octave-band noise, 2) noise with spectral gaps, 3) noise with temporal gaps and 4) noise with both spectral and temporal gaps. Release of masking values (calculated as the difference in hearing thresholds between the condition with maximum masking and the condition with spectral and/or temporal gaps) are used as measures of spectral, temporal and spectro-temporal resolution.

The signal is a pulsed tone (2.22 pulses/sec) with a frequency of 0.5 and 3 kHz, long enough to maintain the tonal character of the stimulus. Noise masks are octave-band noises around the signal frequencies, with or without spectral gaps (0.5-octave wide gaps around signal frequency) and temporal gaps (10-ms silent periods symmetrically placed around the centre of the test tone). The noise level is fixed and the tone level is changed (according to the tracking method, see below) at a rate of 3 dB/sec.

Subjects are instructed to press a button (or space bar) when the tone is audible, leading to a decreased tone level, and to release the button when the tone becomes inaudible, leading to increased sound level. The result is derived from the levels used in the up-down procedure for the last six reversals.

Before starting the measurements, a subject has to be selected (only 'training' can be done without selecting a subject and without saving data), as well as test frequency (0.5 or 3 kHz), test condition ('no gap', 'spectral gap', 'temporal gap', 'spectro-temporal gap'), test ear, noise level and SNR at the beginning of the test. Results are instantly available to the experimenter in the graph on the right.

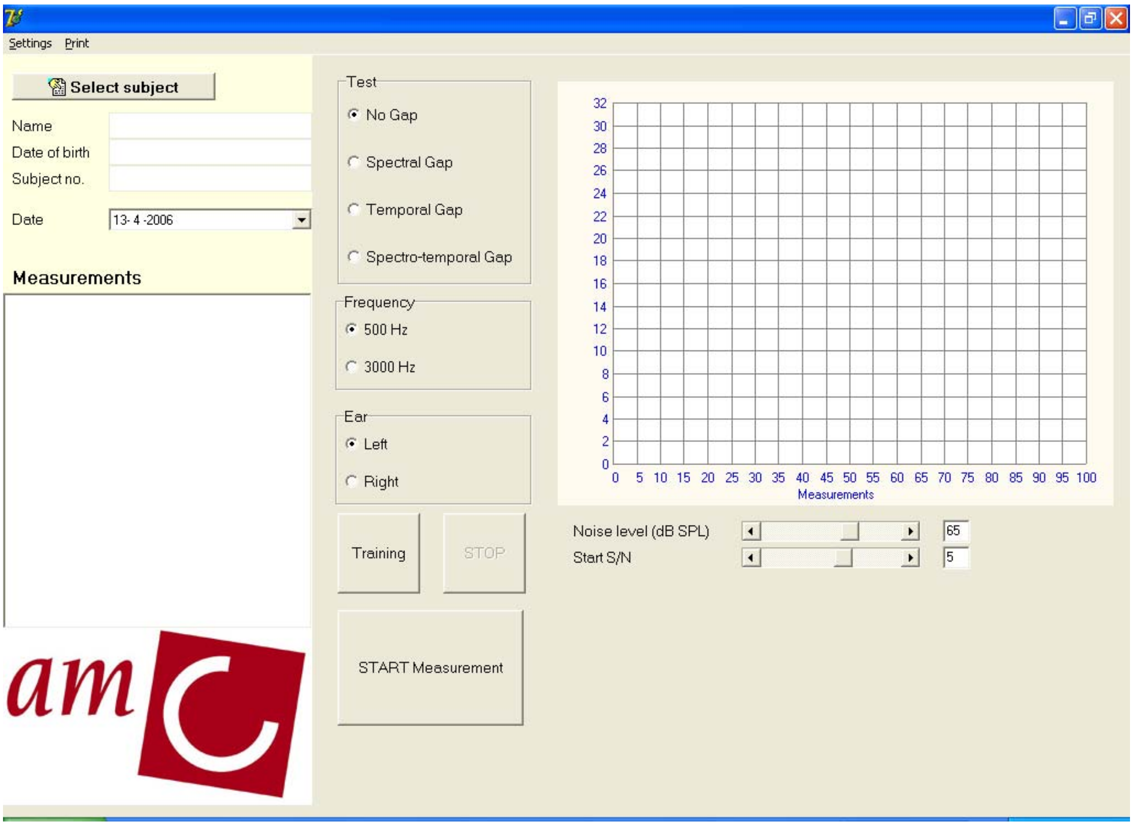


Fig. 4 Measurement screen of the spectro-temporal resolution test

3.3 Speech reception threshold tests

As specified in deliverable D2-1, speech tests with sentences as stimuli are favoured for determination of speech reception thresholds in noise (SRT). Open-set sentence tests are implemented in the OMA demonstrator for the languages Dutch (Plomp and Mimpen sentences: Plomp and Mimpen, 1979) and German (Göttingen sentence test: Kollmeier and Wesselkamp, 1997). The Dutch Verfeld sentences (Versfeld et al 2000) are also already implemented in OMA. For the multi centre study, the Swedish open-set sentence test (Hällgren et al 2005) and the English BKB sentences (Bench et al, 1979) will also be implemented in OMA.

Closed-set sentence tests are implemented in the OMA demonstrator only for the German language so far (Oldenburg sentence test: Wagener et al, 1999a-c). For the multi centre study, the respective Swedish (Hagerman sentences: Hagerman, 1982), Dutch (to be validated within HearCom), and English tests (developed within HearCom, to be validated) will also be implemented in OMA. The Dutch and the English tests have to be validated prior/in parallel to the multi-centre study.

It was decided to use the same interfering noises in the SRT measurements in different languages within the multi-centre study of WP2, namely the stationary icra noise and the fluctuating icra noise that represents one interfering speaker with limited pause durations of 250ms maximum (Dreschler et al, 2001; Wagener et al, 2006). Additional to the respective icra noises that represent a male long-term spectrum (icra1, icra5-250), also icra noise with female long-term spectrum (icra2, icra4-250) were implemented in OMA for the demonstrator and the multi centre study since some sentence tests also include speech material of female speakers (Swedish, Dutch, and English speech tests).

For all sentence tests implemented in OMA it is possible to determine either the intelligibility in percent at a given fixed signal-to-noise ratio (or speech presentation level if the measurement is performed in quiet) or to adaptively determine the SRT. The German sentence tests implemented so far include the adaptive procedure introduced by Brand and Kollmeier (2002). The adaptive procedure can either be used with fixed speech presentation level or with fixed noise presentation level. For unaided measurements, no differences in the results of both approaches are expected according to Wagener and Brand, 2005. The Dutch sentence test includes a simple one-up-one-down adaptive procedure with 2 dB step size. The scoring systems of the tests are also different, the German tests apply word scoring, i.e. each particular word is scored as correct or incorrect. The Dutch sentence test applies sentence scoring, i.e. the entire sentence has to be correctly repeated by the subject to count as a correct response.

Fig. 5 shows the different response boxes that are supplied to the experimenter during the SRT measurements. The Dutch sentence test (upper left panel) applies sentence scoring. Therefore, the response alternatives 'All correct' and 'False' are enabled for the experimenter to be chosen. The test sentence 'Example: Het eten was dit keer erg lekker' is only given to the experimenter to score the subject's response. Both the German Göttingen sentence test (upper right panel) and the Oldenburg sentence test (lower panel) apply word scoring. Therefore, the particular words of the sentences can be chosen as correctly repeated responses.

The different scoring methods can be calculated to each other by taking the number of independent items per sentence into account. Therefore it should be possible to compare results across languages also when different scoring methods are used.

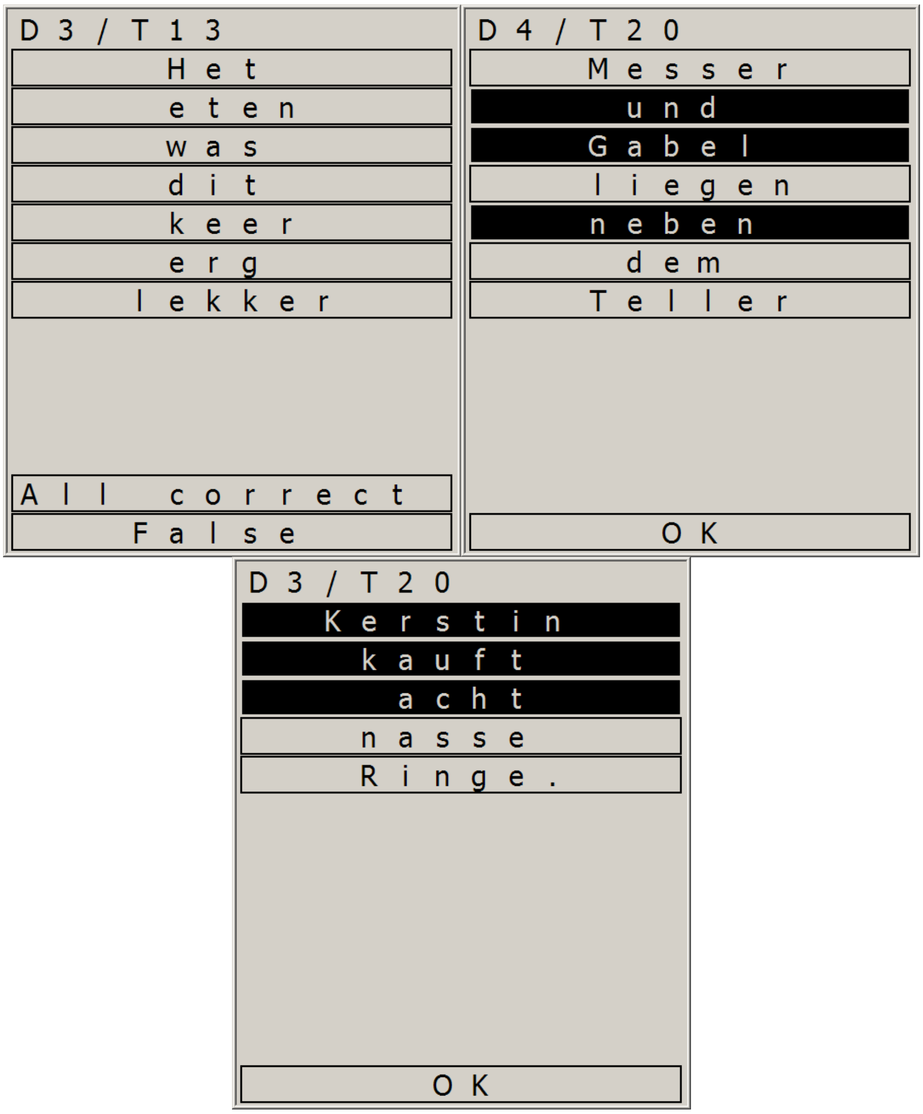
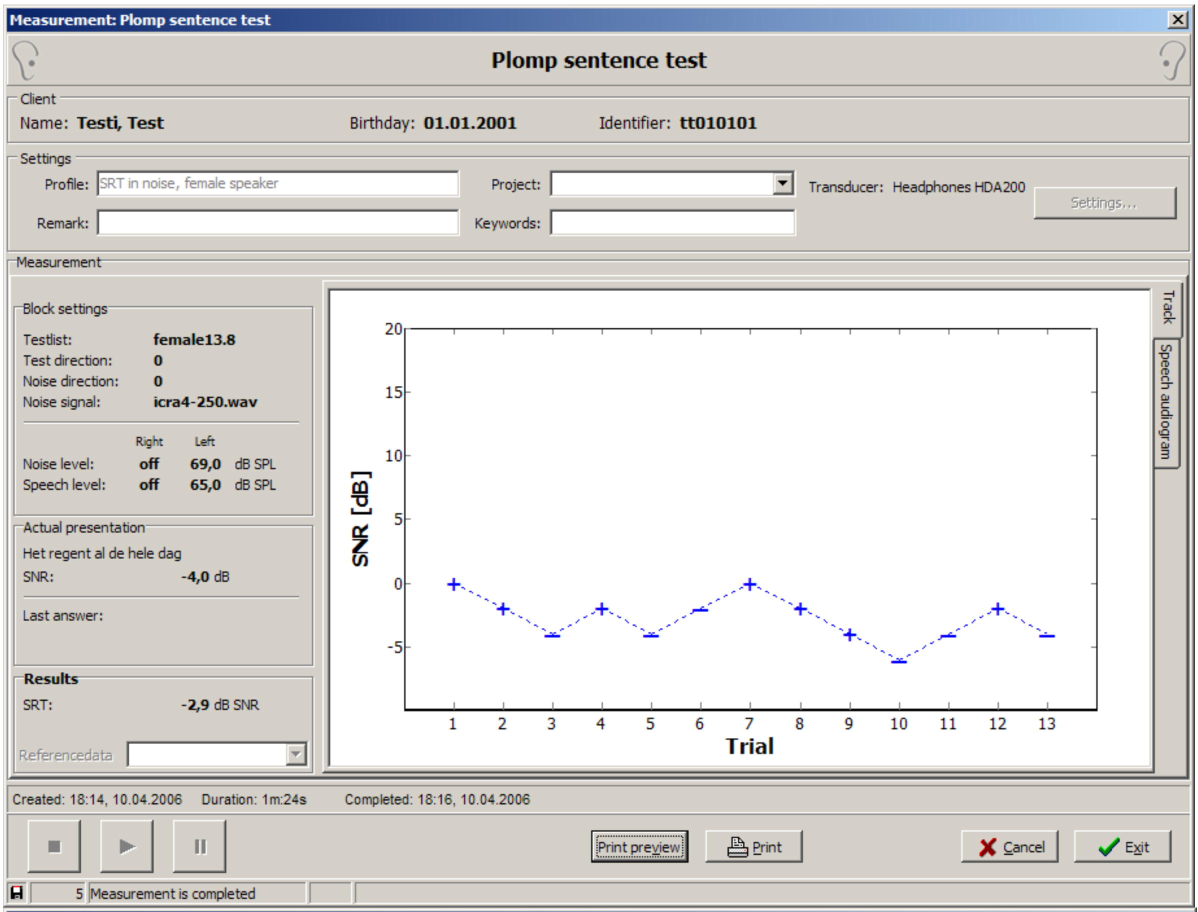
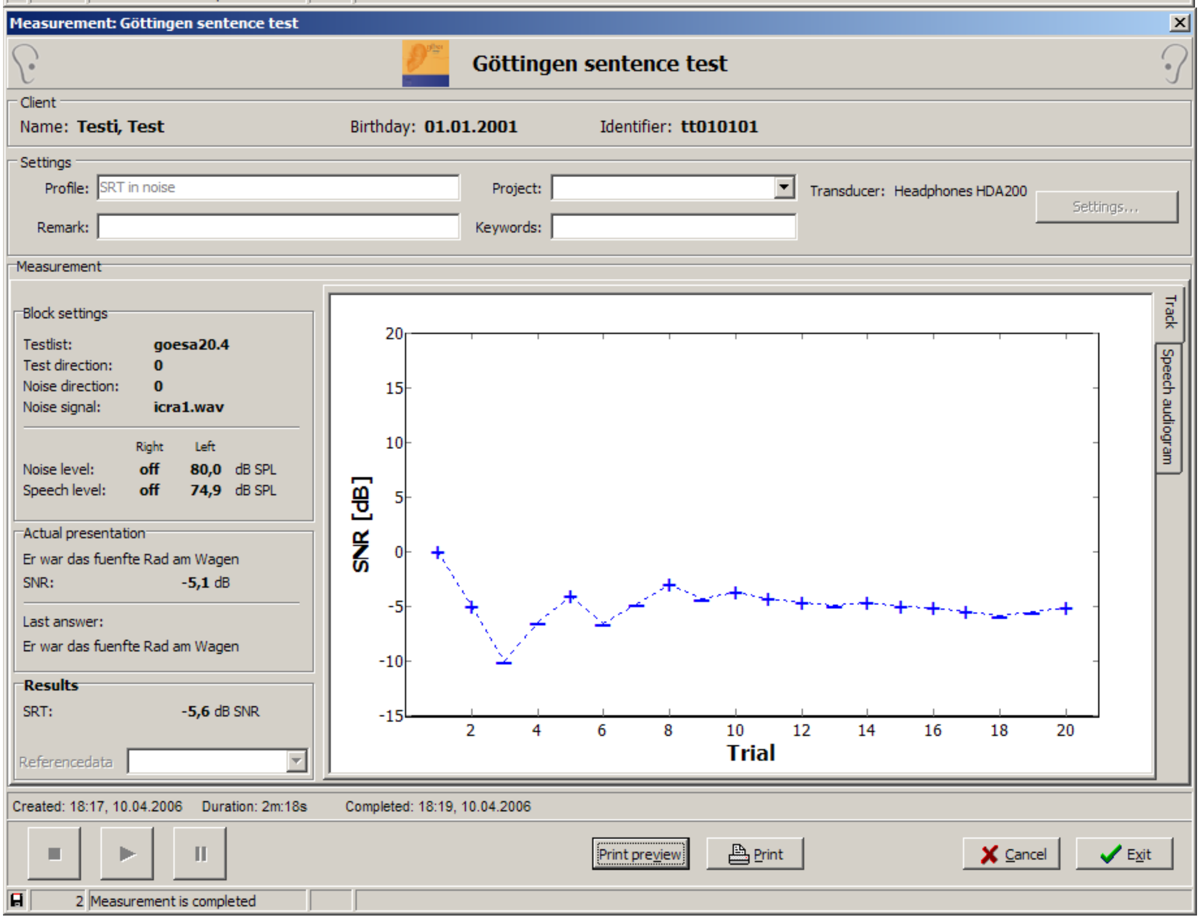


Fig. 5: Response box supplied to the experimenter for open-set sentence tests (upper panel left: Plomp sentences, upper panel right: Göttingen sentence test) and closed-set sentence tests (lower panel: Oldenburg sentence test)


Measurement: Plomp sentence test
Plomp sentence test
Client
Name: Testi, Test
Birthday: 01.01.2001
Identifier: tt010101
Settings
Profile: SRT in noise, female speaker
Project:
Transducer: Headphones HDA200
Settings...
Remark:
Keywords:
Measurement
Block settings
Testlist: female13.8
Test direction: 0
Noise direction: 0
Noise signal: icra4-250.wav
Right Left
Noise level: off 69,0 dB SPL
Speech level: off 65,0 dB SPL
Actual presentation
Het regent al de hele dag
SNR: -4,0 dB
Last answer:
Results
SRT: -2,9 dB SNR
Referencedata
SNR [dB]
Trial
Track
Speech audiogram
Created: 18:14, 10.04.2006 Duration: 1m:24s Completed: 18:16, 10.04.2006
Print preview
Print
Cancel
Exit
5 Measurement is completed


Measurement: Göttingen sentence test
Göttingen sentence test
Client
Name: Testi, Test
Birthday: 01.01.2001
Identifier: tt010101
Settings
Profile: SRT in noise
Project:
Transducer: Headphones HDA200
Settings...
Remark:
Keywords:
Measurement
Block settings
Testlist: goesa20.4
Test direction: 0
Noise direction: 0
Noise signal: icra1.wav
Right Left
Noise level: off 80,0 dB SPL
Speech level: off 74,9 dB SPL
Actual presentation
Er war das fuenfte Rad am Wagen
SNR: -5,1 dB
Last answer:
Er war das fuenfte Rad am Wagen
Results
SRT: -5,6 dB SNR
Referencedata
SNR [dB]
Trial
Track
Speech audiogram
Created: 18:17, 10.04.2006 Duration: 2m:18s Completed: 18:19, 10.04.2006
Print preview
Print
Cancel
Exit
2 Measurement is completed

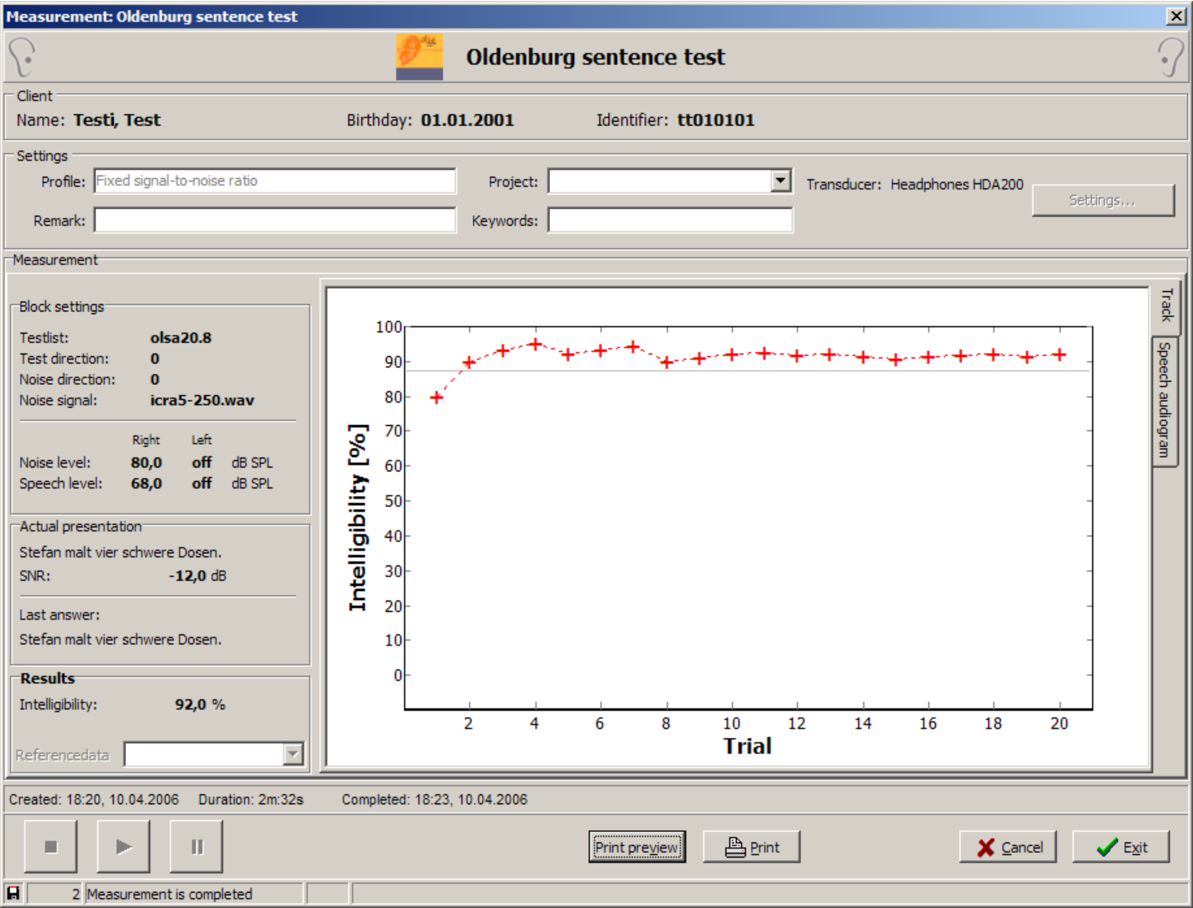


Fig. 6: Screens of the applications 'Plomp sentences' (previous page, upper panel), 'Göttingen sentence test' (previous page, lower panel), and 'Oldenburg sentence test' (panel above caption) after completing the measurement.

Fig. 6 shows the screens of the SRT test applications after completing the measurement. In these examples, the Plomp sentences (1st panel) were used to determine SRT adaptively with the 2dB-one-up-one-down procedure. Since a test list with a female speaker was used, the female fluctuating noise 'icra4-250' was chosen as interfering noise. The Göttingen sentence test (2nd panel) was also used to determine the SRT adaptively with the procedure introduced by Brand and Kollmeier (2002) with decreasing step size. Since the test uses a male speaker, the male non-fluctuating noise 'icra1' was used as interfering noise in this example. The Oldenburg sentence test (3rd panel) was used to determine speech intelligibility at a fixed signal-to-noise ratio (-12 dB SNR), in this example. The male fluctuating noise 'icra5-250' was used in this example since the Oldenburg sentence test uses a male speaker.

For further details on the speech reception threshold tests within OMA (like parameter settings), please see the manuals given as Appendix to this deliverable (05_nlplomp.Plomp_sentence_test.eng.pdf for the Plomp sentences, 05_goesa.Göttinger_Satztest.eng.pdf for the Göttingen sentence test, and 05_olsa.Oldenburg_Sentence_Test.eng.pdf for the Oldenburg sentence test).

3.4 ILD/BILD measurements

The demonstrator D-2-1b also includes the Oldenburg sentence test with two measurement profiles to determine either the intelligibility level difference (ILD) or the binaural intelligibility level difference (BILD) via headphones. For this purpose, head related transfer functions are used to realize stimulus presentation from different directions. For ILD measurements, the SRT is determined with speech and noise coming from the front (both 0°) as well as with speech coming from the front (0°) and noise coming from one side (90° = right direction or -90° = left direction, the noise direction can be chosen during the measurement). The ILD represents the SRT difference between the S0N0 and the S0N+90 or S0N-90 measurement. All signals in ILD measurements are presented binaurally.

For BILD measurements, the SRT is determined from directions S0N+90 or S0N-90, but for monaural presentation using the ear that is contralateral to the noise direction compared to the same measurement with binaural presentation. The BILD represents the SRT difference between monaural and binaural presentation.

When starting the ILD or the BILD measurement profile, a message box asks from which side the interfering noise should be presented. After selecting, for example, 'left' for the noise direction, the start configurations and the test lists for the first phase (ILD: S0N0; BILD: S0N-90, monaural presentation via right ear) and for the second phase (ILD: S0N-90; BILD: S0N-90, binaural presentation) have to be chosen before starting the measurement. After the measurement is started, both phases are automatically performed consecutively.

Fig. 7 shows an example of the measurement application screens of an ILD measurement with the Oldenburg sentence test. The screens can be chosen by the flag 'Test1' or 'Test2'. Screen 'Test1' shows the measurement results of phase 1 (SRT determined in S0N0 configuration, upper panel). Screen 'Test2' shows the measurement results of phase 2 (SRT determined in S0N-90 configuration, lower panel).

The ILD/BILD measurements can easily be made available for any sentence recognition test which is implemented in OMA.

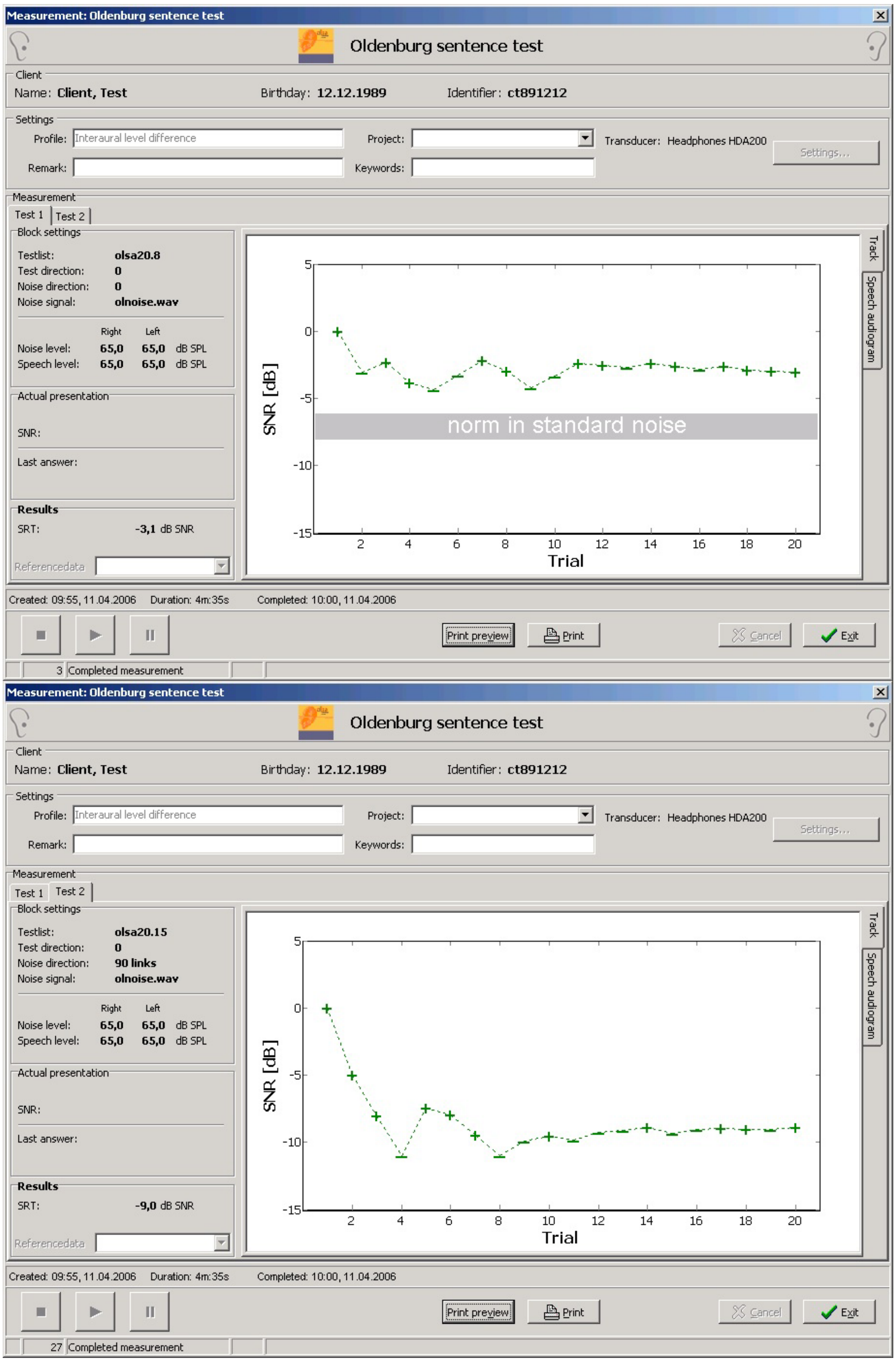


Fig. 7: Screens of the ILD measurement using the Oldenburg sentence test. Upper panel: phase 1 S0N0 measurement, lower panel: phase 2 S0N-90 measurement

3.5 Minimum audible angle

To test sound localisation ability, a virtual headphone version of the minimal audible angle (MAA) test will be implemented on OMA. This test measures the just noticeable difference (JND) in horizontal sound direction.

In this test, two stimuli are presented consecutively from different directions, symmetrically spaced on different sides of the straight-ahead direction. The order of the sounds (left first or right first) is randomised. The task for the listener is to indicate the order of the two sounds. If the sounds are perceived from different angles the result is the impression of a moving sound. The listener has to answer the question: Was the sound going from left to right or from right to left?

When the program starts, first a patient has to be selected from the data directory.

The stimulus settings can be selected under 'settings' in the top left corner. The test uses stimuli based on filtering with head-related transfer functions (HRTFs) for the two ears. These are generic HRTFs that are suitable for the average listener. From these HRTFs we used either an overall value for the interaural level difference (ILD), or the complete difference spectrum. The interaural time difference (ITD) was derived from the generic HRTF functions. Also, we applied low-pass and high-pass filtering to discriminate between the effects for the low frequencies (predominantly ITD effects) and the high frequencies (mainly ILD effects). This resulted in four different sets of stimuli:

- Broad band white noise bursts with ILD derived from the RMS of ILD.
- Broad band white noise bursts with the difference spectrum from the HRTFs for the different directions,
- low-pass noise bursts with the difference spectrum from the HRTFs for the different directions, and
- High-pass noise bursts with the difference spectrum from the HRTFs for the different directions.

Under the tab 'calibration' the calibration settings can be selected. To calibrate the sound level of the stimuli a calibration noise can be played with the 'play' button and with the 'cal' slider the sound level can be adjusted to the desired level.

This test assumes a diffuse-field headphone (like AKG K240DF) with a rather flat frequency characteristic. Within the program, no compensation characteristics are available for other headphones.

The tab 'MAA procedure' gives the start angle of the MAA, and the initial step size, intermediate step size, and final step size together with the number of kneepoints for that step size.

With 'new measurement' the measurement will start. The experimenter will see the results instantly on the screen in the graph on the right. Also, he will get feedback on the order of the stimuli and the response of the listener in the panel to the left of the graph (see Fig. 8). Below the graph the stimulus files for the right and left ear and the current angle are given.

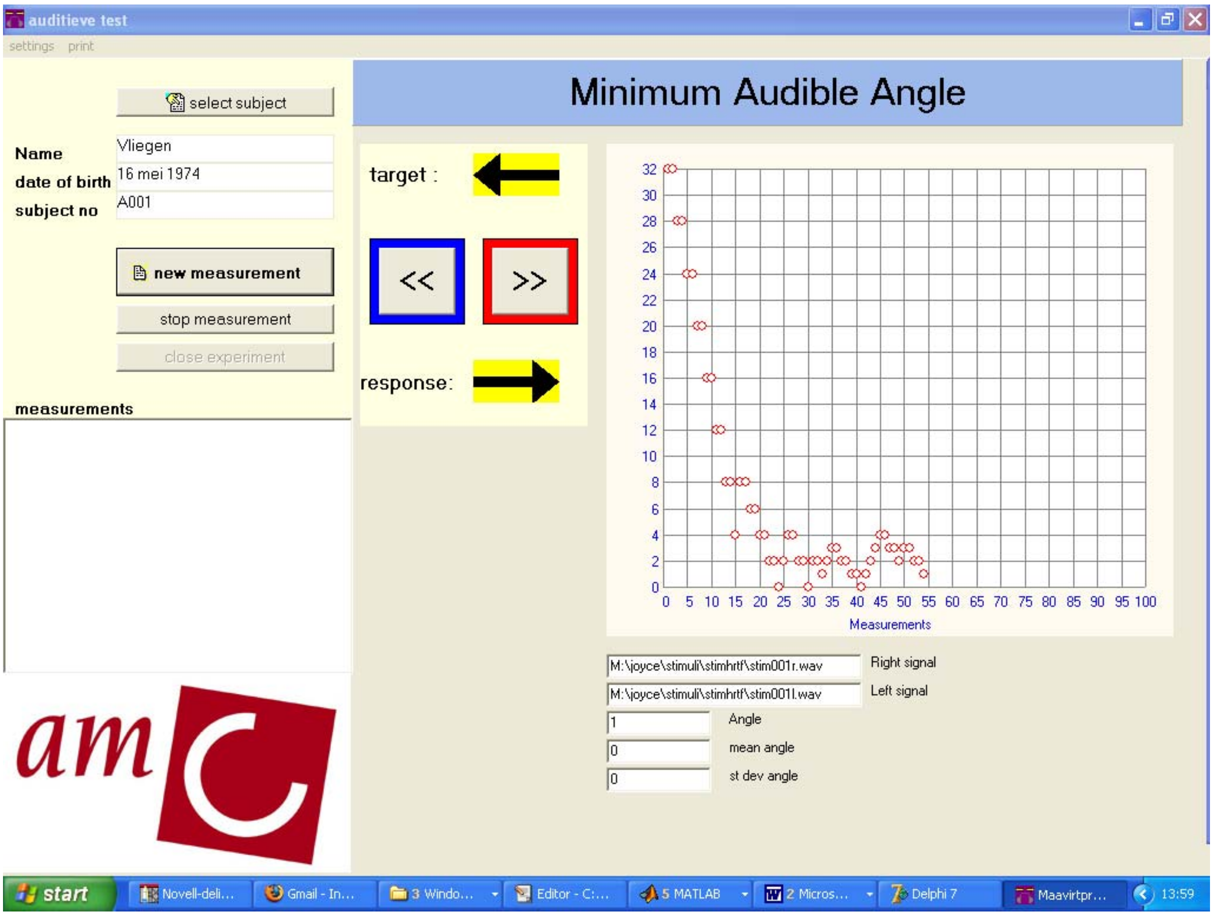


Fig. 8: MAA interface; screen for the experimenter with instant feedback on stimulus order, patient response, current angle, stimulus files and MAA measurement

The listener has a separate screen with a response interface (see Fig. 9), consisting of two buttons with arrows to indicate the order of the stimuli.

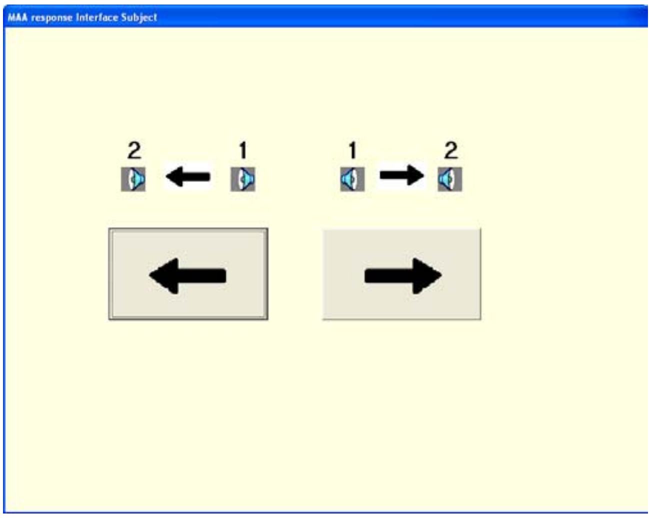


Fig. 9: MAA interface; screen for the patient with response buttons to indicate the order of the stimuli

In the panel on the left ('measurements') previous measurements are displayed. By clicking on a measurement that measurement is selected and the results are displayed in the graph on the right.

With the 'print' command in the top left corner the result panel can be sent to the printer, including the final MAA value (mean over the last eight turning points; together with the standard deviation over those turning points) and additional information like test date, patient information, and stimulus information.

3.6 Oldenburg inventory

The questionnaire "Oldenburg Inventory" (Holube und Kollmeier, 1991, 1994) consists of 2 parts: the "Oldenburg Inventory R" which serves for acquisition of the subjective quality of hearing with a scope to different situations (hearing in quiet, hearing in noise, spatial hearing) and the "Oldenburg Inventory-I" which asks for individual hearing-situations.

Oldenburg Inventory-R (online-version): 12 questions to be selected by mouse click, optionally in two rows for aided and unaided rating at the same time. The procedure and questions are adapted from the paper-pencil version of the test.

Oldenburg Inventory-I: five questions to be filled in by the user and rated afterwards by mouse click. This has also been adapted from the paper-pencil version.

3.6.1 Oldenburg Inventory-R single-spaced/double-spaced

The closed Oldenburg Inventory-R contains questions to address different standard-situations of hearing. The questions for the different scopes are mixed, to avoid systematic errors and bias (e.g. specific response-tendencies).

In the double-spaced version (two response rows per question), the participant has to specify how well he can hear in every situation, once with and once without hearing aids. This questionnaire is best suited for longitudinal studies for gaining a broad overview.

When, for example, the course of a fitting-procedure is to be reviewed with the given standard situations over a longer period of time, the single-spaced version of the Oldenburg Inventory can be used. In doing so, it does not differentiate between hearing with and without hearing aid. Therefore, it is to be specified in advance to which phase of fitting (with or without hearing aid) the answers should correspond.

3.6.2 Oldenburg Inventory-I

In this open questionnaire no determined standard situations are given, but the participant should give the personally (individually) most important situations himself. Afterwards he has to rate how well he can hear and understand within those situations.

It is also possible to combine the open questionnaires with the closed inventory.

3.6.3 Instructions for Execution

The online questionnaire is to be filled in by the hearing-impaired person. The appropriate answer is ticked by mouse or touch screen. The hearing-impaired person should be informed that the information from the questionnaire is handled strictly confidentially (where applicable).

The online versions Oldenburg Inventory-R single-/double-spaced and Oldenburg Inventory-I contain an instruction for the subjects on the first page. Additional to the paper-pencil-version the single-spaced Oldenburg Inventory-R can be used separately for both conditions (unaided/aided), depending on what condition is to be investigated.

In Oldenburg inventory-R, with the given standard situations, it is possible to leave out single standard situations (which are unknown or not occurring in normal course of life) by ticking “the situation is unknown”.

In Oldenburg Inventory-I not all five hearing-situations need be described - according to the subject, less ore more (have to be noticed separately) individual situations can be written down if required.

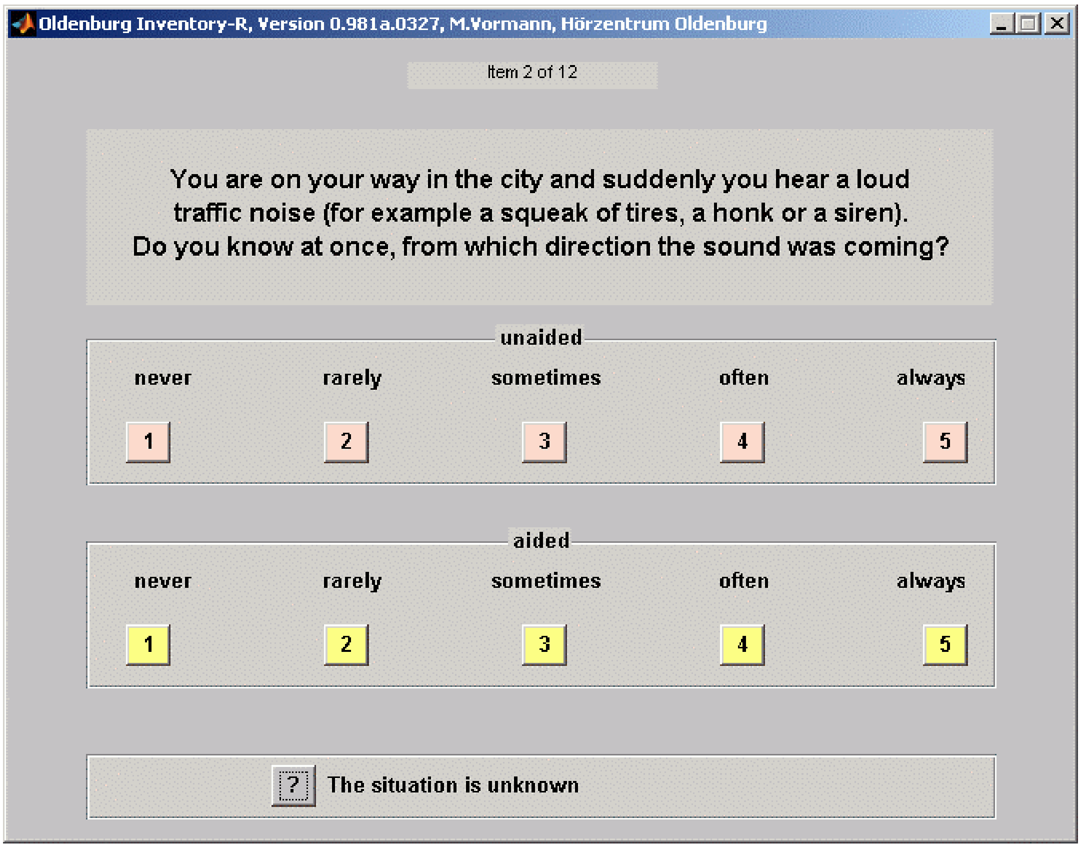


Fig. 4: Oldenburg inventory R: graphical user interface

3.6.4 Instructions for Analysis

For every (answerable) question (= standard-situation) one of the following, given categories can be ticked: "always", "often", "sometimes", "rarely", "never", compare Fig. 10.

In either case the response "always" is the best possible answer, i.e. the answer with reveals the smallest limitations and "never" the worst possible answer, i.e. the answer that reveals most limitations for the hearing-impaired person.

The questionnaire is evaluated by the measurement software numerically by assigning a number to each category. In the following the numbers are ranging from 1 (worst case) to 5 (best case). The assignment from numbers to categories is as follows:

always = 5

often = 4

sometimes = 3

rarely = 2

never = 1

The responses (= numbers) are thus evaluated for all standard-situations individually, in common or separated for each scope. For the double-spaced versions both conditions (unaided/aided) always need to be evaluated separately.

The questions and the responses of the Oldenburg Inventory-R can be grouped into the following scope of hearing situations, respectively:

Scope	**questions (standard-situations)**
Overall	1-12
in quiet	1, 3, 5, 7, 10
in noise	4, 6, 8, 11, 12
spatial hearing	2, 9

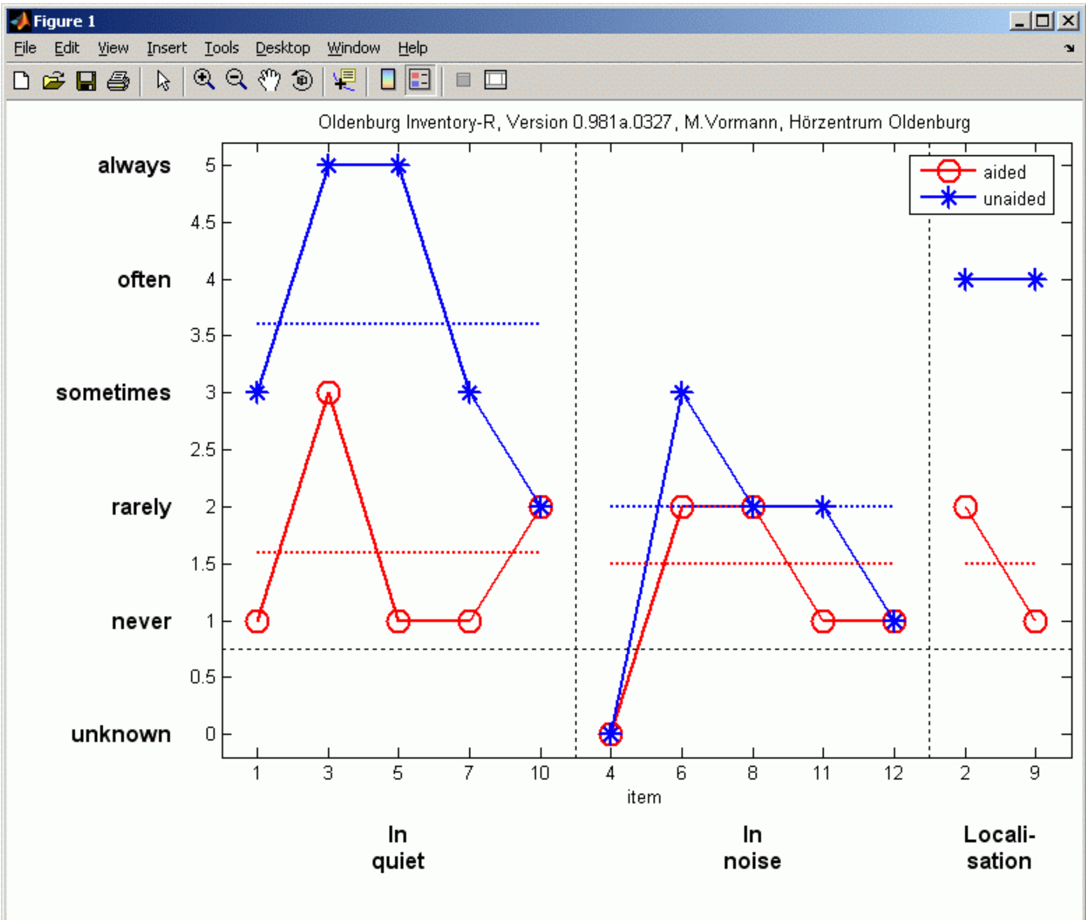


Fig. 11: Oldenburg inventory R: Graphical result screen

```
{
        Measurement:    Oldenburg Inventory-R, Version 0.981a.0327,
        Date:           2006-04-01 17:43:23h
        Subject:        test
        {
        Condition:      unaided
        Answers:        3 4 5 0 5 3 3 2 4 2 2 1
        3.6 - 72% - In quiet
        2.0 - 40% - Im noise
        4.0 - 80% - Localization
        3.1 - 62% - Overall
        }
        {
        Condition:      aided
        Answers:        1 2 3 0 1 2 1 2 1 2 1 1
        1.6 - 32% - In quiet
        1.5 - 30% - Im noise
        1.5 - 30% - Localization
        1.5 - 31% - Overall
        }
}
```

Fig. 12: Oldenburg inventory R: Result table

For a numerical evaluation all responses (= numbers) of the respective standard-situations can be averaged, e.g. sum of all numbers over number of (answered) questions. The higher the calculated average, the better is the hearing for this scope. The best achievable rating is the value of the number that was assigned to "always"; the least achievable rating is the value of the number that was assigned to "never". The software gives the results graphically for each category separately (Fig. 11). The overall average is also given in the result table (Fig. 12).

While comparing two averages, a higher value indicates better hearing in the respective scope. This can be used to compare the situation with/without hearing aids or to monitor the effect of specific settings of the hearing aids throughout an entire fitting procedure (→ follow-up studies).

For this, the following numerical values can be acquired and compared:

- averages (within each scope) for one individual subject
- values (for each standard situation) for one individual subject
- averages (within each scope) for whole groups of subjects, e.g. for objective comparison of different hearing aids
- averages (for each standard situation) for whole groups of subjects, e.g. for objective comparison of different hearing aids

3.7 Gothenburg Profile

The Gothenburg Profile (Ringdahl et al 1993) for measurement of experienced hearing disability and handicap was developed with content partly taken from the shortened Hearing Measurement Scale (HMS25). The Gothenburg Profile consists of 20 items divided into two subscales. The first subscale measures Experienced Disability in hearing speech (items 1-5) and sound localization (items 6-10). The second subscale targets the Experienced Handicap in social settings (items 11-15) and the personal reactions to the experienced handicap (items 16-20). Originally eleven scaling categories were used ("0" = no disability/handicap, "1", "2", … , "10" = maximum disability/ handicap).

In this version, according to Kießling 1996, we used eleven categories, assigning the following names to numbers (categories):

Category "0"	= never
In-between cat. "2" and "3"	= rarely
Category "5"	= sometimes
In-between cat. "7" and "8"	= often
Category "10"	= always

See Fig. 13 for an example. The Gothenburg Profile already exists also in German, translated by Kießling (1996).

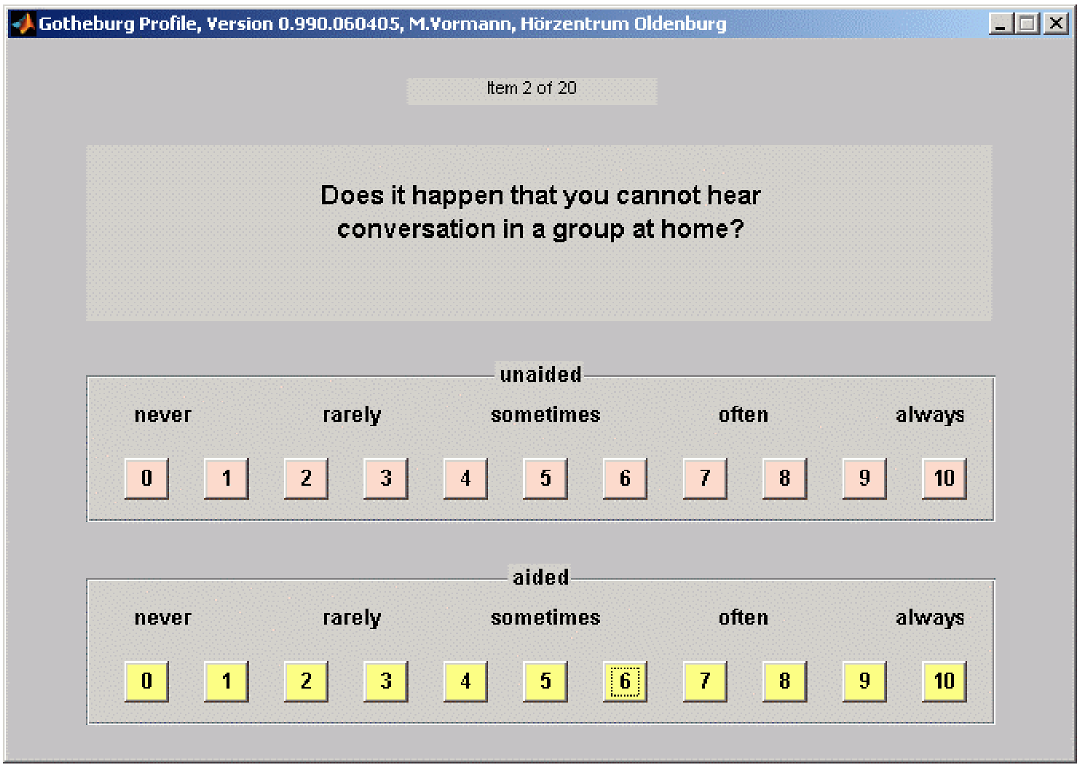


Fig. 13: Gothenburg Profile: graphical user interface

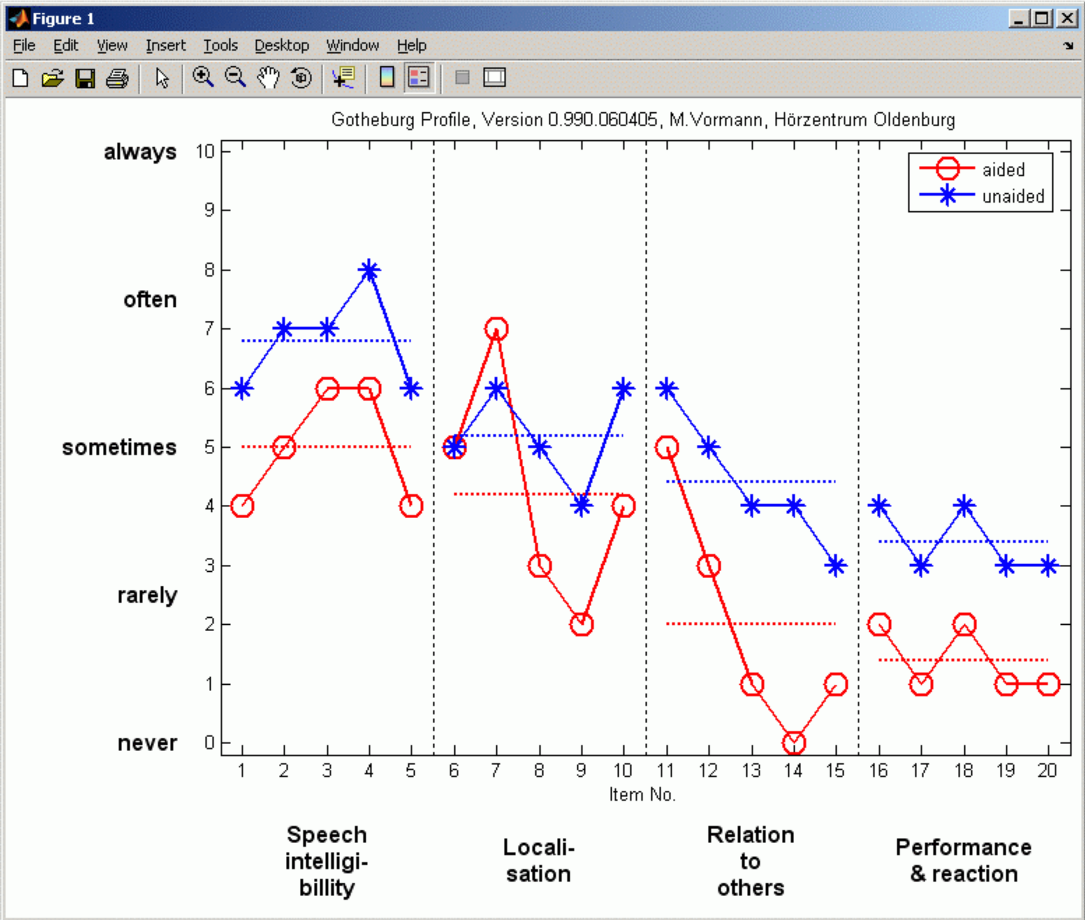


Fig. 14: Gothenburg Profile: graphical results

The software of the Gothenburg profile applies a similar data analysis as the Oldenburg inventory. Fig. 14 shows an example.

The Original Oldenburg inventory and Gothenburg profile as described in this document apply opposite scales. The Oldenburg inventory asks for potentials, the Gothenburg profile asks for problems. It may be useful for the muti-centre study to align the scales.

3.8 Effort scaling

The subjective effort of hearing / understanding of speech in noise is an important point because even if speech is identified correctly, there may be a higher load on cognitive resources, such as working memory, to achieve this identification. "Even levels of noise that do not have measurable effects on intelligibility may cause measurable decrements in the ability of listeners to remember spoken discourse. Noise may, in effect, impose an additional "secondary task" that must be carried out whenever speech has to be understood" (Suprenant 1999).

Therefore the Hörtech Effort Scaling Procedure was developed and a study was carried out to find a suitable way to rate the subjective effort of hearing / understanding speech in noise. The best method to measure the effort was to ask the subjects "how exhausting (hard) is it to follow the conversation?" A continuous scale was established ranging from "not exhausting to follow the conversation" to "exhausting to follow the conversation". For the computer implementation the graphical user interface was used that is shown in 15.

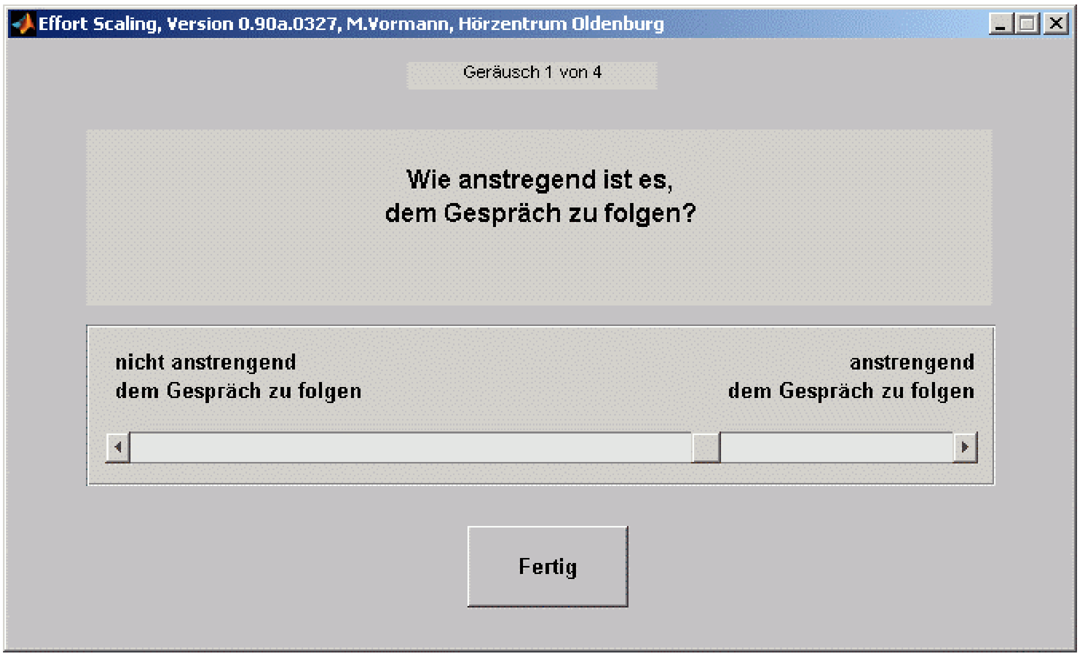


Fig. 15: Effort scaling: graphical user interface in German

The subject can move the slider in 100 steps over the entire range of the scale using the computer mouse. If the rating action is finished, this has to be indicated by pressing a button and the next signal to be rated will be played.

The presented signals are digitally mixed online using fluent speech with either ICRA-1 or ICRA-5_250 noise at an SNR of either 0 or +10dB. All possible combinations of noises and speech are rated by the subject.

3.9 Lexical decision test

The lexical decision task estimates the lexical skills of subjects (e.g., Becker, 1979; Streeter and Nigro, 1979; Bowles and Poon, 1981; Howard, 1983). The task is to discriminate words from non-words. These word items are organised in lists of real-word / non-word combinations.

Fig. 16: Screen of the Lexical Decision Task

During the test, items are selected at random from these word pairs. Subject can identify the nature of the presented items (word or non-word) by pressing a corresponding mouse button (left and right mouse buttons, respectively, see Fig. 16). The measurement program records response times and correct scores (where the response times usually constitute the more interesting data).

The settings of the measurement are controlled by subject-parameter files, called at start-up. Parameter files can contain several measurements that can then be selected by number using the Measurement selector (at the bottom left of the screen, with the blue field). Fig. 17 shows an example of a parameter file for subject "c01."

```
Project ID: Lexical Decision task
Subject ID: c01
Condition : first test
Sent. List: 1
Sent. Seq : Random
List. Len.: 20
First AvNR: 1
Word Path : C:\Info\
Word File : bosman_plus_pseudo.txt
Res. Path : C:\Data\Lex00\
Res. File : lex0c01.txt
Ms. Status: todo
Minimum SN: 1
Maximum SN: 20
WordShowTm: 2000
IntStimPse: 1500
Input Dev.: Mouse
Fixed Time: No
Extra 0004:
```

Fig. 17: Parameter file for Lexical Decision Task

The parameter file controls the word / non-word lists (Word Path, Word File), which specific list is used (Sent. List), how long the list is (List. Len.), and the words used from that list (Minimum SN and Maximum SN). The sequence in which the words from the lists are presented can be “Random” or “Fixed” (Sent. Seq.). The resultant average response time is calculated from “First AvNR.” “WordShowTm” controls the duration that each item is displayed and “IntStimPse” controls the pause between items. This pause can be randomised over +0.5 to –0.5 seconds from the average set value in “IntStimPse” when “Fixed Time” is set to “No.” Finally, “Res Path” and “Res Name” control the output file location, and “First AvNR” controls the number of items over which the averaged results are calculated. Next to the averages, the output file also contains the individual scores (response time and correct score) for each presented item for a more detailed analysis. “Project ID” and “Condition” can be used to describe the experiment.

3.10 Visual SRT test (TRT)

The Visual-SRT test is a visual analogue of the Speech Reception Threshold in noise test (SRT). This test uses the same sentences as are used for the SRT measurements. It estimates the amount of speech information that a subject requires to fully comprehend a displayed sentence. In contrast, SRT test estimates the “amount” of speech that listeners require for correct comprehension of sentences presented via speakers or head phones (see above). In this way, the Visual-SRT test, or Text Reception Test (TRT) is thought to reflect the non-auditory part of

SRT measurements. Prerequisite of this visually performed speech-recognition test is a good visual ability.

Fig. 18: Example of partially obscured sentence in Swedish

In the Text Reception Threshold test, the sentences that are displayed in red, are partially obscured by black vertical bars (see Fig. 18 for an example using the Swedish sentence “Farfar ska vaxa bilen”). Using an adaptive procedure after Plomp and Mimpen (1979) the width of the vertical bars is varied to approximate the width where subjects are able to correctly repeat 50% of the presented sentences (sentence scoring). The outcome of the test is the percentage of displayed text information (100 minus the percentage of the field that is obscured by the bars.

The TRT program has three screens. Screen 1 (under the tab Info) is used to record the data concerning the participant: status number (one letter and six numbers), name, sex, date of birth, and any extra remarks (see top panel of Fig. 19). Screen 2 (tab Options) is used to control the settings of the measurement, such as display duration of the sentence, initial width of the bars, step size of the changes in the bar width, text font and colour, and the pattern used to obscure the text (either bars or dots, only bars is used here). In addition, the target directory of the result files can be given here in the box “data”. For demonstration purposes, screen 2 also hold a box with an example sentence in the box “Preview.” The slider in that box can be used to change the width of the bars, and pressing the button “Random sentence” gives a new, randomly chosen, sentence from the practice lists.

The actual measurement is performed using screen 3 (tab Measurement) which holds the display of Fig. 18, a box to select the sentence-list number, and a start button.

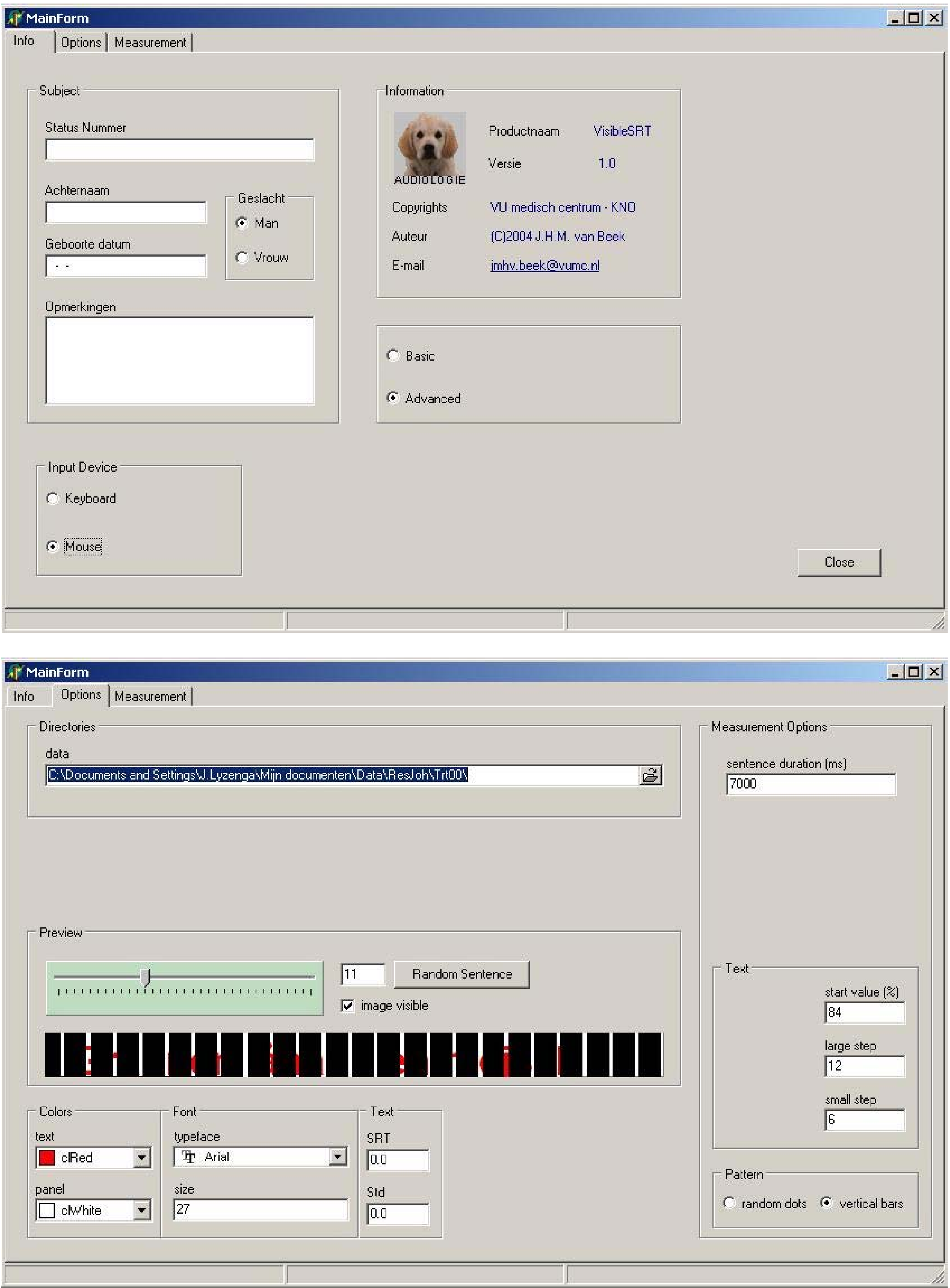


Fig. 19: Screen 1 (top) and screen 2 (bottom) of the TRT test

During the measurement, the experimenter scores the repeated sentences correct by pressing the right mouse button and incorrect by pressing the left mouse button. To end the measurement before the adaptive run is complete, the right mouse button must be pressed while holding the control key on the keyboard.

The result of the measurement is displayed on screen 2 after the adaptive run is completed. Here the runs' average percentage of obscured text and its standard deviation are shown in the boxes "SRT" and "Std." To calculate the average percentage displayed text, subtract the number in the box "SRT" from 100 percent. All results and a log of all actions are saved two files with the name of the status number in the specified target directory. The result file has the file-name extension ".txt" and the log file has the extension ".log."

4 Dissemination and Exploitation

This report shortly describes the particular elements of the demonstrator D2-1b. This demonstrator will be further developed and used in HearCom for the multi-centre studies in WP2. After the procedures, that should be components of the final auditory profile, are selected these procedures are planned to be implemented in OMA as real OMA applications and therefore can be exploited as a HearCom measurement software outcome.

The video is highly suitable for dissemination of the HearCom procedures in presentations or via the HearCom web space.

Before the test set described in this deliverable can be used in the multi-centre study, the language-specific components have to be extended to the four languages that will be covered in the multi-centre study: Swedish, English (UK) Dutch and German. Based on all preliminary work conducted in WP1, we expect that this can be realized before July 1st, 2006

The multi-centre field trial investigates the added value of a broad well-structured approach to the complex problems of hearing impairment. If this approach works, the innovative approach through an auditory profile will be disseminated to the clinics in the countries, represented in the multi-centre study (and beyond). The availability of all tests, well integrated in a single software and hardware platform is an essential prerequisite for the acceptability in the field and for further dissemination and exploitation of the HEARCOM results.

5 Conclusions

The implementation of the tests of the preliminary auditory profile has been realized in a well-structured way into one platform: the Oldenburg Measurements Applications (OMA). OMA will have a great impact on the dissemination of the test procedures and will stimulate a broad clinical acceptance of this innovative approach to auditory testing.

The next steps prior the multi-centre study are to make all tests available in the different languages that participate in the study (including evaluation of test procedures when language dependent).

6 Literature

Becker CA (1979) Semantic context and word frequency effects in visual word recognition. J Exp Psychol Hum Percept Perform. 5, 252-259.

Bench J, Kowal A, Bamford J (1979) The BKB (Bamford-Kowal-Bench) sentence lists for partially-hearing children. Br. J. Audiol. 13, 108-112.

Bowles NL, Poon LW (1981) The effect of age on speed of lexical access. Exp Aging Res. 7, 417-425.

Brand T, Hohmann V (2002) An adaptive procedure for categorical loudness scaling. J Acoust Soc Am 112:1597-1604.

Brand T, Kollmeier B (2002) Efficient adaptive procedures for threshold and concurrent slope estimates for psychophysics and speech intelligibility tests. J Acoust Soc Am 111:2801-2810.

Dreschler WA, Verschuure H, Ludvigsen C, Westermann S (2001) ICRA noises: artificial noise signals with speech-like spectral and temporal properties for hearing instrument assessment. International Collegium for Rehabilitative Audiology. Audiology 40 (3): 148-157.

Hagerman B (1982) Sentences for testing speech intelligibility in noise. Scand Audiol 11:79-87.

Hällgren M, Larsby B, Lyxell B, Arlinger S (2005) Speech understanding in quiet and noise, with and without hearing aids. Int J Audiol , in press.

HearCom Deliverable D-2-1 (2005) Implementation of a preliminary test set for auditory impairments.

Holube I, Kollmeier B (1991) Ein Fragebogen zur Erfassung des subjektiven Hörvermögens: Erstellung der Fragen und Beziehung zum Tonschwellenaudiogramm. Audiologische Akustik 30: 48-64.

Holube I, Kollmeier B (1994) Modifikation eines Fragebogens zur Erfassung des subjektiven Hörvermögens und dessen Beziehung zur Sprachverständlichkeit in Ruhe und in Störgeräuschen. Audiologische Akustik 33(4): 22-35.

Howard DV (1983) The effects of aging and degree of association on the semantic priming of lexical decisions. Exp Aging Res. 9, 145-151.

Kießling, J (1996) Scaling methods for the selection, fitting and evaluation of hearing aids. In: Kollmeier, B. (ed.): Psychacoustics, speech and hearing aids. World Scientific, Singapore.

Kollmeier B, Wesselkamp M (1997) Development and evaluation of a German sentence test for objective and subjective speech intelligibility assessment. J. Acoust. Soc. Am. 102, 2412-2421.

Plomp R, Mimpen AM (1979) Improving the reliability of testing the speech reception threshold for sentences. Audiol. 18, 43-52.

Ringdahl A, Eriksson-Mangold M, Karlsson K (1993) Gothenburg Profile: Self-report inventory for measuring experienced hearing disability and handicap. International Collegium of Rehabilitative Audiology Newsletter 6, 31-33.

Streeter LA, Nigro GN (1979) The role of medial consonant transitions in word perception. J Acoust Soc Am. 65, 1533-1541.

Surprenant AM 1999 The Effect of Noise on Memory for Spoken Syllables. International Journal of Psychology, Volume 34, Number 5, 328-333.

Versfeld NJ, Daalder L, Festen JM, Houtgast T (2000) Method for the selection of sentence material for efficient measurement of the speech reception threshold. J Acoust Soc Am. 107, 1671-1684.

Wagener K, Brand T, Kollmeier B (1999a) Entwicklung und Evaluation eines Satztests für die deutsche Sprache I: Design des Oldenburger Satztests (Development and evaluation of a German sentence test part I: Design of the Oldenburg sentence test). Z. Audiol. 38, 4-15.

Wagener K, Brand T, Kollmeier B (1999b) Entwicklung und Evaluation eines Satztests für die deutsche Sprache II: Optimierung des Oldenburger Satztests (Development and evaluation of a German sentence test part II: Optimization of the Oldenburg sentence test). Z. Audiol. 38, 44-56.

Wagener K, Brand T, Kollmeier B (1999c) Entwicklung und Evaluation eines Satztests für die deutsche Sprache III: Evaluation des Oldenburger Satztests (Development and evaluation of a German sentence test part III: Evaluation of the Oldenburg sentence test). Z. Audiol. 38, 86-95.

Wagener KC, Brand T (2005) Sentence intelligibility in noise for listeners with normal hearing and hearing impairment: influence of measurement procedure and masking parameters. Int J Audiol 44:144-156.

Wagener KC, Brand T, Kollmeier B (2006) The role of silent intervals for sentence intelligibility in fluctuating noise in hearing-impaired listeners. Intern J Audiol 45 (1): 26-33.

7 Appendix

Manuals of OMA explaining all features of the measurement platform and the respective tests.

'01_inst.Installation.eng.pdf':	Documentation of installation procedure
'02_tech.Technical Notes.eng.pdf':	Documentation of technical specifications
'03_start.Start_dialog.eng.pdf':	Documentation of start dialog (handling, database access…)
'04_cal_od.Calibration.eng.pdf':	Documentation of calibration
'06_faq.FAQ.eng.pdf':	Frequently asked questions