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Pre-ample

One of the key achievements of the HearCom project is to develop and publicly introduce a hearing screening test to be used by the general public in several European countries. This screening test is a triple-digit test first introduced by Smits, Kapteyn and Houtgast (2004) in the Netherlands. The test and its implementation in different languages (Dutch, German, English, Swedish, and French) has been described in deliverable D-1-1 and D-1-2. The way in which a test has to be recorded and optimised in any new language has been described (primarily as an input to a standardisation and normalisation body) in deliverable D-1-3. The current deliverable is a description on how the screening tests are implemented for use via internet. The backbone of executing these tests is the Oldenburg Measurement Application (OMA) platform which has been described in D-2-1. The main issue in adapting the PC-based communication test into internet applications for screening and diagnostic proposes is to add a generic "response box" application (JAVA-applet) which operates in conjunction with the end users' web browser to play the audio data and collect the users responses.

D-1-4 is separated into two parts:

Part 1: Preliminary report and

Part 2: Final report and demonstrator

Of which the current deliverable is part one.

1 Executive Summary

An efficient and flexible method of implementing communication screening tests in several languages via the Internet is described and evaluated in this deliverable. An easy-to-use self-administered speech reception test in noise, the so-called triple-digit test has been implemented for the languages Dutch, German, English, Swedish and French. The test is executed on the PC-based audiology testing platform "OMA" (Oldenburg Measurement Applications) with a proper web-interface using a JAVA-applet that operates on the individual users' terminal in connection with a web browser. The feasibility of this approach is demonstrated including the use of MP3-coded audio files to perform a speech test without affecting the expected results. Eventually, the test will be provided by non-profit-organisations in several countries who use the test both to promote better hearing services and to promote public awareness of hearing problems. This will also increase the public awareness of suitable solutions to communication problems using appropriate hearing devices provided for the individual user.

2 Introduction

Self screening tests via internet have the following purposes:

- Provide the user with a fast and comparatively easy assessment of his/her own auditory capability in relation to the normal hearing population
- Allow the general practitioner to check a patient's hearing ability without having to invest into specialized equipments and training of employees to administer the test
- Allow the internet test provider to differentiate among internet users and to provide persons with poor performance specific guidance information (such as, e. g., where to find the nearest professional audiologist or specialized audiological centre)
- Allow the provider to make a statistic about hearing ability in internet users and in specialized user groups
- To increase public awareness of hearing impairment and treatment options for patients with a hearing problem.

Based on the Dutch triple-digit test (Smits et al, 2004, Smits and Houtgast, 2005), a self screening test for testing speech reception in noise via telephone was introduced in the Netherlands in 2004 to great success. A similar test – developed and introduced at the end of 2005 within the HearCom project – was developed for British English and reached several 100.000 callers within few weeks. In comparison to the telephone version

of the test, an internet implementation of such a test yields the following advantages:

- More targeted information can be transferred efficiently to the user upon the individual user's request
- Easier interfacing to obtain more additional information from the user (such as, e. g., age gender or any previous hearing problems) in a structured way
- Worldwide accessibility

On the other hand, an internet version has the following disadvantages:

- Audio-presentation mode is not as standardized (within certain limits) as the telephone channel
- Variable transmission delay between provider and end user may distort the audio signal
- The target population (typically aged citizens) only have a limited familiarity with using the internet
- In contrast to the telephone, business models with respect to using the internet for providing services at a certain service charge (pay-per-use) are not generally accepted and not generally available.

Due to the potential multi language support in an application scenario that extends across (European) borders, the internet application of a self-screening hearing test is a challenging task for the integrated European HearCom project. Hence, an internet implementation of the triple-digit speech intelligibility screening test in noise was constructed under the auspices of this project. In order to make efficient use of the already developed stand alone-versions of speech intelligibility tests, using the Oldenburg Measurement Application (OMA) platform developed within HearCom, an extension of OMA was developed to connect it to the internet (see chapter 4). In addition, special care had to be taken to allow conducting the test with a low-speed connection. This calls for an audio compression scheme for the sound data (speech and noise) transmitted from the provider to the user when conducting the test. Chapter 5, therefore, describes the first listening tests to ensure that a well-chosen audio coding does not influence the test results in a negative way. Finally, to provide the test in a sustainable way is only feasible within an appropriate dissemination and exploitation plan for the product "internet screening test for speech perception and noise" by HearCom (see chapter 6).

3 Screening test of speech recognition

As documented in D-1-2, digit-triplets tests were chosen for swift screening of communication abilities. They provide speed over accuracy, producing threshold estimations in just a few minutes at the expense of measuring only a subgroup of all the abilities necessary for good communication skills. The latter shortcoming is mainly caused by the small number of actual stimuli used in the test, compared to, for example, open-response set sentence tests.

Digit-triplets tests are speech-recognition-in-noise tests using spoken combinations of three digits, presented in a noise background. By adaptively varying the signal-to-noise ratio, a threshold value can be established for a preset correct score (usually 50 percent correct = SRT, speech reception threshold). This threshold then represents a measure of speech recognition abilities under adverse conditions. Because of the simple instructions, digit-triplets tests are extremely suitable for automatic and self-screening operation. Combined with the speed of the test, this makes them particularly suitable as screening tests (Smits et al., 2004, Smits and Houtgast 2005).

The format of digit-triplets tests is described in detail in D-1-1, D-1-2, and D-2-1.

During the course of the HearCom project, the format of digit-triplets test was transferred to the following languages: German (Wagener et al., 2005, Wagener et al., 2006a), Swedish, British English (work in progress, test material has to be optimized and evaluated), and French (work in progress, test material was implemented but optimization measurements, optimization of the material, and evaluation will be performed in the near future). All five tests were already implemented for measurements via headphones or telephone, respectively. These implementations and comparisons of normal-hearing reference data were presented at the International congress of Audiology in Innsbruck in September 2006 (HörTech/HearCom booth and poster by Wagener et al, 2006b). Lyzenga and Smits (2006) presented at this congress the effects of co-articulation and influence of noise samples on the results of the digit-triplets test.

Fig. 1 shows the normal-hearing reference data for digit-triplets tests in different languages determined by measurements via headphones (left panel) and via telephone (right panel). Tab. 1 gives the parameters that describe the psychometric curves. The psychometric function (Eq. 1) was used as model function for these figures.

$$SI[\%] = \frac{100}{1 + e^{4 \cdot s(SRT-L)}} \quad (\text{Eq. 1})$$

SI: speech intelligibility; s: slope of psychometric function; SRT: speech reception threshold; L: signal-to-noise ratio

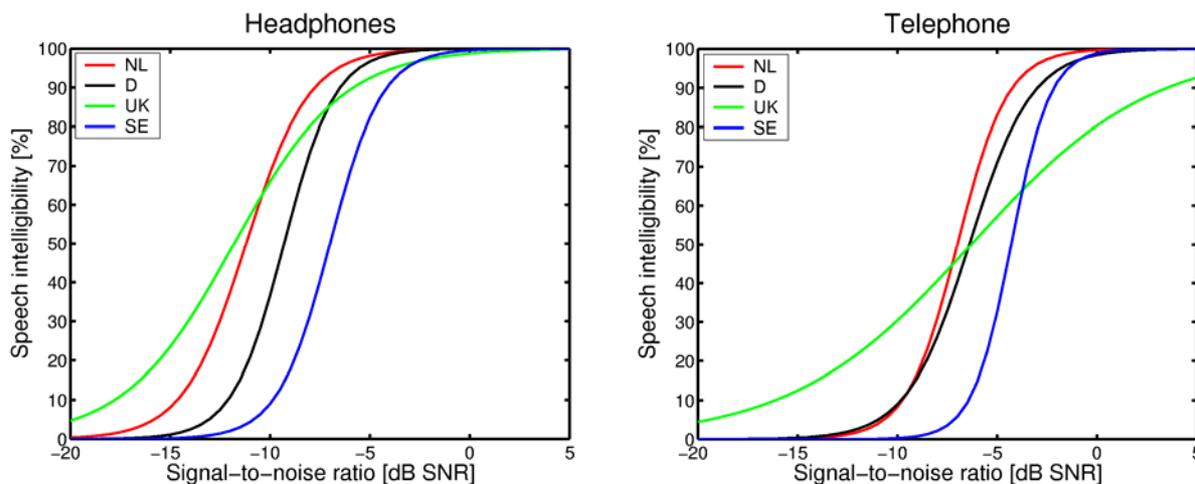


Fig. 1: Reference psychometric functions for normal-hearing listeners, determined via headphones (left panel) and via telephone (right panel).

Tab. 1: Parameters of psychometric curves for normal-hearing listeners via headphones (upper panel) and via telephone (lower panel)

	SRT [dB SNR]	slope at SRT [%/dB]
NL	-11.2	16.0
D	-9.3	19.6
UK	-11.8	9.2 (est.)
SE	-7.0	19.3

	SRT [dB SNR]	slope at SRT [%/dB]
NL	-7.0	20.0
D	-6.4	16.1
UK	-6.3	5.6 (est.)
SE	-4.3	25.8

The slope values of the UK version are significantly lower than the slope values of other languages since the test material was not optimized yet and the values are given for digit scoring instead of triplet scoring. Opti-

mization (equalization of intelligibility across items) will increase slope for the UK version.

As already pointed out in D-1-2 a telephone version of the digit-triple test has been running in The Netherlands since 2003. The telephone version provides users with a test outcome in one of three categories: good, insufficient, and poor. The “good” results lie within 2 standard deviations of the average score of young normally-hearing listeners. If the measured SNR falls above this threshold value with up to 2 dB, the outcome “insufficient” is given, and for even worse results the outcome “poor” is provided. For the latter two outcomes, the advice is given to the callers to have their hearing further examined by a professional (Smits et al., 2004). The same limits were included in the German telephone implementation. The UK version is already used as telephone screening test by since December 2005. It uses similar limits as the Dutch and German versions, but different category denominations: “within normal range”, “below normal” (with the advice to discuss this with general practitioner at some time), and “well below normal” (with the advice to obtain a referral from the GP for an audiology assessment).

The different denominations and advices will be discussed and one common approach for all languages will be chosen for the internet application.

4 Technical structure of internet screening test

4.1 Structure of the Oldenburg Measurement Applications (OMA)

4.1.1 Basic structure

The digit-triplets test was developed in multiple languages on the HörTech audiological workstation (Oldenburg Measurement Applications – “OMA”) within WP1 (Deliverable D-1-1). The highly modular architecture of OMA makes it possible to adapt the PC-based version for lab use to other interfaces (see Fig. 2).

OMA consists of a main module (‘Shell’) that can load multiple modules dynamically and that provides a command interface (inter-module communication) and shared storage for all modules. So called ‘functional modules’ (blue) provide shared basic functions for different purposes, e.g. database access, sound I/O, response box features, calibration, and they can be used by all other modules using the command interface of the shell with symbolic module names. Each measurement procedure is implemented as a functional module as well.

This approach has two major advantages:

1. Different functions may be shared across multiple modules and have only to be implemented once,
2. A particular module may be exchanged for different hardware/software requirements, providing the identical command interface to other modules, but implementing completely different underlying commands: all other modules will be unaffected by this exchange (e.g. different modules for different hardware audiometers, different database modules for different underlying database types).

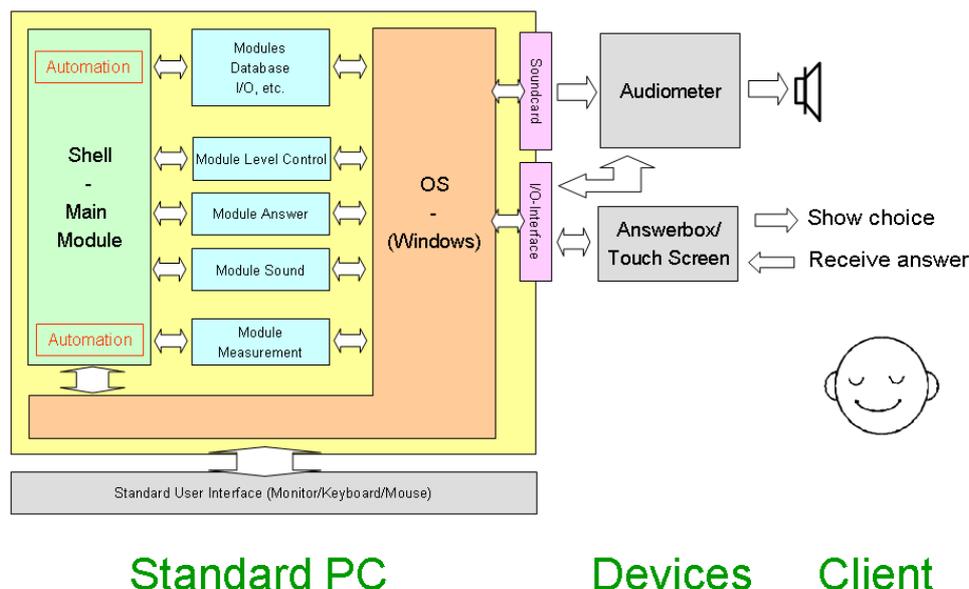


Fig. 2: Structure of OMA

This is especially useful to adapt measurement modules developed on OMA for different HearCom purposes, without having to rewrite the measurement procedures themselves. Furthermore, most of the existing measurement procedures implemented on OMA will be available for internet use once the general OMA adaptation is complete.

4.1.2 Adaptations of OMA for telephone use

The approach of adjusting functional modules in OMA was successfully used in WP1, Task 2, to implement the digit-triplets test in German and Swedish for self-screening by telephone with OMA: the modules 'Answer' and 'Sound' were adapted to use the Microsoft Telephone API interface (TAPI) to play sound using a modem and receiving answers by detecting DTMF signals (Fig. 3). Additional changes for the automation of the shell to automatically perform actions like client selection, measurement start (Automation) were implemented to be able to use OMA without user interaction.

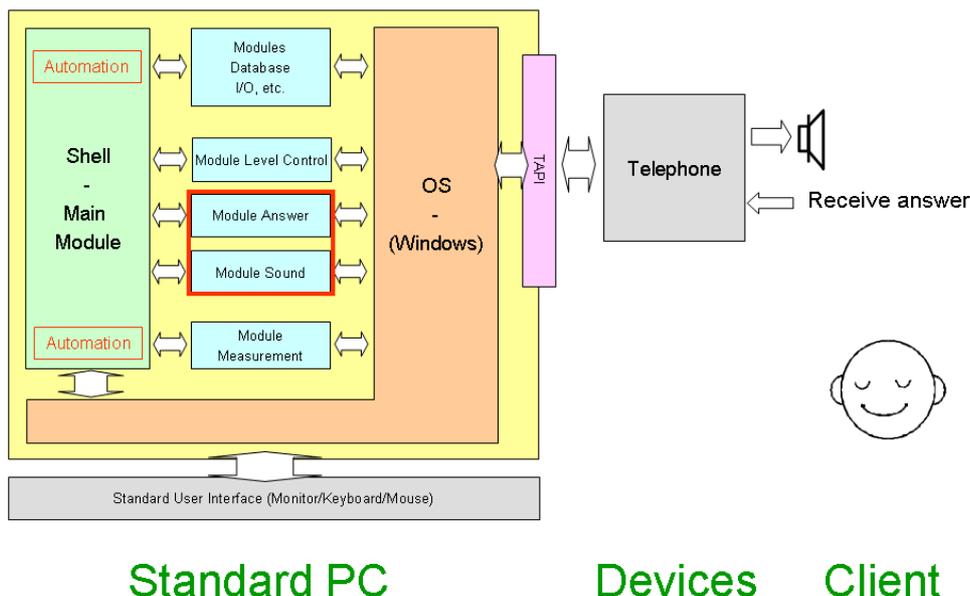


Fig. 3: OMA adaptations for telephone use

4.1.3 Adaptations of OMA for internet use

The adaptations of OMA implemented for internet use are shown in Fig. 4:

1. The automation of the shell developed in WP1 Task 2 and described in 4.1.2 can be used here without changes.
2. The module 'Sound' is extended to optionally allow the final sound output to be redirected to an MP3 file with a configurable bit rate, rather than to a sound card or modem.
3. A new module 'Answer' is developed with the following capabilities:
 - a. Translation of OMA response box descriptions to the XML scheme of the "Generic Java response box applet" (see below)
 - b. Communication with a Proxy-Web Service (see below) to exchange XML data describing different commands using a TCP/Socket connection.

The external components "Generic Java response box applet" as user interface and the "Proxy Web Service" for 'translating' the OMA communication to Web Service communication are described in the following chapters.

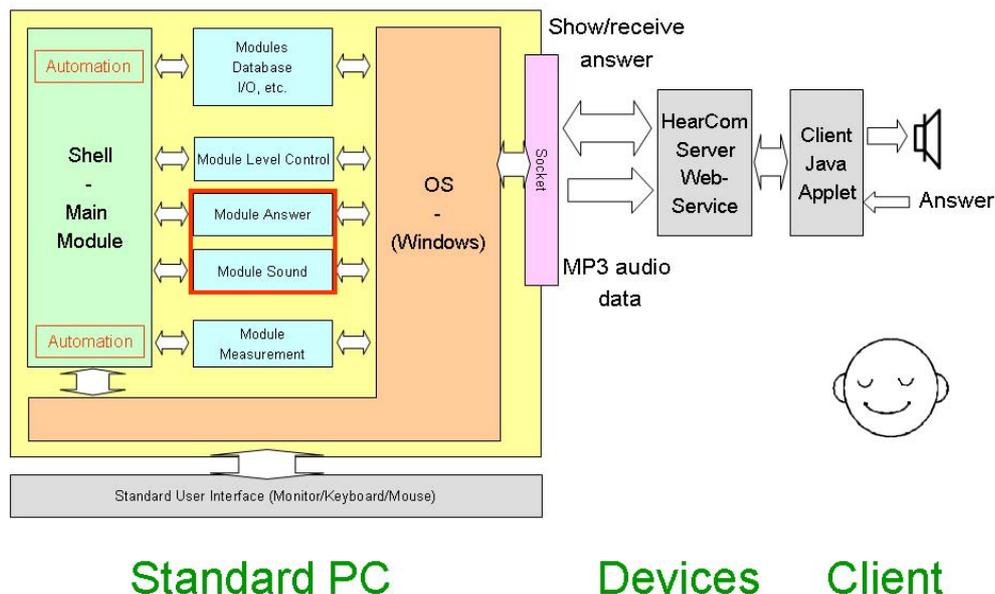


Fig. 4: OMA adaptations for internet use

4.2 Generic Java response box applet

The user interface and audio output for the user of the internet test is implemented as a generic Java applet and may therefore be used with any browser that is capable of Java 1.3 or higher. The applet has the following main features:

1. Communication with a Web Service on the HearCom portal to receive interface description and other commands and to send user responses (see below).
2. Highly flexible user interface. An XML scheme is used to describe multiple screen pages each containing a variable number of so called 'Units'. Each of these units is variable in size, position, color, font, caption and 'behaviour', where behaviour describes the functionality of a unit, e.g. if it is a selectable button or a simple text field.
3. Command interface to set and retrieve the state of such units (e.g. if a button is/was pressed)
4. Support for Session-IDs (set by Web Service to distinguish different simultaneous connected clients)
5. Playback of MP3 files over the internet including the following control features:
 - a. Start playback

- b. Stop playback
- c. 'Synchronous playback': automatic enable all selectable units after playback is complete (e.g. enable user interaction only after a stimulus has been presented completely)

The complete description of the "Generic Java response box applet" can be found in the separate manual "AppletManual.pdf". Some screenshots of the running applet in different configurations can be found in the appendix.

This generic Java response box applet is designed as 'HearCom-response-box-applet' to be used for all audiological tests implemented on the HearCom portal (where applicable). This allows end users and professionals to perform multiple tests without the need to load multiple test interfaces, and lets the user have the same 'look-and-feel' for all HearCom-tests.

4.3 Proxy Web Service for the HearCom portal

The purpose of the Proxy Web Service is to receive and route messages from the generic Java response box applet, running on the end users computer, to the server that runs the measurement. This allows running the measurement procedure on a different server than the web server itself and allows the communication to be implemented on OMA using a TCP/Socket connection. A description of the Proxy-Web Service for the HearCom portal can be found in the separate manual "ProxyManual.pdf".

5 Listening tests of MP3 coding for internet testing

For internet based listening tests, it is crucial to know the optimal bit rate of the (MP3-) coded signals. On the one hand the bit rate must be high enough to provide sufficient signal quality for the tests; on the other hand the bit rate must not be higher than needed to save bandwidth.

5.1 MP3 test: Procedure

To investigate the optimal bit rate for the internet based digit-triplets test, we used a 3-alternative forced-choice (3-AFC) procedure with ten typical examples of digit-triplets in German. Similar to the original German digit-triplets test these ten digit-triplets were built using a proclamation "the digits", followed by three different, randomly chosen digits ranging from 0 to 10 excluding digit 7 (only monosyllabic digits were used). These signals were mixed with the corresponding noise at signal-to-noise ratios (SNR) of -3 and +3dB and after which they were coded with the BladeEnc MP3-encoder version 0.94.2, which is freely available under the GNU LGPL (lesser general public license) with four bit rates: 64, 128, 192, and 256

kbps. The original (not coded) signal was also included in the experiment. Therefore, 5 bit rate conditions * 10 different digit-triplets = 50 trials were tested in the experiment. All sound processing including the decoding of the MP3-signals was done prior the 3-AFC tests (“offline”).

In the 3-AFC procedure, three test signals were presented per trial at most comfortable loudness level MCL (individually chosen for every subject according to hearing loss to assure that the noise was audible). Two of the three test signals were the original, not coded signal and the third was the target signal which was coded and decoded as described above. The order of the 50 trials and the order of the three test signals within a trial were chosen randomly. The task of the subjects was to detect which of the three signals was different from both others. In other words, they had to detect the coded and decoded signal, but this was not made explicit in the instructions given to the subjects.

5.2 MP3 test: Subjects

Six normal-hearing subjects (NH) and four hearing-impaired (HI) subjects participated in the measurements. The hearing-impaired subjects showed slight to medium hearing losses (Fig. 5).

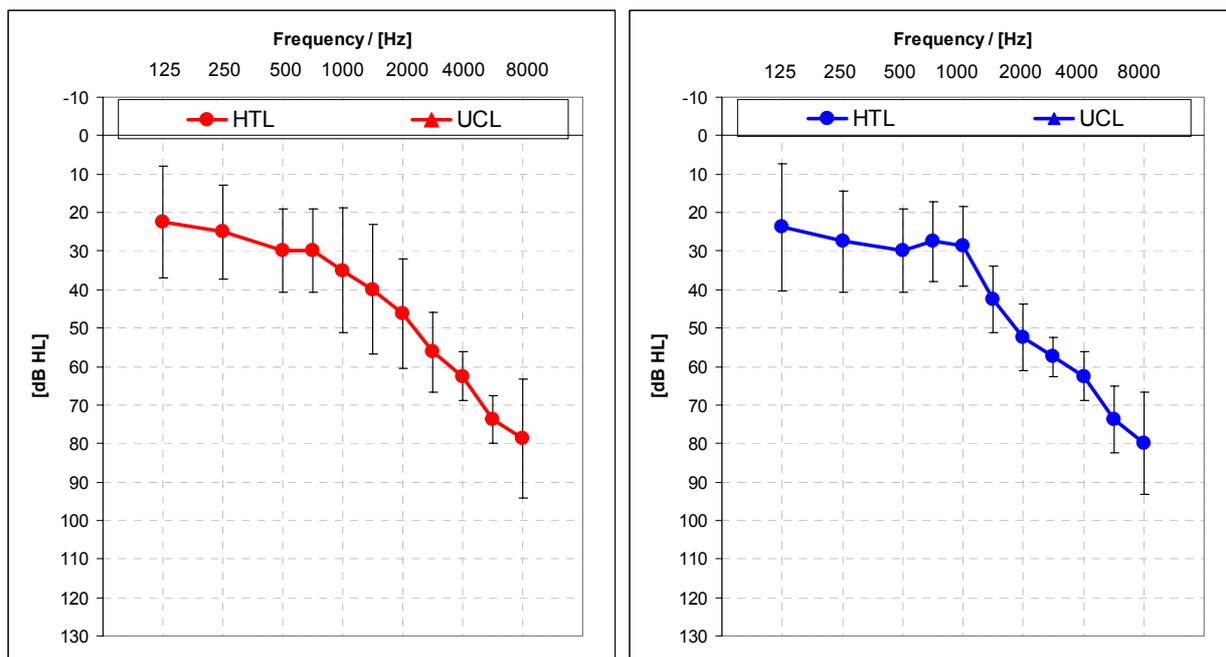


Fig. 5: Mean audiograms and standard deviations of the hearing-impaired subjects. Left panel (red): right ears, right panel (blue): left ears

5.3 MP3 test: Results

The 3-AFC measurement results are shown in Fig. 6 where d' (d-prime) according to Hacker and Ratcliff (1979) is plotted against the different bi-

trates. d' is the standard deviation of the Gaussian chance function. It is used in terms of a discriminability index and therefore is a measure of the strength of the signal according to Green and Swets (1988). Hence, the percent correct results of the 3-AFC measurement were transferred to d' taking the probability of guessing into account (see Lyzenga 1997).

In Fig. 6 d' is used for classifying the ratings of different bitrates: A d' of zero means that the subject was guessing (had not a clue which of the signals was the coded one). A d' of one usually is considered as significance threshold, therefore values below one indicate that the task was hard for the subjects and they could not reliably detect differences between the original and the coded versions. Values exceeding one show that the subjects were able to differentiate between the two presented signals. d' -values exceeding two are interpreted to be differentiated very easily.

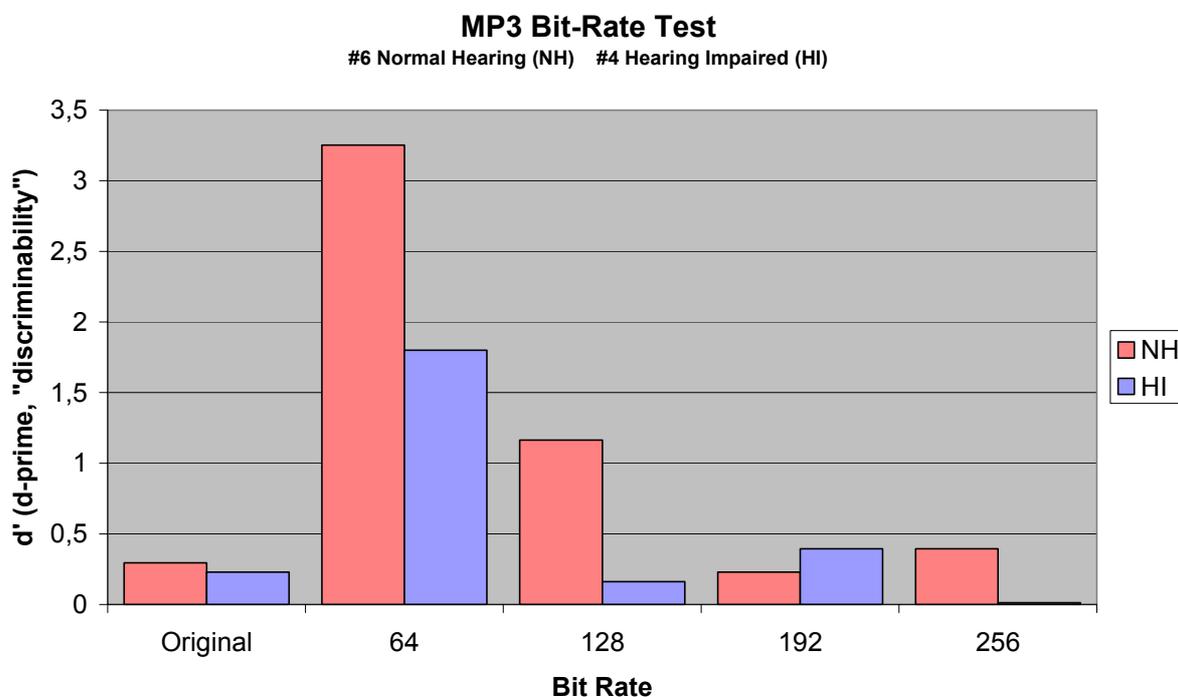


Fig. 6: Influence of bit rate on differentiability of the signals for both conditions: SNR -3dB and +3dB accumulated

Thus Fig. 6 shows that all normal-hearing subjects could correctly detect signals coded with bitrates of 64 kbps. The coding was obvious since the noises used for masking were influenced significantly by the coding-procedure. Although the hearing-impaired people were less accurate, they were also able to detect signals with bitrates of 64 kbps. (Only one out of the four subjects could not detect the 64 kbps-coded signals and therefore blurred the accumulated result for the 64 kbps bit rate.) The hearing-impaired subjects were not able to significantly detect any signals which were coded with bitrates higher than 64 kbps. The normal-hearing sub-

jects managed to detect the signals with a bit rate of 128 kbps, but not for higher bit rates.

Since no significant differences between signals with SNR values of -3dB and +3dB were found, the data is accumulated in Fig. 6.

5.4 MP3 test: Conclusions

These results imply using a bit rate of 192 kbps for the internet implementation of the digit-triplets test, since for this bit rate no differences can be heard by normal-hearing and hearing-impaired listeners. Because there is only a small effect for signals with bit rates of 128 kbps and bandwidth should be saved as much as possible, it may be worthwhile to check if such a coding will affect the intelligibility of the digits themselves. Therefore speech intelligibility measurements with 128 kbps signals will be performed with the digit-triplets test. If intelligibility is not affected when decreasing the bit rate to 128 kbps, it is possible to save a further one third of the bandwidth without losing any information in the screening tests. Therefore the decision about bit rate for the internet screening test will be made after the intelligibility measurements.

6 Dissemination and Exploitation

Once the screening test by internet is implemented and successfully tested, it will be hosted on the internet by the following institutions:

- HearCom portal to be hosted by DE-FHG (Fraunhofer Gesellschaft) during the runtime of the HearCom project (internet pages for the general public in all available languages)
- HearCom partner organisations that were involved in producing and establishing the test will be entitled to use the respective implementation embedded in their own institutions' web pages (i. e., Kompetenzzentrum HörTech (DE-HTCH) in German, Royal National Institute for the Deaf (UK-RNID) in English)
- Other country-specific and international non-profit-organisations that are eligible for a licence to use the test for their own proposes from HearCom (see below).

In order to make the test known to the public and to potential organisations, that might want to obtain a licence for offering the test themselves, the following measures will be taken:

- Dissemination via the internet: Hints and links to the test will be given by the HearCom portal, by all HearCom partner institutions (incl. EFAS, the European Federation of Audiological Societies), as well as national audiological societies and consumer organisations representing

hearing-impaired persons (such as, e.g., the Deutsche Schwerhörigenbund in Germany)

- In future public campaigns for the telephone screening test the internet version will also be advertised.
- Separate publicity campaigns will be performed by those institutions that will acquire a licence for the test to integrate it into their individual own web pages (such as, e. g., the National Acoustic Laboratories (NAL) in Australia, the Hear-It information web site for hearing-impaired listeners and other non-profit organisations).

The business model for generating revenue from the test is as follows:

- In the initial phase, the test will be offered free of charge to the internet users by the respective HearCom partners. This will promote the public access to the test and its credibility as being developed by an independent, EU-financed consortium.
- As soon as a “pay-per-use-model” is easily available, it will be adapted and incorporated into the way the test is provided to the individual user. It is expected that a very small amount of money (i.e., a few cents) will be collected for the usage of the test, so that this approach is only worthwhile if a large number of users will regularly access the test.
- Within a time range of a few years, the more sophisticated speech-intelligibility tests in noise developed and marketed by HearCom-partners (such as, e.g., the OMA marketed by HörTech and partner organizations) will be commercially available to professional audiologists. These audiological specialists will need to provide evidence that they are especially trained and able to perform speech intelligibility tests in noise and to counsel the patient in a competent way. A possible business model will direct potential costumers (i. e., test users that “fail” the screening test) to these especially equipped and trained audiological specialists. Hence revenue will be generated indirectly from the screening test by supporting the sales of OMA and/or by collecting a fee from those professionals who register in order to be listed in the referral directory of the internet screening test.

In order to comply with ethical rules and regulations, a licence to use the test as a public test (both for the internet and the telephone version) will only be granted to certain institutions under the following conditions:

- Non-profit organization: It should be warranted that the test shall not be connected to any other commercial product (such as, e. g., a certain brand of hearing aids).
- Non-discriminative referral model: The persons that fail the test should be counselled / referred to professional help in a non-discriminative

way. I. e., an unbiased referral should be provided to health-care professionals from a comparatively wide range of possible choices. With other words, the screening test shall not be used by a specific professional group to gain market against any other professional group on the health care market.

- Proper reference to HearCom: Institutions can, for example, directly provide a link to the appropriate HearCom web sites with the implementation of the (multi language) screening test. Such a simple link and/or a hosting of the original HearCom sites (with a strong reference to the HearCom project) are free of charge. However, institutions and organisations are requested to pay larger licence fees if less proper reference is made to HearCom.

7 Conclusions

This report describes the main features of the internet implementation of the digit-triplets test that was chosen as screening tests for communication skills. First measurements to decide on the MP3 quality are described in this report. According to these measurements the bit rates 192 and 128 kbps were preselected to perform further speech intelligibility measurements. The final selection will use the lowest bit rate that does not influence intelligibility.

The final report and demonstrator of the internet screening test will include the digit-triplets test in all languages that are available as evaluated versions at that time. At the moment the test is already available as evaluated test in three languages (Dutch, German, and Swedish).

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9 Appendix

9.1 Example screenshots of the Generic Java response box applet

This section shows a few screenshots of the generic Java response box applet configured for different measurement tasks. The colours, sizes and fonts are examples and can be customized.

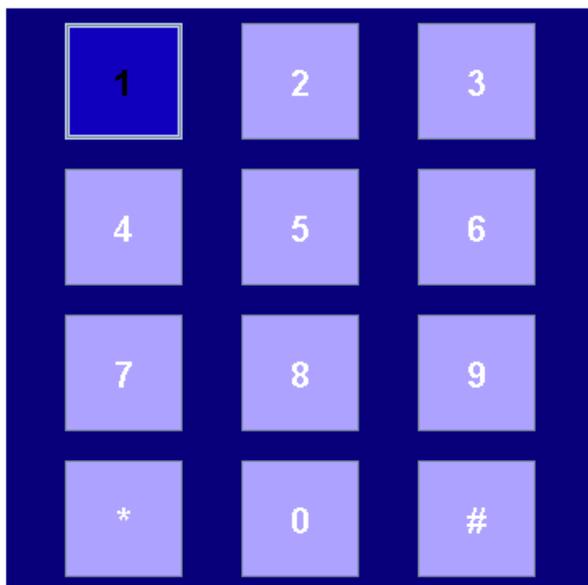


Fig. 7: Applet configured for the digit-triplets test

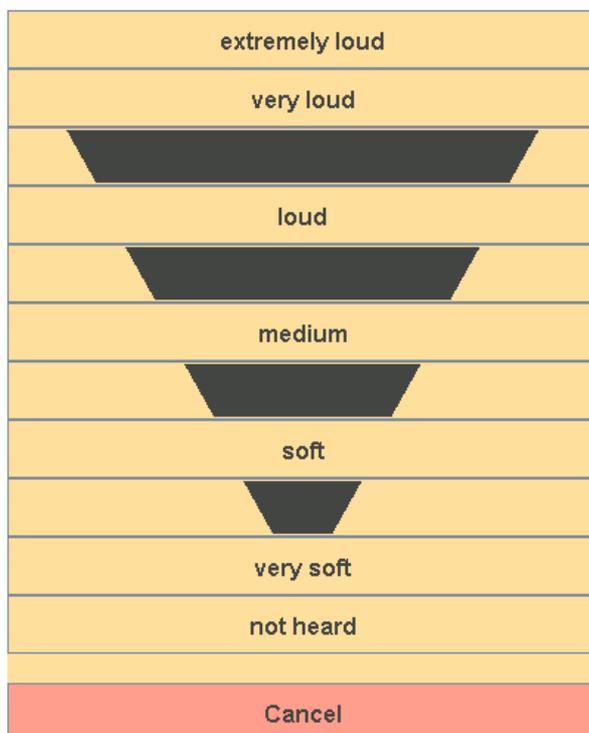


Fig. 8: Applet configured for categorical loudness scaling (ACALOS)

Britta	bekommt	zwei	alte	Autos
Doris	gewann	drei	große	Bilder
Kerstin	gibt	vier	grüne	Blumen
Nina	hat	fünf	kleine	Dosen
Peter	kauft	sieben	nasse	Messer
Stefan	malt	acht	rote	Ringe
Tanja	nahm	neun	schöne	Schuhe
Thomas	schenkt	elf	schwere	Sessel
Ulrich	sieht	zwölf	teure	Steine
Wolfgang	verleiht	achtzehn	weiße	Tassen
?	?	?	?	?
Nina	nahm	fünf	große	
Ok				
Cancel				
trial information				

Fig. 9: Applet configured for the Oldenburg sentence test