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Table of Contents

List of Figures

List of Tables

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Pre-Amble

One of the key aims of the HearCom project is to develop a number of hearing-screening tests. These tests will be made available to the general public in several European countries via the Internet and other means. An important aspect of communication is the ability to localise sound sources. This skill is involved in quickly establishing the direction from which dangers approach, or, less dramatically, from which information is arriving so that the attention can be directed at correct location. Such skills can be measured using localisation tests that directly estimate the localisation capabilities of listeners. The present screening test is a localisation test that is made publicly available via the Internet. It is an adaptation of the minimum-audible angle (MAA) test as described in D-2-1 for the auditory profile. The MAA test in the auditory profile uses stimuli that have been processed using head-related transfer functions for presentation over special headphones, whereas the present, screening, version only requires two computer speakers for the signal presentation. This makes it much more suitable for use by the general public via the Internet.

The current deliverable describes the test, preliminary normalisation results, and the way the test is implemented for use via the Internet.

1 Executive Summary

A fast and simple screening test for localisation is described along with the way it was implemented and made available via the Internet. The present localisation test is an adaptation of a minimum-audible angle test that has often been used in laboratories around the world. The adaptations included transformation of the test stimuli to versions that are suitable for presentation via the Internet (MP3 coding) over two simple computer speakers (cross-talk cancellation techniques). A laboratory experiment is described in which the feasibility of this transformation was tested against results from the literature. The implementation is based on a Multi-Client - Windows measurement application and the “HearCom Generic Java response box applet” and “Proxy Web Service” described in deliverable D-1-4. Eventually, the test will be provided by non-profit organisations in several European countries. This screening test, along with the other screening tests in the HearCom project, will be used to promote better hearing services and promote public awareness of hearing problems and the solutions available for addressing those problems.

2 Introduction

The main aim of work package 1 is to make a set of self-screening tests available to the general public via telephone and Internet. Self-screen tests 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 specialised equipment 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 specialised audiological centre)
- Allow the provider to make a statistic about hearing ability in internet users and in specialised user groups
- To increase public awareness of hearing impairment and treatment options for patients with a hearing problem.

The current test is one of the self-screening tests made available via the Internet. It is one of two test for spatial hearing included in the set of tests. One such a localisation test has a virtual environment that can be controlled by the user, who has to locate a ringing telephone out of a set of six possible telephones (the Auditory Virtual Environment or AVE test). The six telephones are arrayed in a circle around the listener is a virtual environment, in which the listener can control the direction in which he or she is looking. The present test, on the other hand, is a minimum-audible angle (MAA) test where listeners have to determine whether a sound travels form the left to the right or the other way round. The present test version uses sound presentation via normal computer speakers, to make it easily accessible for a large number of users.

In the MAA test, two noise bursts are presented from a different speaker very rapidly after each other. This produces a “motion” in the direction of the speaker that produced the first sound towards the speaker that produced the second sound. Using the 2-speaker presentation scheme with the cross-talk cancellation, the apparent sound source positions can be controlled in small steps from an angle of 30 degrees to the left to 30 degrees to the right. The listener will perceive the sounds to originate from chosen directions. However, for listeners with asymmetric hearing, a timbre difference will also exist for sounds coming from the left as compared to those coming from the right. This creates an extra cue, not related to localisation, with which the task can be performed. Therefore, the test will only be reliable for listeners with symmetric hearing (or symmetric hearing losses). This shortcoming might be resolved with the alternative localisation test in the test set, the AVE test. Preliminary investigations have shown that this test is particularly hard for listeners with asymmetric hearing. This may mean that a listener will have to achieve a good score on both tests in order to receive affirmation of good localisation abilities. For this reason, and others such as efficiency, it has been decided that these two Internet localisation tests will be evaluated in the same experiment for the same groups of normally-hearing and hearing-impaired listeners.

Internet implementations of screening tests yield a number of advantages:

- Targeted information can be transferred efficiently to the user on the individual requests
- The possibility of extended interfacing to obtain more additional information from the user (such as, for example, age, gender, or any previous hearing problems) in a structured way
- World-wide accessibility.

On the other hand, Internet tests have the following disadvantages:

- Audio-presentation mode is not as standardised (usage of MP3 coding)
- Variable transmission delay between provider and end user may distort the audio signal
- The target population (typically aged citizens) may only have a limited familiarity with using the Internet
- 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.

3 Screening test for the minimum-audible angle

A paradigm for estimating the localisation skills of listeners in term of their minimum-audible angle was developed by Mills (1958). It has since been used extensively in both the horizontal and the vertical plane. For the present screening test we are only interested in de horizontal plane. In laboratory set-ups, the minimum-audible angle, or MAA, for positions straight in front of the listener is usually found to lie between one and two degrees, depending on the circumstances, e.g. Hartmann and Rakerd, (1989), and Grantham et. al. (2003). In these studies average values of about 1.5° were reported for the MAA in the horizontal plane.

Two broad-band noise stimuli are presented consecutively from different directions, symmetrically spaced on different sides of the straight-ahead direction (as sound localisation acuity is highest there). 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, moving either from the left to right or in the opposite direction. The order, i.e. direction, of the sounds is randomised. The present version of the test has been adapted for the Internet. Since most people who have a computer have a set of speakers connected to the computer, we have chosen for using such sets of speakers as the means for the sound presentations. The various positions in space, produced using different speaker positions in the laboratory versions, have now been created using a cross-talk cancellation technique. When the speakers are positioned correctly, listeners should be able to observe sound-presentation angles from 32° the left to 32° to the right. In the Web page that holds the start of the test, ample pictures and examples are given to enable users to position their speakers correctly.

The cross-talk cancellation technique used to construct the stimuli is based on ear-and-loudspeaker position-related filtering of the stimuli (Tavan et. al., 2005). In this technique, the four head-related transfer functions that relate the two ears to the two speakers are inversed using a fast-deconvolution method to create the cross-talk cancellation filters. For different spectral content of the stimuli, these filters function best for different speaker positions. For the present stimuli, a mid-frequency telephone-type range was chosen (300 to 3400 Hz), for which the filters function optimally for loudspeakers that are about 30° apart at -15° and + 15° from the centre line (Takeuchi and Nelson, 2002). Using band-limited stimuli prevents problems with so called “ringing frequencies” for virtual source positions that coincide with a real speaker position.

To make the starting point of the task easy for the listener, the test starts at a large angle (plus and minus 32°) between the two sound stimuli. In subsequent trials, the angle will be decreased after two correct responses and it will be increased after one incorrect response, resulting in a two-down, one-up, adaptive procedure. In this way, a threshold value is obtained for 70.7% correct. In order to quickly reach the approximate threshold value, the step size is large (4°) for the first four reversals. After four reversals the step size is decreased to 2°, and after two more reversals it is decreased to a final value of 1°. The test will continue for eight reversals after this step size is reached. The MAA value is the average over those last eight reversals. Users are directed to result pages that show their result in one of the categories: Good, Sufficient, and Poor. The boundaries between these categories were set using the results from the listening tests described in the next section.

As listeners at home are not used to performing such an adaptive procedure, a lot of attention to the peculiarities of performing a test with such a method are described in the Web pages concerning this localisation test. Attention is given to the fact that it is especially important to try hard to prevent mistakes at the start of the test when the step size is still large, while for the rest of the test, which will take place near the threshold, a lot of guessing will have to be done. The results are checked for consistency using the standard deviation (SD) of the average of the last eight reversals (the MAA). When a large SD is found, the result page is adapted and the users are given the advice to read the instructions and tips once more very carefully, and to try again. This gives users the chance to acquaint themselves with the procedure. In order to prevent learning effects in the task itself, no correct/incorrect feedback is given after the individual trials, only the end results are given.

A further adaptation for providing the test via the Internet was using MP3 coding for the stimuli. This reduces the size of the stimulus files considerably and thus reduces the chance of glitches in the sound reproduction. In this way the test will be also be usable for users with relatively slow Internet connections. The possible effects, of using such

MP3 coding, on the outcome of the localisation test are investigated in the next section.

The present implementation of the test and the structure of the Internet service (see below) are ready for multi-language execution. The language in which the test is executed can be set by the web page that starts the test. At the moment the test only runs in English, but when the English web pages about the test are translated into Dutch, German, and Swedish, the test can be executed in those languages.

4 Listening test of MP3 coding for sound presentation via the Internet

To check for any possible detrimental effects of using MP3-coded stimuli in the localisation test, we performed a laboratory experiment using an example version of the proposed set-up. The functions of the server and the local web browser were running on the same machine, using a TomCat™ Internet emulation. So, any effects of delay and possible glitches were not included in this investigation, we were purely looking at the effects of the MP3 coding of the stimuli.

4.1 MP3 test: Procedure

The stimuli were transformed from Windows Wav files to MP3 using three different, fixed, bit rates: 128, 192, and 256 Kb/s. Twelve subjects performed two blocks, a test and a retest block. Each block consisted of three tests, one for each bit rate. The six possible orders of the three bit rates were all used for two groups of six subjects, while the order of the bit rates per subject was the same for the test and the retest blocks. The subjects performed the test and retest either on the same day or on consecutive days. The test was executed in the way described in the previous chapter.

4.2 MP3 test: Subjects

Twelve normally-hearing subjects participated in the experiment, two for each possible order of conditions. The ages of the subjects ranged from 21 to 58 years, with an average age of 32 (SD = 11). Most of these listeners were experienced in doing psychoacoustic measurements. About five of the group were relatively new to such experiments, but their results did not differ noticeably from those of the experienced listeners.

Table 1. *Average results of the listening experiments*

Bit rate (Kb/s)	Average (°)	SD (°)	Average Test-retest difference (°)	SD (°)
128	1.72	0.70	-0.25	0.97
192	1.66	0.76	+0.12	1.03
256	1.42	0.86	-0.19	0.54

4.3 MP3 test: Results

The average results of the listening test are shown in Table 1. They show a trend for the average score to decrease (i.e. improve) with better MP3 quality. However, a repeated measures ANOVA (with the different subjects as the repeats) with factors MP3-quality X test/retest showed neither significant main effects for MP3 quality ($p = 0.15$), nor for test/retest ($p = 0.55$). Overall, the average score was 1.6° with an SD of 0.8°. The overall test/retest reliability was 0.6°. So, the trend in the data of better results for better MP3 quality (at best 0.3°) is small in comparison to the test-retest reliability.

The observed average overall score is remarkably close to the average score for comparable conditions in laboratory experiments as found in the literature: 1.5°. This shows that the application of the MP3 coding had no detrimental effects on the localisation cue that was used by the listeners. This leads us to believe that this cue is related to the time differences between the left and right stimuli, as the overall sound quality of the stimuli, in particular their timbre, was somewhat affected by the MP3 coding. The time differences in the left and right stimuli lead to the interaural time differences experienced by the listeners. This is known to be a good cue for localisation. In addition, the time differences between the left and right channels of a stereo signal are robust to MP3 coding as that coding does not alter the timing of signals.

Since there was no significant difference for the three MP3 bit rates or qualities, we chose the smallest bit rate for the stimuli in the Internet test: 128 Kb/s. For this bit rate the average score was about 1.7° with a test/retest reliability of 0.7°. The result boundary of the Internet test between the categories Good and Sufficient was chosen at a value just over the average plus two times the SD for this bit rate: 3.5°. The Sufficient to Poor boundary was set at 5.0°, which is just over four times the SD above the average.

4.4 MP3 test: Conclusions

Though there was a trend of better results for better MP3 quality, the listening experiment showed no significant differences between conditions using stimuli with different MP3 bit rates (qualities). Therefore, it was decided to use the most efficient bit rate used in the test: 128 Kb/s.

The overall average MAA found in the listening test was (1.6°) is very close to the value for laboratory tests in the literature (1.5°). Therefore, it can be concluded that the MP3 coding does not affect the localisation cue used by the listeners.

The finding that the localisation cue was hardly affected by the MP3 coding indicates that this cue may well be the time differences between the left and right stimuli.

Figure 1. *Example of applet response box*

5 Technical structure of Internet screening test

The technical structure of the MAA internet screening test is divided into three functional parts:

5.1 Generic Java response box applet

The "Generic Java response box applet" is used as user interface (response registration) and audio presentation. It is described in detail in deliverable D-1-4, Chapter 4.2 and appendices. The applet communicates with the "Proxy Web Service" (see below) to receive instructions from the test application and sends user input to it.

For the MAA test the applet is configured to play an audio stimulus while presenting the interface shown below to the user. After playback has finished, the buttons are enabled (see Figure 1) and, after clicking one of the buttons, the response of the user is transferred to the server. The applet then waits for new instructions from the server containing the next stimulus condition or the instruction to quit to a result or error page after finishing the test or on errors respectively.

5.2 Proxy Web Service for the HearCom portal

The “Proxy Web Service” is used as a data forwarder on the HearCom portal. It is described in detail in deliverable D-1-4, Chapter 4.3 and appendices. It forwards data between the applet (Web Service connection) and the Windows server (TCP connection) where the test application is running.

5.3 Multi-Client-MAA-Windows-Application

The test procedure is implemented as a Windows application with Borland Delphi. The application acts as a TCP-server listening to a particular port for incoming client connections established by the “Proxy Web Service”. It is implemented as a scalable system supporting an unlimited number of parallel measurement procedures, so called “sessions”.

On each incoming valid initialisation message, a new “session” with a unique ID is created and a complete measurement task is performed:

- A unique session ID is created. This session ID is resent by the applet in all its later requests. These resent IDs are used at the server side on incoming requests (non-initialising requests) to determine to which session a response belongs. Requests from unknown session (or timed out) IDs are rejected.

- XML scheme containing the page description and audio stimulus URL is sent (as answer to the applets request) to the applet. The stimulus files are stored on the HearCom Web Server in order to allow the applet to access them (Java applet restriction).

- The session waits for a new request by the applet containing the client’s response.

- If no new request occurs within a configurable timeout period, the session is closed.

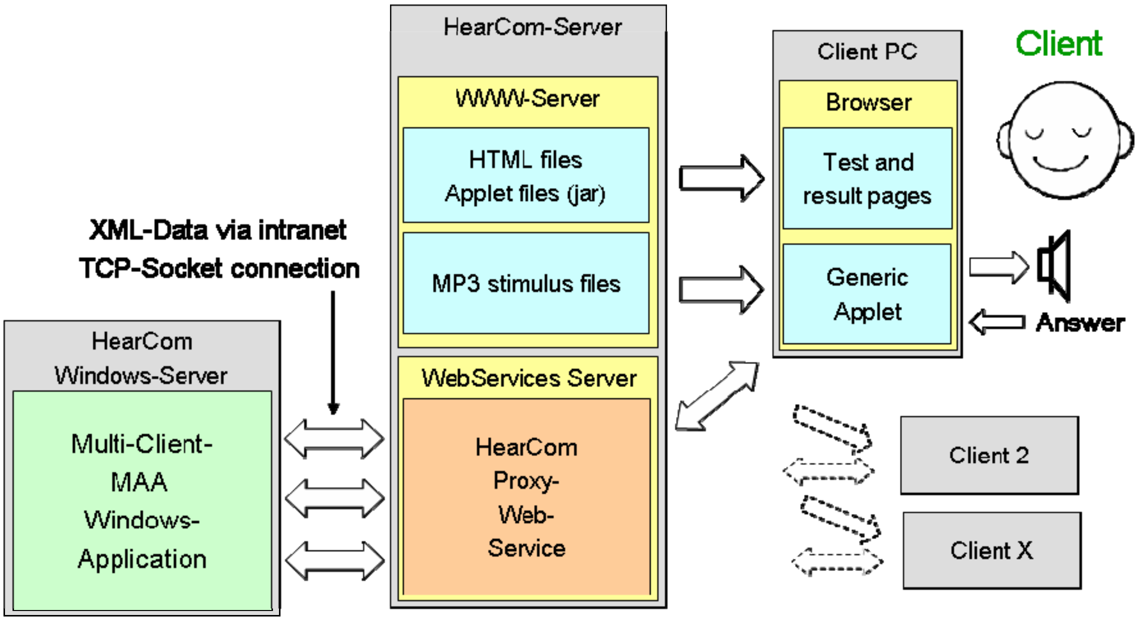
- Otherwise the response is evaluated (answer correct/wrong) and the next corresponding stimulus URL is generated and sent back to the applet.

- This procedure is repeated until all trials are performed. A final answer is sent to the applet containing the URL of a result page depending on the performance of the client.

- Data are stored and session is closed.

The system architecture of the MAA internet test containing all three functional parts is shown in figure 2.

Figure 2. *The system architecture of the MAA internet test*



For detailed information on the XML scheme and communication protocol between the applet and the measurement application please refer to the applet documentation and D-1-4.

6 Dissemination and Exploitation

6.1 Internet hosting

Once the localisation screening test by Internet is successfully validated, it will be hosted on the internet by the following institutions:

• HearCom portal to be hosted by DE-FIT (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, VU University Medical Center (NL-VUMC) in Dutch).

• 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).

6.2 Dissemination

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, and the Nederlandse Vereniging voor Slechthorenden in the Netherlands)

• In future public campaigns for the telephone screening test the internet screening tests 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 a., e. g., the National Acoustic Laboratories (NAL) in Australia, the Hear-It information web site for hearing-impaired listeners and other non-profit organisations).

6.3 Business model

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, for the benefit of those involved in providing the test, so that this approach is only worthwhile if a large number of users will regularly access the test.

6.4 Ethical and legal issues

The present test is not making a medical diagnosis. It is a self-screening test that members of the general public can use to check their hearing abilities. When the outcome of a test is negative, the users are advised to seek professional help when they feel they should acquire a real diagnosis.

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 organisation: 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. In other words, the screening test shall not be used by a specific professional group to gain market share 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 explicit reference is made to HearCom.

7 Conclusions

This report describes the main features of the Internet implementation of the minimum-audible angle test that was chosen as screening tests for hearing and communication skills. A listening experiment was used to decide on the MP3 quality needed. According to the results of these measurements the bit rate 128 Kb/s was selected. The implementation of the Internet screening test is in English, but it is ready for execution in four languages (Dutch, German, Swedish, and English).

8 Literature

Grantham, D.W., Hornsby, B.W.Y., Erpenbeck, E.A. (2003) “Auditory spatial resolution in horizontal, vertical, and diagonal planes”, J. Acoust. Soc. Am. 114, pp. 1009-1021.

HearCom Deliverable D-1-4. (2006). First version on Internet screening tests in three languages.

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

Häusler, R., Colburn, S., Marr, E. (1983). “Sound localization in subjects with impaired hearing: Spatial-discrimination and interaural-discrimination tests” Acta Oto-Laryngol. Supplement 400, pp 1-62.

Hartmann, W.M., Rakerd, B. (1989). “On the minimum audible angle – A decision theory approach” J. Acoust. Soc. Am. 85, pp. 2031-2041.

Mills, A.W. (1958). “On the minimum audible angle” J. Acoust. Soc. Am. 30, pp. 237-246.

Takeuchi, T., and Nelson, P.A., (2002). “Optimal source distribution for binaural synthesis over loudspeakers,” J. Acoust. Soc. Am. 112, pp. 2786-2797.

Tavan, D., Mannerheim, P. and Nelson, P.A. (2005). “An investigation of the design and implementation of cross talk cancellation filters for virtual acoustic imaging,” ISVR Technical Memorandum 951.