Application of Binaural Technology in an Adaptive Auditory Speech Test for Children

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Introduction

A screening procedure to identify hearing loss in children was developed by using a speech test under various spatial noise conditions.

An Adaptive Auditory Speech Test (AAST) using spatial noise as part of a possible screening procedure for Auditory Processing Disorders (APD) was carried out. The AAST was developed to determine the Speech Recognition Threshold (SRT) in a fast and reliable way under quiet and noisy conditions for children aged 3 to 4 years or older. AAST can be used for adults as well.

In the present study the existing basic version of AAST was extended by adding a Two-Talker-Conversational-Noise (two children talking to each other) and a Multi-Talker Noise (4 persons simultaneously reading a newspaper text aloud). Tests were carried out using two different spatial conditions: with the signal (AAST test words) and noise coming from the same and/or different positions in the horizontal plane.

Auditory Processing Disorders (APD)

Auditory Processing Disorder (APD) is a dysfunction in the information processing in the auditory pathway and in the brain. Individuals with APD usually have a normal peripheral hearing ability.

Auditory processing disorders may include a variety of symptoms, demonstrating problems in

- selection of signals in noise
- phoneme discrimination
- sound localization and lateralization
- paying attention to and remembering information presented orally (presented in multiple modalities)
- listening to fast speech

AAST – Adaptive Auditory Speech Test

The Adaptive Auditory Speech Test (AAST) assesses the Speech Recognition Threshold (SRT) and was designed especially for young children. The procedure is minimally dependent on the person's vocabulary. Only 6 easy words are used and the test subject has to point at a picture to identify the word. The test is already established in many languages. In German, Dutch, and English, for example, the test uses spondee words (such as airplane, toothbrush, Eisbär, Fussball etc.). These "double words" have a redundancy comparable with short everyday sentences also containing only two key words. An automatic adaptive procedure is used to evaluate the SRT.

Because of the easy closed set paradigm with picture pointing as a response task, the introduction time is short and learning effects correspondingly fast and small. Average testing time is typically 2 minutes per condition. Standard deviation of SRT in noise measurements is as low as 2 dB for children (Coninx [2]). The steepness of psychometric curves for speech-in-noise measurements is 14 %/dB. Figure 1 shows the graphical interface of the AAST test.

Figure 1: Graphical interface of the AAST test.

First spatial test set-up

In order to test the subject's performance in a lifelike environment the AAST test is extended by adding spatially distributed sound sources. In the first test set-up a simple situation is modeled.

The test signal (a teacher) comes from frontal sound incidence and the two-talker-conversational-noise (in this case German children talking to each other) comes in the first subtest from frontal sound incidence and in the second subtest from 90° in the horizontal plane. Figure 2 shows the test set-up.

The signals were generated using head-related transfer functions which are appropriate for this age group.

Figure 3 shows the differences of the free-field-HRTF for an adult and a 6-year-old in the horizontal plane.

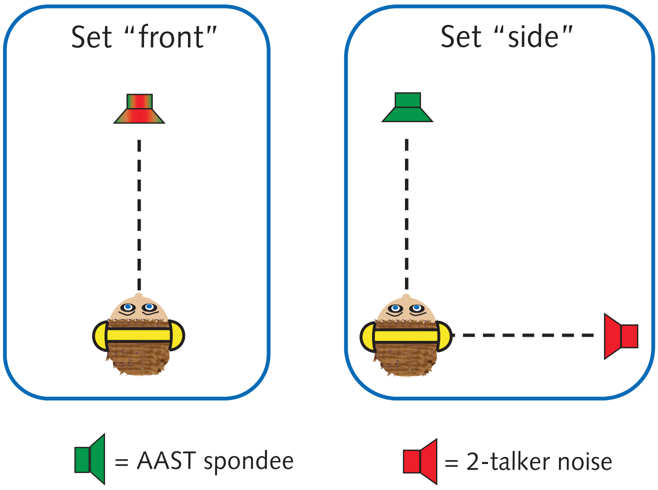

Figure 2: First test set-up. Basic test using spatially distributed sound sources.

The growth dependency of HRTFs was studied in detail in [1]. It became evident that children and adults differ tremendously as far as their respective head-related transfer functions are concerned. Furthermore it turned out that the head-related transfer function of a child cannot be obtained by scaling down the dimensions of an adult head.

Differences in the anatomy of children and adults thus result in different binaural cues. Using inappropriate HRTFs for this test would cause errors in the spatial localization of sound and a correct and lifelike situation could not be modeled. Therefore, the test words and the talker-noise were convolved with the corresponding children HRTFs. The scenarios were presented with the help of headphones in order to make this test easy to handle in all environments.

Tests were performed on location (in the school setting), using a standard notebook system to run the AAST software, an external 24-bit sound soundcard (m-Audio Transit) and Sennheiser HD280pro headphones.

The first test was carried out with N=46 children aged from 6 to 10 years. Children in the test group (N=31) had a suspected APD. Children in the control group (N=15) were normal hearing, i.e. did not have any APD symptoms. For the evaluation, however, 15 children of each group were taken into account.

Figure 4 shows the results of the AAST SNR values. At 0 dB SNR, the noise (two-talker-conversational-noise) and the AAST spondees have the same intensity. The test results show a lower SRT under the „side" condition for both groups (test group = 8 dB, control group = 11.5 dB). A higher standard deviation can be detected in the test group. Subject 1 and 13 (and 7) show higher SRT in both subtests. This leads to the conclusion, that the suspicion of APD could be confirmed for these subjects. In that case further diagnostics in a specialized clinic or institution is required.

The test has proven to be feasible: it works well with children and tests can be carried out on location.

The "two-talker-conversational-noise" signal causes two types of masking effects: acoustical masking and informational masking. The processes related to informational masking were analyzed in this study as well (but not included in this paper). Including informational masking will cause a higher standard deviation. In the second test, informational masking was excluded by using a different type of noise masker.

Second spatial test set-up

The second test set-up differs from the first test in two aspects:

- informational masking is excluded by using a multi-talker noise. As the four speakers are talking simultaneously the contents can not be understood
- this test setup has the advantage that this is not a one-sided (unilateral) test. A limitation to only one direction could yield problems or errors if children are tested with a one-sided or asymmetric hearing loss or auditory processing. Using the previous test setup, the side test would have to be carried out separately for the left and right ear.

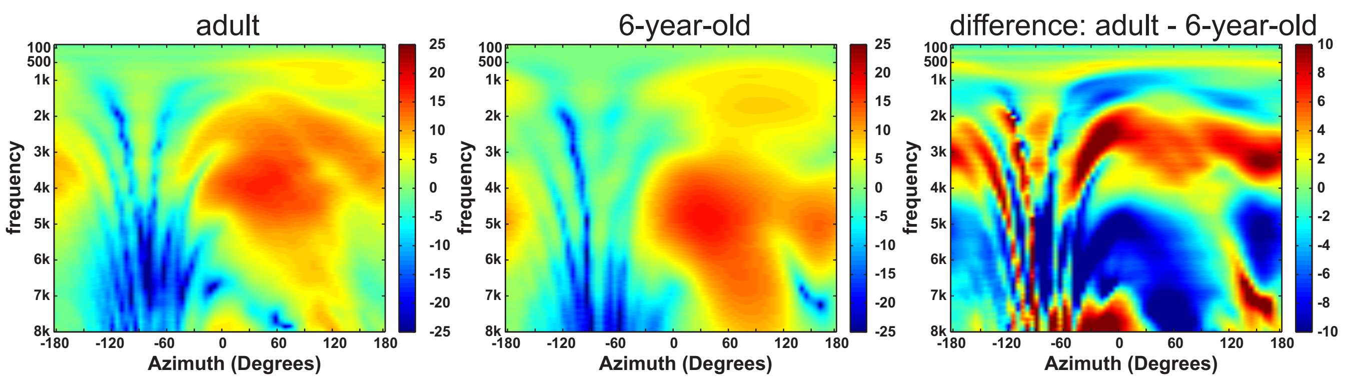

Figure 3: HRTFs in the horizontal plane of an adult and a 6-year-old. The right plot shows the difference of the HRTF between the adult and the 6-year-old (from [1]).

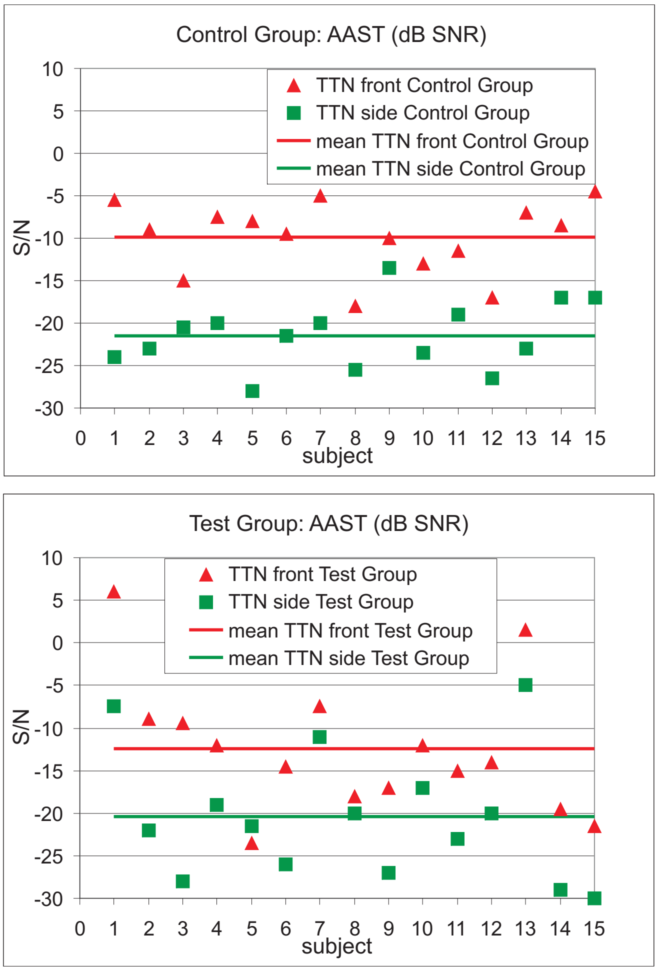

Figure 4: AAST (dB SNR) results of the first test set-up.

A more realistic and lifelike situation was modeled for the second test. Figure 5 shows the two subtests of the test. The “front” subtest consisted of the signal coming from 0° in the horizontal plane and the multi-talker-noise was placed on the left and right-hand side of the signal. The “side” test was now composed of the signal at 0°, half of the noise (2 speakers) on the left and the other half of the noise (2 speakers) on the right-hand side around ± 90°.

The second spatial test set-up was symmetrical and has the advantage that also for subjects with unilateral hearing loss only one test had to be done. In contrast, the first spatial test set-up was asymmetrical; consequently, testing had to be done twice with the noise source on the left and the right-hand side.

The second spatial test set-up saves time not only but also reduces the risk of comparing two consecutive subtests in which the concentration and motivation of the subject might be different which might result in different SRT's.

This test was carried out with 14 test subjects. Six adults (25-58 years) and eight 11-year-old children took part in this test.

Tests were performed on location, using a standard notebook (with AAST software), an external 24-bit sound soundcard (m-Audio Transit) and Sennheiser HD280pro headphones.

The second test was carried out in Poland and a Polish version was used. In this case the multi-talker-noise was Polish, too.

The test leader did not report any problems and the test basically requires no additional instructions. This more complex test set did not pose any problems for the children (and for the adults).

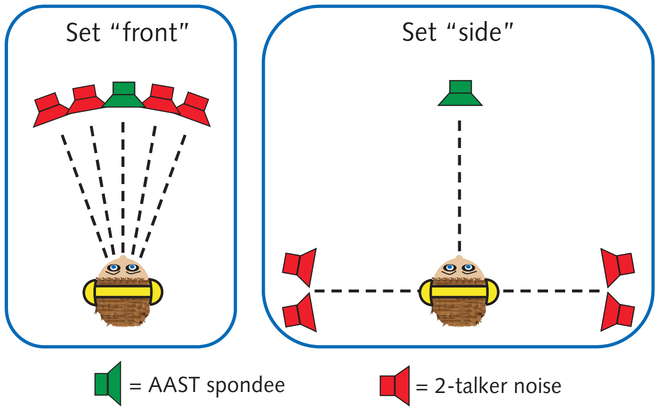

Figure 5: Second test set-up. More lifelike test corresponding to a real classroom/kindergarten situation.

Figure 6 shows the results for the second test set-up including the adults (subjects 1 to 6) and the children (subjects 7 to 14). The children in this test had been positive in a school hearing screening program (on APD) and entered a follow-up diagnosis procedure. Therefore, some of the children may have APD.

Results show that the SRTs for subjects 9, 11, 13 and 14 are higher in both conditions “front” and “side”, indicating problems with acoustical masking. Independent from that, the difference between the two conditions seems to be the same for all subjects: 5.8 dB (with a low standard deviation of 1.3 dB)

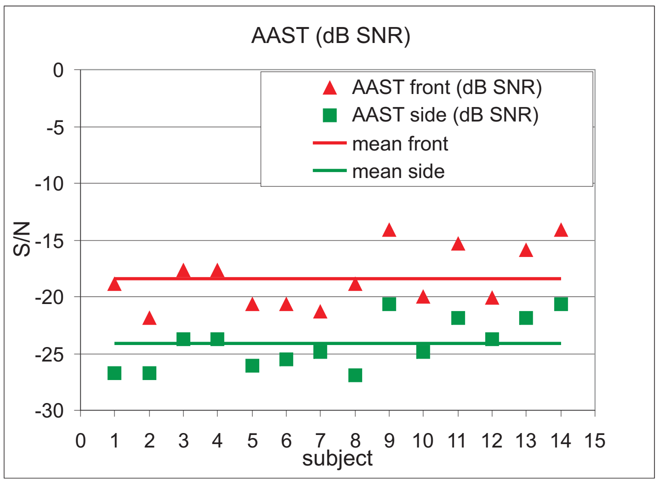

Figure 6: AAST (dB SNR) results of the second test set-up.

Conclusion

The combination of spatial sound sources using binaural technology and the AAST can be used as a screening test for children to detect APD. The spatial test setup has been established using appropriate HRTFs to create a lifelike and correct spatial sound field.

Outlook

In the next phase researchers will have to focus on the application in younger children (4 years) and the possible use of speech-like noises (standardized ICRA noise signals) for cross-lingual comparability.

Also the elderly will be included as a relevant target group with and without hearing loss and in comparison to free sound field presentation to evaluate the benefit of bilateral hearing systems [3].

If this test is carried out with children of different ages, the appropriate HRTF set for this age should be considered for the convolution with the signals and noise. However, subjective listening tests will have to be carried out to proof the relevance for this kind of speech tests.

References

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