Post-print of: P. Odya, A. Czyzewski, A. Sroczynski, and B. Kostek, "A Device for Measuring Auditory Brainstem Responses to Audio," Engineering Brief 485, (2018 October.). http://www.aes.org/e-lib/browse.cfm?elib=19749

A device for measuring auditory brainstem responses to audio

Piotr Odya[1], Andrzej Czyzewski[1], Andrzej Sroczynski[1] and Bozena Kostek[2]

[1] *Gdansk University of Technology, Faculty of ETI, Department of Multimedia Systems, 11/12 Narutowicza Str., 80-233 Gdansk, Poland*

[1] *Gdansk University of Technology, Faculty of ETI, Audio Acoustics Laboratory, 11/12 Narutowicza Str., 80-233 Gdansk, Poland*

Correspondence should be addressed to Piotr Odya (piotrod@multimed.org)

ABSTRACT

Standard ABR devices use clicks and tone bursts to assess subjects' hearing in an objective way. A new device was developed that extends the functionality of a standard ABR audiometer by collecting and analyzing auditory brainstem responses (ABR). The developed accessory allows for the use of complex sounds (e.g. speech or music excerpts) as stimuli. Therefore, it is possible to find out how efficiently different types of sounds are processed in the hearing system including brain. The paper contains technical details related to the design of the device, including its hardware and software parts. The test results, that have been carried out to verify the operation of the device, are also described.

1 Introduction

Hearing tests can be divided into two main categories: subjective and objective ones. Subjective methods (e.g. pure tone audiometry) require examiner-patient interaction. In some situations it can be difficult to organise. This applies mainly to children (including newborns), but also to elderly people, unconscious subjects or coma patients. The main advantage of objective methods is ability to examine hearing without any form of the subject's cooperation [1] [2].

One of the most popular objective method of hearing assessment is auditory brainstem response (ABR). The method is non-invasive, painless and it does not involve any complications typical to subjective methods. It is advisable to carry it out when the patient remains calm and is not distracted by external factors. Therefore, the best results can be obtained during the patient's sleep (this applies especially to children). A certain drawback of the ABR method is test duration - it may exceed 1 hour. It depends on the number of test signals and their type.

The ABR method relies on the recording of electrical potentials from electrodes placed on the scalp. These potentials are generated by repetitive stimulation of auditory pathways. Recorded responses (potentials) are presented in the form of waves acquired as amplitude versus time after the auditory stimulus. Peaks observed in the recorded responses are called waves. They are formed in different areas of the auditory pathway, and their position (in relation to the stimulus) is predictable [3]. The presence of the Vth wave is the most important from the clinical point of view - it indicates that the subject is able to hear sound at the given level. Latencies between waves may also indicate problems in the functioning of the hearing organ.

The most common stimulus in the ABR method is click, being a short (100-200 μs) square-wave impulse. Due to rapid build-up of the sound pressure wave, it provides high amplitude of the response and ensures its high quality. Since the click has broadband spectrum, thus recorded potentials are not frequency-specific. The problem can be solved by using tone bursts as a stimulus. In this way it is even possible to obtain a subject's hearing threshold levels, similar to the acquired ones with the pure tone audiometry. Unfortunately, responses to burst stimulus have lower amplitudes and the waves are less recognizable (in comparison to the click stimulus of the same level).

Both mentioned above stimuli are simple and artificial signals - they can be used for evaluating subject's ability to hear sounds, but they are not suitable to assess the auditory system for speech/music communication. This drawback can be overcome by using speech-(audio-)evoked auditory brainstem responses (audio ABRs) [4] [5].

In the paper, the method of expanding the functionality of the standard device for measurement auditory brainstem responses is presented. An additional accessory was developed, capable of playing back pre-recorded sound samples, being triggered using impulse signals from the ABR device.

2 Audio ABR device

The Department of Multimedia Systems owns the Echodia Elios device. It is a portable device, its

parameters can be set using touchscreen and then all results are saved in the built-in database [6]. The gathered data can be easily imported to the PC computer for a further analysis. The PC computer might be also used to supervise the measurement process. The Echosoft application allows for setting all parameters of the device, including these related to the ABR measurement. The Echodia Elios device is capable of performing the ABR tests using both stimuli: clicks and tone bursts. Unfortunately, its manufacturer did not provide option to use different types of signals.

The aim of the project was to expand the functionality of the device to carry out tests with audio stimuli. Since any modifications in software part of the device (neither application nor firmware) were not possible, it was decided to develop an external hardware accessory (called "audio ABR") capable of:

- storing acoustic samples in wav format (mono, 16-bit, 44.1 kHz);
- generating noise in the selected acoustic output channel;
- alternating playback of the stored samples (one sample in phase, and the other out of phase - as required by the ABR method);
- adjusting the level of the output signal;
- triggering with an acoustic signal generated by the Echodia Elios device;
- controlling the accessory parameters via the USB interface using the dedicated application.

The block diagram showing components of the proposed audio ABR measurement method is presented in Fig. 1.

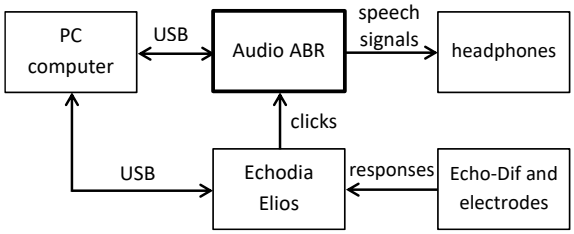

Figure 1. Components of the engineered audio ABR measurement method

The main part of the audio ABR consists of two main modules (Fig. 2):

- Microchip DM320018 evaluation module with PIC32MX270F256D microcontroller;
- Microchip AC327755 evaluation module with AK7755 audio codec.

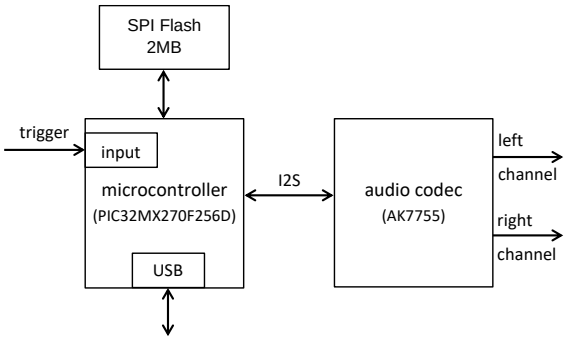

Figure 2. Block diagram of the audio ABR device

The first module is used for handling sound samples - transferring them from PC (using USB connection), storing in the memory and then (during the measurement), reading them from the memory and sending them to the audio codec. The total available memory allows for 20 s – long recording. Playing back of stored sound samples is triggered using the click stimulus taken from the headphones output of the Echodia Elios device. The rising slope of the click signal starts the playback process. The audio data is sent to the audio codec module where PCM samples are converted to the analogue signal. The signal is then passed to the headphones. The measured latency between the click stimulus and the beginning of the speech stimulus on the audio ABR device output is constant and it equals to 81 ms. The latency must be compensated during analysing recorded responses to obtain proper intervals between signals.

The audio ABR device is managed employing a dedicated application (working under Microsoft Windows operating systems). The main window of the application is presented in Fig. 3. The application allows for copying sound sample files to the device memory and it is used for setting the level of the stimulus.

MOST WIEDZY Downloaded from mostwiedzy.pl

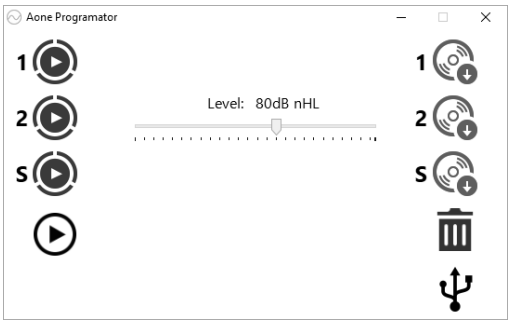

Figure 3. Main window application for managing the audio ABR device

The final step in the developing the audio ABR device was its calibration. The aim of the process was to assign values set in the application (in dB nHL - decibels above normal adult hearing level) to the sound pressure levels obtained in the headphones connected the audio ABR device output. It has been done in the anechoic chamber employing the Bruel & Kjaer sound analyser 2260 and the artificial ear 4152. The calibration of the device is valid under a condition that: sound files used as stimulus have to be normalized to the total RMS amplitude value of -13.47 dB.

The audio ABR device is enclosed in a plastic housing (113 x 67 x 26 mm) with a silicone cover (Fig. 4).

Figure 4. Audio ABR device, the speech-oriented version

3 Preliminary tests

The preliminary tests consist of ABR measurements employing click, burst and speech stimuli. Parameters of the particular stimuli were as follows:

- click - duration: 150 µs, number of stimuli per second: 17;
- burst - frequency: 1kHz, duration: 12 ms, number of stimuli per second: 17;
- speech - a syllable in Polish language: “gło” (/gwɔ/), duration: 330 ms, number of stimuli per second: 2.

All stimuli were presented at levels: 80, 70 and 60 dB nHL.

Five subjects (all males) with normal hearing (no problems observed in the pure-tone audiometry) participated in the preliminary tests (Fig. 5). Subjects’ age varied between 25 and 30, the average age of the subjects was 27.2 years. Measurements have been carried out in the acoustically isolated room to avoid any disturbances that may affect results of the tests.

Measurements employing click and burst took about 8-9 minutes (each), the longest examination was observed for the speech stimulus, namely it lasted about 56-57 minutes.

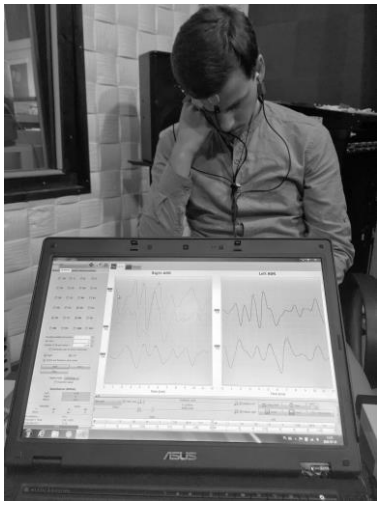

Figure 5. Subject during the preliminary tests - results displayed on the monitor employing a commercial ABR software interface [6]

As expected, peaks of recorded responses were the most distinguishable in case of the click stimulus

MOST WIEDZY Downloaded from mostwiedzy.pl

application. In turn, responses to the speech stimulus were the most difficult ones to assess. Thus, the results can suffer due to some inaccuracies caused by the subjective analysis of the waveforms. A comparison of the recorded responses for one of the subjects is presented in Fig. 6.

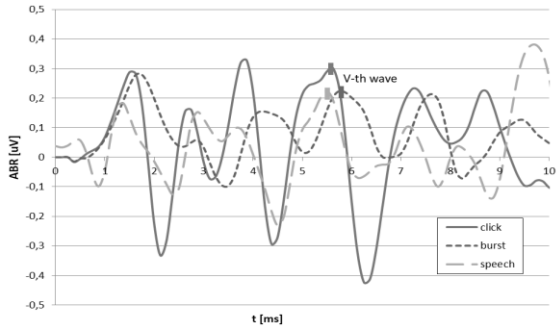

Figure 6. Sample recorded responses for 70 dB nHL stimuli

On the basis of the recorded responses, latencies of the V-th wave were determined for all the subjects. Results are presented in Fig. 7 (right ear) and in Fig. 8 (left ear). As expected, decreasing stimulus intensity led to an increase in response latencies. It is normal situation in the ABR method. However, it should be noted that the differences of latency values are largest for the speech stimulus.

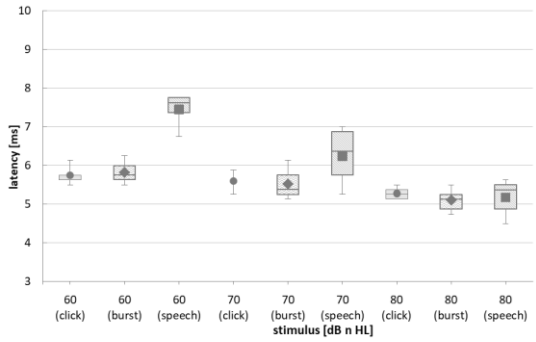

Figure 7. Latencies of the V-th wave - right ear

Furthermore, alterations between the left and the right ear are clearly visible. It may result from the different processing occurring in the brain for the speech signal. The left hemisphere is considered to be dominant in the speech analysis, thus speech from the right ear requires shorter pathway [7][8].

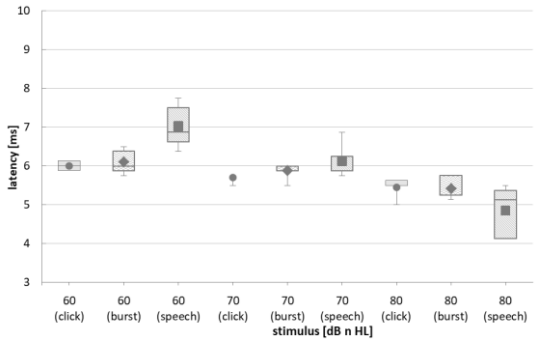

Figure 8. Latencies of the V-th wave - left ear

4 Conclusions

Tests proved that the developed accessory, called the audio ABR, meets the design assumptions and it allows for extending the functionality of the typical ABR device. An important gain offered by the audio ABR device is that it opens new directions of research in hearing and speech or music perception. It should be pointed out, that the developed device is capable of playing back any wave files, containing speech (phonemes, allophones, syllables) or music excerpts.

The main drawback of the proposed method is the comparatively long duration of the measurement procedure. It results from the stimulus length - 330 ms. In effect, the number of repetitions had to be limited to 2 stimuli per second (typically 17 stimuli per second is used in the classic method). The only way to speed up the process is to decrease the number of repetitions. However, it may significantly reduce the quality of the recorded responses.

The preliminary tests showed that the responses to speech stimuli seem to differ from those obtained employing the click or bursts. However, at this stage, additional tests and experiments are required and are planned to explain the nature of those differences. A hypothesis was made, that sounds familiar to the subject are processed faster in their entire hearing system, including especially its brain-located part.

MOST WIEDZY Downloaded from mostwiedzy.pl

Acknowledgements

The project was partly supported by the National Science Centre on the basis of the decision number DEC-2014/15/B/ST7/04724.

References

[1] Y.S. Sininger, C. Abdala, B. Cone-Wesson, "Auditory threshold sensitivity of the human neonate as measured by the auditory brainstem response" *Hearing Research* vol 104, pp. 27—38 (1997).

[2] A.R. Rodriguez, M. Bussière, M. Froeschl, H. J. Nathan, "Auditory-evoked potentials during coma: Do they improve our prediction of awakening in comatose patients?" *Journal of Critical Care* vol. 29, issue 1, pp. 93—100 (2014).

[3] J.R. Berger, A.S. Blum, "Brainstem Auditory Evoked potentials" In: A.S. Blum, S.B. Rutkove (eds) *The Clinical Neurophysiology Primer,* Humana Press (2007).

[4] E. Skoe, N. Kraus, "Auditory brainstem response to complex sounds: a tutorial" *Ear Hearing* vol. 31, no. 3, pp. 302—324 (2010).

[5] S. Krishnamurti, J. Forrester, C. Rutledge, G.W. Holmes, "A case study of the changes in the speech-evoked auditory brainstem response associated with auditory training in children with auditory processing disorders" *International Journal of Pediatric Otorhinolaryngology* vol. 77, no. 4, pp. 594—604 (2013).

[6] *Echodia Elios User Guide*, ver. 2.1.1. (2015).

[7] D.-E. Bamiou, S. Sisodiya, F.E. Musiek, L.M. Luxon, "The role of the interhemispheric pathway in hearing" *Brain Research Reviews* vol. 56, issue 1, pp. 170—182 (2007).

[8] F. Pulvermüller, J. Kiff, Y. Shtyrov, "Can language-action links explain language laterality?: An ERP study of perceptual and articulatory learning of novel pseudowords" *Cortex* vol. 48, issue 7, pp. 871—881 (2012).

MOST WIEDZY Downloaded from mostwiedzy.pl