Case Report

Auditory Processing Rehabilitation Follow-Up through Speech-Evoked Auditory Brainstem Response in Contralateral Noise; A Case Report

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Highlights

- Electrophysiological tests are valuable tools for auditory training follow-up
- S-ABR in noise is better for auditory training follow-up than conventional s-ABR

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ABSTRACT

Background: Auditory Training (AT) is an effective intervention for Auditory Processing Disorder (APD), and its outcomes are usually assessed through behavioral and electrophysiological tests. Among objective tools, speech-evoked Auditory Brainstem Response (s-ABR) has been used to evaluate AT effects, and it has shown promise, but s-ABR recorded in contralateral noise —a method activating both afferent and efferent auditory pathways —has not been applied to monitor rehabilitation progress in APD.

The Case: Here we compare pre- and post-intervention different tests' results of a 7-year-old boy with APD (with documented deficits in dichotic processing and speech-in-noise perception) to investigate which is the most appropriate tool for assessing rehabilitation efficacy. The case underwent behavioral and electrophysiological evaluations, including s-ABR with and without contralateral noise, before and after 15 sessions of targeted AT tailored to the child's specific processing weaknesses. Post-training results revealed significant improvement in behavioral tests and questionnaire scores. S-ABR assessments also demonstrated improvements, including increased V/A slope as well as improvements in wave latencies and amplitudes, with more pronounced changes observed in recordings with contralateral noise.

Conclusion: This case highlights the novel use of s-ABR in contralateral noise as a promising objective tool for monitoring auditory rehabilitation in APD. While behavioral assessments remain the gold standard, this electrophysiological test may provide valuable complementary information, particularly for patients with limited behavioral test cooperation or when behavioral results are unreliable. As this case report involves a single child with APD, further studies are needed to validate these findings in broader APD populations.

Keywords: Auditory processing disorder; auditory training; speech-evoked auditory brainstem response

Introduction

Auditory Processing Disorder (APD) refers to abnormal processing of auditory information in brain which leads to poor auditory performance, including difficulty discriminating sounds and understanding speech in noisy environments. Common signs may include difficulty following multi-step instructions, mishearing spoken information, delayed responses to auditory information, listening fatigue, problems interpreting prosodic cues, and difficulty localizing sounds. Prevalence of APD in children has been reported 2–11%, and early intervention is necessary to prevent its negative consequences [1]. Auditory Training (AT) is a vital rehabilitation component for children with APD to improve their auditory processing skills through targeted listening exercises [2].

Effectiveness of AT is commonly evaluated using behavioral tests and questionnaires [3]; however electrophysiological assessments provide objective measures less influenced by cognitive and language factors. Therefore, they can provide valuable information about auditory processing in people suspected of APD, especially those who are unable to complete behavioral tests, including younger children and uncooperative individuals [3, 4].

The use of electrophysiological tests, including click-evoked auditory brainstem response (click-ABR) [5], speech-evoked Auditory Brainstem Response (s-ABR) [6, 7], Middle Latency Response (MLR) [8], Late Latency Response (LLR) [9] and P300 [5], for monitoring auditory training has been studied in different studies. Among these, s-ABR offers advantages due to its exogenous nature and high sensitivity to subcortical auditory pathway function. Besides, it examines the processing of complex acoustic signals, such as speech syllables, at subcortical levels of the auditory nervous system [6, 10]. Despite these advantages, limited studies with small sample sizes have investigated effects of AT on s-ABR in the APD population. One study reporting significant changes in the latency and amplitude of some of the waves [6], whereas another found no statistically significant differences between pre- and post-training measures [7].

It has been suggested that contralateral noise activates various levels of the auditory efferent system [11], and adding it to s-ABR test enables evaluation of this system —alongside the afferent pathways —by increasing its activation [10]. As the auditory efferent system has an undeniable role in various auditory processing skills [10, 12], it was hypothesized that s-ABR in contralateral noise might be a more appropriate tool to monitor AT effects on subcortical levels of auditory system and to investigate the efficacy of the intervention in patients with APD. Based on this rationale, the present study compared pre- and post-training s-ABR results recorded in contralateral noise, as well as those recorded without noise, alongside behavioural and questionnaire assessments, in a child with APD in order to identify the most appropriate tool for evaluating rehabilitation efficacy. To date, s-ABR in contralateral noise has not been applied for monitoring rehabilitation progress in APD; this case report therefore introduces a novel application of this method.

Case presentation

A 7-year-old boy (NM) was referred to Audiology Clinic of Rofeideh Rehabilitation Hospital with complaints of difficulty understanding speech in noisy settings and poor academic performance, mainly in mathematics. According to school and medical records, the child had no history of cognitive, neurological or psychiatric disorders (e.g. learning disability, attention-deficit/hyperactivity disorder). Family history revealed his older sister had similar auditory difficulties, and had benefited from auditory rehabilitation. After explaining the test and rehabilitation process, written consent was obtained from the parent and verbal assent from the child. Initial audiological evaluation showed normal middle ear function (type An tympanogram and presence of acoustic reflexes at 500–4000 Hz) and normal hearing in both ears (hearing thresholds <20 dB HL at 250–8000 Hz). The tests were done using AT235 tympanometer (Interacoustics, Denmark) and AC40 audiometer (Interacoustics, Denmark). Subsequently, behavioral auditory processing assessment was conducted in accordance with the MAPA model. This included the assessment of temporal processing using Pitch Pattern Test (PPT) [13], dichotic processing using Persian version of Dichotic Digits Test (DDT) [14], and speech perception in noise using the Persian version of Bamford-Kowal-Bench Speech in Noise (BKB-SIN) test [15]. Persian version of Forward Digit Span test and DDT in the directed recall condition were also used for the assessment of auditory memory and auditory selective attention, respectively. Furthermore, sustained auditory attention was assessed using five subtests of the Test of Everyday Attention (TEA), in which the child met the minimum required criteria. In addition, Persian version of Scale of Auditory Behaviors (SAB) questionnaire [16] was completed by his mother. It is important to note that scores below 46 on this questionnaire suggest suspected auditory processing disorder. Then, electrophysiological tests of the right ear were recorded using speech stimuli (/da/) at the intensity of 80 dB SPL and rate of 10.9/s, without and with contralateral white noise at –10 dB SNR. Recordings were made using Biologic Navigator Pro system (Navigator Pro; Bio-Logic Systems Corp, Mundelein, IL, USA). During the electrophysiological assessment, the case sat on a comfortable chair, watching silent animated movies. A detailed explanation of the electrophysiological procedure can be found in the original article describing the method [10].

Based on the ASHA criteria [1], the child was diagnosed with APD due to scores more than two standard deviations below the mean on the BKB-SIN test (both ears) and the DDT (left ear). Accordingly, in line with principles outlined in the literature [1, 2], AT program was designed and initiated. The program included auditory memory and auditory attention training, followed by exercises targeting dichotic listening (dichotic interaural intensity difference training), speech-in-noise perception and auditory temporal processing, utilizing both the materials from the assessment tests and additional stimuli specifically developed based on the child's individual needs. After 15 sessions of AT, all the tests were repeated and post-AT assessment showed significant improvement in all the assessed auditory processing skills. SAB score also raised from 29 to 52, and most of the auditory complaints had been resolved. Comparing pre- and post-AT electrophysiological tests' results revealed increased V/A slope in both s-ABR and s-ABR in noise, with greater improvement in the latter. Decrease of latencies and increase of amplitudes of some of the waves were noted, however this pattern was not consistent across all the waves, and for some of the waves, it was even reversed. In the domain of spectral auditory processing, first Formant (F1) amplitude in both tests had increased but Higher Frequencies (HF) amplitudes had slightly decreased after training. Generally, s-ABR in contralateral noise demonstrated more pronounced neurophysiological changes in comparison to s-ABR. Pre- and post-intervention behavioral and electrophysiological tests' results are shown in Table 1 and Table 2, respectively, with electrophysiological waveforms displayed in Figure 1.

Table 1. Results of pre- and post-auditory training questionnaire and behavioral measurements of the auditory processing

	DDT, free recall (%)		PPT(%)		BKB-SIN		DDT, directed recall (auditory selective attention%)		FDST (auditory memory)	SAB questionnaire
	RE	LE	RE	LE	RE	LE	Attention to RE	Attention to LE		
Pre-intervention	82.50	50.00	63.33	53.33	1.00	0.50	92.50	90.00	4	29
Post-intervention	97.50	92.50	93.33	83.33	–4.50	–3.50	100.00	100.00	6	52

DDT; dichotic digits test, PPT; pitch pattern test, BKB-SIN; bamford-kowal-bench speech in noise, FDST; forward digit span test, SAB; scale of auditory behaviors, RE; right ear, LE; left ear

Table 2. Results of pre- and post-auditory training electrophysiological assessments

		Latency (ms)							Amplitude (µV)							V/A (µV/ms)	F1 (µV)	HF (µV)
		V	A	C	D	E	F	O	V	A	C	D	E	F	O			
Pre-intervention	s-ABR (without noise)	6.92	7.80	18.67	23.18	32.00	40.04	48.53	0.16	0.13	0.16	0.04	0.18	0.05	0.12	0.19	0.81	0.76
	s-ABR in contralateral noise	6.92	7.81	18.67	23.18	31.92	41.05	48.63	0.01	0.12	0.04	0.29	0.30	0.32	0.10	0.14	0.78	0.77
Post-intervention	s-ABR (without noise)	6.53	7.53	18.37	22.95	30.86	39.36	48.11	0.19	0.11	0.07	0.13	0.19	0.08	0.07	0.22	1.12	0.62
	s-ABR in contralateral noise	6.70	7.70	18.95	22.87	30.86	39.01	48.60	0.21	0.13	0.13	0.11	0.15	0.09	0.11	0.22	1.10	0.64

F1; first formant amplitude, HF; higher frequencies amplitude, s-ABR; speech-evoked auditory brainstem response

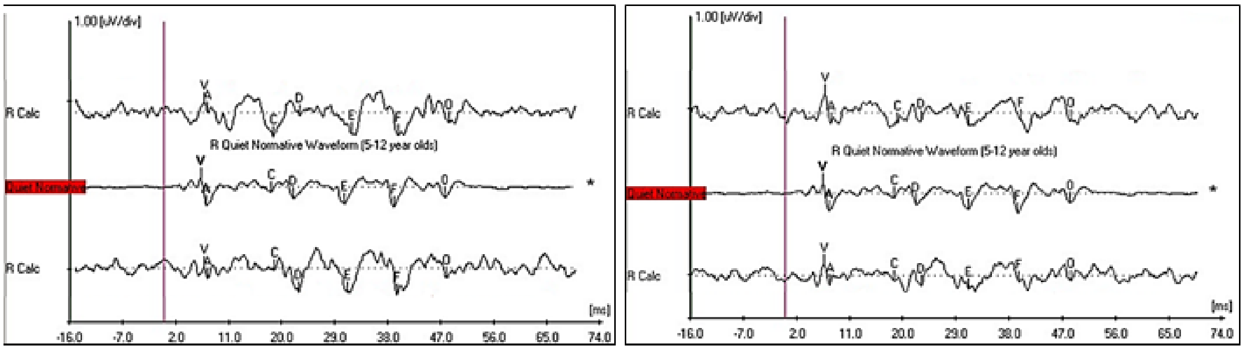

Figure 1. Results of pre-auditory training (left picture) and post-auditory training (right picture) electrophysiological evaluation

In Figure 1, the topmost and bottommost waveforms in each picture show s-ABR and s-ABR in contralateral noise results, respectively. The middle waveform demonstrates the device-provided norm for s-ABR in the age range of 5–7 years.

Discussion

Determining the effectiveness of APD intervention approaches is still a challenge in the field of APD management. While most studies have focused on behavioral assessment outcomes, it has been suggested that some electrophysiological tests also reflect rehabilitation-induced changes correlated with improvement in auditory processing skills [3, 4]. This case report indicates while s-ABR and s-ABR in noise both can to some extent show positive results of AT on neurophysiological bases of auditory processing, s-ABR in contralateral noise may better reflect rehabilitation-induced neurophysiological changes by engaging both afferent and efferent auditory pathways at the brainstem level. Nevertheless, findings revealed that behavioral assessment and SAB questionnaire provide more reliable and robust outcomes. This can be attributed to the fact that since behavioral tests' results depend on different bottom-up and top-down processing skills, AT positive outcomes may not always manifest in electrophysiological results at brainstem level. Thus, examining electrophysiological responses of higher levels of auditory system is recommended. Moreover, the extent of improvement in one electrophysiological test does not necessarily match the improvement observed in behavioral tests. Even so, further research with larger samples is needed to validate these results.

Conclusion

Based on the findings, behavioral improvements and questionnaires should still be considered the gold standard for monitoring Auditory Training (AT) effects; however, electrophysiological tests, especially speech-evoked auditory brainstem response in noise, can provide valuable complementary information, particularly in patients with limited behavioral test cooperation. It is important to note that this study was conducted on a single child diagnosed with auditory processing disorder (with dichotic processing and speech-in-noise perception deficits) who underwent individualized AT, and therefore, further research with larger sample sizes is required to support and generalize these results to the broader auditory processing disorder population. Further studies in this area may help develop protocols for the use of these tests to evaluate the effectiveness of different AT approaches.

Ethical Considerations

Compliance with ethical guidelines

The present paper is extracted from the MSc thesis of M. Vahabi with the Ethics Code of IR.USWR.REC.1402.114 approved at the University of Social Welfare and Rehabilitation Sciences. Informed consent was obtained from the case and the parent.

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Authors' contributions

MV: Study design, acquisition of data, interpretation of the results, and drafting the manuscript; MJ: Supervision, study design, acquisition of data, interpretation of the results, and critical revision of the manuscript; EB: Statistical analysis. All authors approved the final version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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