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Original articles

Auditory middle latency responses and hearing skills in adults

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ABSTRACT

Purpose: to compare the Auditory Middle Latency Response in adults, one group with and another group without altered auditory skills. In addition, the aim was to compare cut-off values of 30% and 50% for the Ear Effect in terms of sensitivity and specificity.

Methods: the sample comprised 32 individuals of both genders with no hearing loss who were divided into Group 1 (16 individuals with no alterations in auditory skills) and Group 2 (16 individuals with alterations in auditory skills). All participants received an audiological evaluation and measurement of Brainstem and Auditory Middle Latency Potentials.

Results: when Group 1 and Group 2 were compared, a statistically significant difference was only observed in Na and Pa amplitude of waves A1C3 and A2C3. In the analysis of sensitivity and specificity of the Auditory Middle Latency Response, a cut-off value of 50% gave a better balance between sensitivity and specificity.

Conclusion: adults presented with altered auditory abilities had smaller response amplitudes in the Na and Pa components of the waves generated in the left hemisphere. A cut-off value of 50% gave a better discrimination of the Ear Effect for identifying subjects with altered auditory skills.

Keywords: Evoked Potentials, Auditory; Adult; Hearing

INTRODUCTION

The American Speech-Language-Hearing Association (ASHA)[1] defines Central Auditory Processing (CAP) as the effectiveness with which the central auditory nervous system utilizes information. Moreover, if there are difficulties in processing auditory information or in the underlying neurobiological activity, then the term Central Auditory Processing Disorder (CAPD)[2] is used. In recent years, there have been many studies on the subject, but it is not yet known if CAPD represents a specific disability or if it is part of a multimodal sensory deficit[3,4].

In this context, electrophysiological evaluations of hearing are proving their worth in evaluating auditory skills, over and above behavioral tests, since they are less affected by general cognitive skills[4]. A guideline published in 2010 points to the Auditory Middle Latency Response (AMLR) as a good measurement parameter, since, despite certain limitations, it identifies a particular generating site where auditory information is processed[1]. The AMLR is generated when an acoustic signal is presented, and records the activity of the subcortical and cortical regions of the auditory system[5]. In particular, the Na, Pa, Nb, and Pb components of the AMLR are observed at a latency of 15 to 72 milliseconds (ms), after stimulation[6] and these components are analyzed for latency and amplitude. In addition to the aforementioned temporal analysis (of latency and amplitude), the study of the Ear Effect (the amplitude difference between the left and right ears, here called OE) and the Electrode Effect (the amplitude difference between two electrodes, called EE) can also be performed[1,7].

The literature indicates that the OE of the AMLR is usually observed more frequently in individuals with altered hearing abilities when compared to EE[8]; this suggests a bigger difference in the amplitude of the AMLR responses when stimulation of each ear is compared. Despite the importance of the AMLR and the OE analysis for the assessment of individuals with altered auditory skills, some aspects still require investigation, such as, for example, the cut-off values of these measures and their variability.

A previous study sought to analyze the sensitivity and specificity of the cut-off values of 30%, 40%, and 50% for OE and EE of the AMLR in individuals who had CAPD and lesions of the central nervous system[9]. At the time, the researchers indicated that for OE, the cut-off value of 30% performed better in diagnosing auditory skill alterations. However, currently, there seems to be no consensus regarding this normative value, and a value of 50% is also recommended in the literature[10]. This disparity is one of the justifications for this study.

In summary, the present study aims to compare the latency and amplitude of the Na, Pa, Nb, and Pb components of the AMLR in young adults, some with and some without auditory skill disorders and calculate the sensitivity and specificity for these young adults by using cut-off values of 30% and 50% for the OE. In this way, this work could contribute to the better diagnosis of auditory skill disorders.

METHODS

The present study complied with the ethical precepts included in Resolution 466/12 of the National Health Council of Brazil. It used a quantitative, descriptive, and cross-sectional approach and was approved by the Research Ethics Committee of the Federal University of Santa Maria, Brazil, under number 5933514.1.0000.5346 und CAAE number 23081.019037/2017-19. Written consent of all participants was obtained after clarifying the objectives, risks, and benefits of the study and guaranteeing the confidentiality of personal data.

Eligibility criteria were that the participants should be between 18 and 35 years of age; Brazilian Portuguese speakers; right-handed; normal external auditory meatus; hearing thresholds better than 25 dB in octaves from 0.25 to 8 kHz11; type A tympanometric curves bilaterally12; contralateral stapedial acoustic reflexes present at normal levels in both ears; and have responses within normal standards for Brainstem Auditory Evoked Potentials (BAEPs)13. Collection and analysis was carried out in 2019.

Participants were excluded if they had diagnosed or evident cognitive and/or psychiatric impairment; continuous exposure to noise; diagnosed illness of any nature; chronic tinnitus, hyperacusis, misophonia, or dizziness; therapeutic monitoring or continuous use of medication; or continuous use of licit or illicit drugs.

All subjects were submitted to inspection of the external auditory meatus; tonal threshold audiometry; logoaudiometry; acoustic immittance measurements (tympanometry and acoustic reflexes); and Brainstem Auditory Evoked Potential. These measures needed to be normal for inclusion in the study. In order to verify the integrity of the auditory pathway, BAEP was performed using electrodes placed on Fpz, Fz, A1, and A2 (ear lobes). The stimulus was a 100 μs click of rarefied polarity and intensity of 80 dBnHL. There were 2,048

stimuli in total delivered at a rate of 27.7/s. Amplification involved a gain of 100K using a band-pass filter of 0.1–3 kHz. The BAEP was considered normal if the latency of waves I, III, and V and their interpeak intervals I–III, III–V, and I–V had normal values. The parameters and standard of normality were those suggested by Webster (2017)13 based on two standard deviations2. Acquisition was monaural, and wave marking considered reproducibility and morphology of the wave forms.

Central Auditory Processing Skills were assessed with behavioral tests and with the Auditory Middle Latency Response (MLAEP).

Two behavioral tests were used to screen central auditory processing: the Dichotic Digit Test (DDT)14 and the Random Gap Detection Test (RGDT)10. Given the lack of a gold standard for central auditory processing assessment, the guidelines of the American Academy of Audiology (2010)1 and the American Speech-Language-Hearing Association (2005)[2] were followed, which call for at least two tests with altered results (based on two standard deviations) to identify altered auditory skills and therefore CAP.

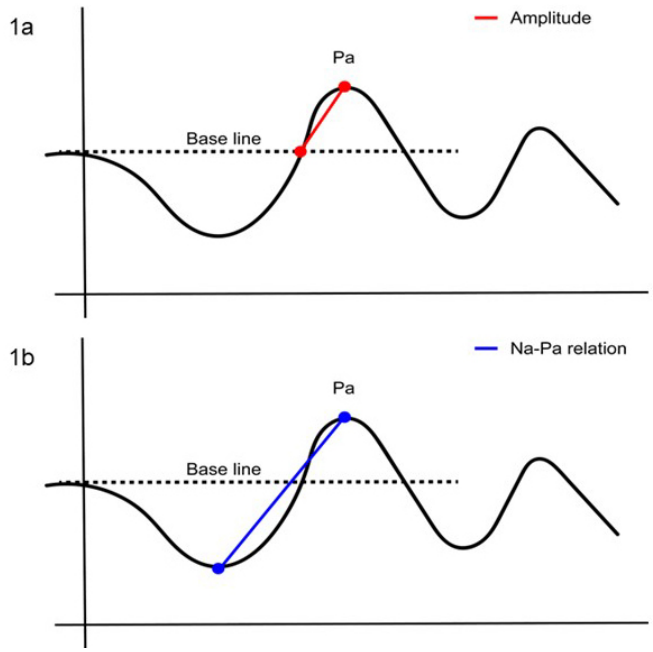
The DDT (Pro-Fono version 2011) was presented to both ears simultaneously at an intensity of 40 dB added to the tritone average. The result was considered within normal standards if the final score was ≥ 95% correct for both left and right ears15. For this test only the binaural integration part was applied.

The RGDT (Auditec version) was applied binaurally at frequencies of 0.5, 1, 2, and 4 kHz at an intensity of 40 dB added to the tritone average. However, the final result was relative to the average of the responses at the four frequencies16. The result was considered normal if the average of the responses (for the four frequencies) was ≤ 9.51 ms17.

In the Electrophysiological Evaluation of Hearing, electrode placement was based on the 10–20 system of electroencephalography18. The electrode impedance was kept below 3 kΩ and the interelectrode impedance below 2 kΩ. The transducer used was the ER-3A. The research equipment was the SmartEP from Intelligent Hearing Systems, which receives annual acoustic calibration following standard 645-3 (1994) of the International Electrotechnical Commission (IEC).

For the AMLR, the electrodes were positioned at points Fpz, C3, C4, A1, and A2 (ear lobes). Each ear was studied monaurally. The stimulus was a click of 100 μs with rarefied polarity and intensity of 70 dBnHL. In total, there were 1,000 stimuli, which generated two waves per ear. The click rate was 7.1/s, the gain was 100k19, and the band-pass filter was 0.02–1.5 kHz. The four components of the waveform were labeled Na, Pa, Nb, and Pb using reference values proposed by Hall (2007) 20.

Subsequently, for analysis of the AMLR data, four waves were generated, two in each ear. These waves were named according to the electrodes they referred to: A1C3 and A1C4 were the waves related to the stimulus output from the left ear (A1) and the arrival in the left (C3) and right (C4) hemispheres; A2C3 and A2C4, in turn, were the waves related to the stimulus output from the right ear (A2) and the arrival in the left (C3) and right (C4) hemispheres. The Na, Pa, Nb, and Pb components were identified in all four waves. Marking of the AMLR components was done by two audiologists experienced in performing the examination. For the temporal analysis of the AMLR (latency and amplitude), the amplitude was marked from the baseline (zero point) (Figure 1). A 10-ms pre-stimulation period was used as the baseline. In addition, to calculate the OE, the relative difference of the mean Na–Pa (peak-to-peak) amplitude values in the right and left ears was calculated. That is, the following formula was used: |(left ear at C3 + left ear at C4)/2| – |(right ear at C3 + right ear at C4)/2|7.



Author's own collection.

Figure 1. Illustration of amplitude marking for the temporal analysis of the Auditory Middle Latency Response (1a) and for the analysis of the Ear Effect (1b)

The final sample consisted of 32 individuals (20 females and 12 males) from the university community, mean age of 22.6 years (18 to 34 years) and with 14.9 years of schooling, distributed into two groups. Group 1 (G1) was made up of 16 individuals, 10 females and 6 males, with an average of 15.0 years of schooling and no alteration in the two CAP tests performed. Group 2 (G2) was made up of 16 individuals, 10 females and 6 males, with an average of 14.9 years of schooling and altered auditory skills – that is, with alterations in the Dichotic Digit Test15 and in the Random Gap Detection Test17.

In the statistical analysis, the normality of the data was investigated using the Shapiro–Wilk test. From the result of this, the other statistical tests were selected. The comparative analysis of the latency and amplitude of the AMLR components for G1 and G2 was performed using a one-way ANOVA test. The homogeneity of variances was analyzed using Levene's test. To test the homogeneity of the sample, a Chi-square test was applied. All these tests used a *p*-value of 0.05 as the level of statistical significance.

The sensitivity and specificity analysis of the cut-off values was performed using the calculation shown in Chart 1.

Chart 1. Sensitivity and specificity analysis of the Auditory Middle Latency Response Ear Effect

AMLR 30% OR 50%.	BEHAVIORAL CAP TESTS		
	Changed	Normal	Total
Changed	A	B	a+b
Normal	C	D	c+d
Total	a+c	b+d	N
Sensitivity	a/a+c		
Specificity	d/b+d		

Captions: CAP = Central Auditory Processing; AMLR = Auditory Middle Latency Response.

RESULTS

The sample was composed of 32 individuals subdivided into two groups with homogeneity for age (p = 0.86), sex (p = 0.16), and education (p = 0.8).

Comparison between G1 and G2 in terms of latency and amplitude of the Na, Pa, Nb and Pb components (a temporal analysis) was carried out for all the AMLR waves (A1C3, A2C3, A2C3, and A2C4). Figure 2 shows traces of the results obtained, and Table 1 sets out the latency data.

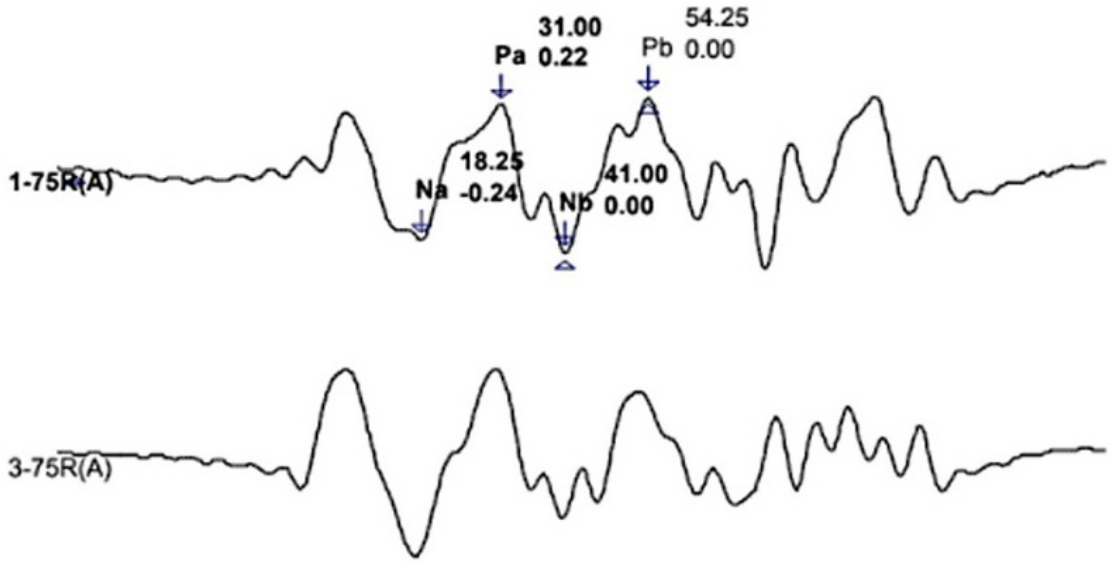


Figure 2. Auditory Middle Latency Response tracing for an individual with no alteration in auditory abilities. Data from this study

Table 1. Comparative analysis, for Groups 1 and 2, of the latency of the components of the Auditory Middle Latency Response.

WAVE/COMPONENT	G	n	Average	SD	Min	Max	p-value
A1C3							
Na	G1	16	16.71	1.78	13.44	19.08	0.10
	G2	16	18	1.36	15.99	20.09	
Pa	G1	16	29.33	0.88	27.08	30.99	0.24
	G2	16	30.11	0.79	28.76	31.42	
Nb	G1	16	40.24	0.81	39.16	41.26	0.32
	G2	16	41.22	0.88	39.56	43.42	
Pb	G1	16	51.10	1.09	49.18	52.11	0.56
	G2	14	51.86	0.91	50.53	53.18	
A2C3							
Na	G1	16	16.37	1.46	13.44	18.98	0.3
	G2	16	17.64	1.27	15.99	19.76	
Pa	G1	16	29.15	1.07	27.15	30.79	0.58
	G1	16	29.93	1.18	28.54	32.93	
Nb	G1	16	40.17	0.76	30.09	41.49	0.61
	G2	16	40.78	0.87	39.65	42.27	
Pb	G1	16	50.76	1.09	40.16	52.82	0.36
	G2	14	51.40	1.16	49.49	52.99	

WAVE/COMPONENT	G	n	Average	SD	Min	Max	p-value
A1C4							
Na	G1	16	16.81	1.25	14.44	18.99	0.44
	G2	16	17.04	1.26	15.08	19.57	
Pa	G1	16	29.59	1.12	27.32	31.79	0.47
	G2	16	30.49	1.33	28.18	32.98	
Nb	G1	16	40.83	1.28	39.95	42.98	0.44
	G2	16	41.28	1.05	39.65	42.92	
Pb	G1	16	51.26	1.16	49.22	52.96	0.66
	G2	16	51.42	1.25	49.94	53.29	
A2C4							
Na	G1	16	16.49	1.47	13.44	18.49	0.44
	G2	16	17.03	1.20	14.90	19.98	
Pa	G1	16	29.29	1.14	27.15	30.79	0.4
	G2	16	30.37	1.23	28.54	32.98	
Nb	G1	16	40.77	0.87	39.66	42.85	0.39
	G2	16	41.09	0.98	39.65	42.92	
Pb	G1	16	51.13	1.13	49.22	52.96	0.10
	G2	16	52.03	1.32	48.49	53.02	

Captions: G = group; n = number of subjects; SD = standard deviation; Min = minimum; Max = maximum; G1 = group with no auditory skills changes; G2 = group with auditory skills changes. Analyses performed by one-way ANOVA tests.

When G1 and G2 were compared, there were no statistically significant differences for the latency of the Na, Pa, Nb, and Pb components in all waves (Table 1). However, two absences of the Pb component were observed for wave A1C3, as well as for A2C3 in G2. However, in the amplitude analysis of the components, a statistically significant difference was observed between G1 and G2 for Na and Pa (Table 2). This difference was observed in waves A1C3 and A2C3.

Table 2. Comparative analysis, for Groups 1 and 2, of the amplitude of components of the Auditory Middle Latency Response

WAVE/COMPONENT	G	n	Average	SD	Min	Max	p-value
A1C3							
Na	G1	16	0.57	0.10	0.36	0.79	0.02*
	G2	16	0.34	0.10	0.14	0.53	
Pa	G1	16	0.66	0.14	0.34	0.79	0.02*
	G2	16	0.39	0.11	0.23	0.55	
Nb	G1	16	0.40	0.09	0.36	0.50	0.67
	G2	16	0.39	0.09	0.32	0.48	
Pb	G1	16	0.38	0.10	0.28	0.47	0.65
	G2	14	0.37	0.08	0.3	0.45	
A2C3							
Na	G1	16	0.61	0.08	0.54	0.69	0.04*
	G2	16	0.51	0.11	0.33	0.69	
Pa	G1	16	0.67	0.13	0.41	0.9	0.05*
	G2	16	0.58	0.07	0.45	0.62	
Nb	G1	16	0.40	0.08	0.33	0.58	0.59
	G2	16	0.38	0.07	0.35	0.5	
Pb	G1	16	0.38	0.08	0.3	0.54	0.49
	G2	14	0.34	0.07	0.32	0.51	

WAVE/COMPONENT	G	n	Average	SD	Min	Max	p-value
A1C4							
Na	G1	16	0.56	0.06	0.48	0.69	0.5
	G2	16	0.54	0.06	0.43	0.67	
Pa	G1	16	0.59	0.06	0.48	0.67	0.53
	G2	16	0.56	0.07	0.44	0.7	
Nb	G1	16	0.36	0.08	0.3	0.58	0.66
	G2	16	0.37	0.07	0.28	0.53	
Pb	G1	16	0.33	0.1	0.31	0.6	0.51
	G2	16	0.3	0.09	0.29	0.58	
A2C4							
Na	G1	16	0.57	0.08	0.48	0.69	0.65
	G2	16	0.56	0.08	0.43	0.67	
Pa	G1	16	0.58	0.1	0.4	0.7	0.42
	G2	16	0.53	0.09	0.46	0.69	
Nb	G1	16	0.39	0.07	0.31	0.49	0.66
	G2	16	0.38	0.06	0.32	0.48	
Pb	G1	16	0.35	0.07	0.3	0.46	0.59
	G2	16	0.32	0.07	0.29	0.44	

Captions: G = group; n = number of subjects; SD = standard deviation; Min = minimum; Max = maximum; G1 = group with no auditory skills changes; G2 = group with auditory skills changes. Analyses performed by one-way ANOVA tests.

The sensitivity and specificity analysis of cut-off values of 30% and 50% for the Ear Effect (OE) are presented in Charts 2 and 3.

Chart 2. Sensitivity and specificity analysis of the 30% cut-off value for the Ear Effect of the Auditory Middle Latency Response

AMLR 30%	BEHAVIORAL CAP TESTS		
	Changed	Normal	Total
Changed	15	4	17
Normal	1	12	15
Total	16	16	32
Sensitivity			93%
Specificity			75%

CAP = Central Auditory Processing; AMLR = Auditory Middle Latency Response.

Chart 3. Sensitivity and specificity analysis of the 50% cut-off value for the Ear Effect of the Auditory Middle Latency Response

AMLR 50%	BEHAVIORAL CAP TESTS		
	Changed	Normal	Total
Changed	14	1	17
Normal	2	15	15
Total	16	16	32
Sensitivity			87%
Specificity			93%

Captions: CAP = Central Auditory Processing; AMLR = Auditory Middle Latency Response.

DISCUSSION

The AMLR in CAP has been studied for some years. However, most studies are not recent and concentrate on children. Furthermore, the sensitivity and specificity of the cut-off values of the AMLR have been little studied in the specialized literature, even though it is one of the main parameters of this potential7. Thus, the present study contributes to the literature in this area, trying to investigate the performance of the AMLR in relation to alterations in auditory skills.

In this study, altered auditory skills do not seem to have affected the latencies of the components. Schochat et al. (2010)21, studying the effects of auditory training on the AMLR, also did not observe changes in the latencies of the components. These observations can be explained based on the generating sites of the potential. It is known that the AMLR components are generated in subcortical/thalamic and cortical regions5, and so the number of activated neurons in these structures is higher than in lower areas (such as the brainstem or VIII cranial pair). This means that AMLR responses tend to be more robust, with a more convex and less sinuous morphology, compared to the Brainstem Auditory Evoked Potential (BAEP)19. In the present study, this factor may have meant that small changes in the encoding time of the acoustic stimulus (stemming from altered auditory skills) did not have any impact on the measured latency of the responses.

The presence of almost all components was observed, with the exception of Pb in waves A1C3 and A2C3 for G2, where there was no response in two individuals. The Pb component of the AMLR is usually present in adult subjects, and the absence is more commonly observed when evaluating infants or children22,23. Since the waves here were absent in G2, it is believed that in these individuals, their altered auditory abilities may involve secondary regions of the auditory cortex (Pb generators)5, leading to the negative result.

Another interesting aspect to note is that the absence of Pb occurred in the responses coming from the left hemisphere (A1C3 and A2C3) and, considering that all individuals in the sample were right-handed, a few considerations are in order. It is understood that the secondary areas of the left auditory cortex are closely related to the comprehension of auditory information24; therefore, any absences could indicate added difficulty in these individuals for auditory comprehension. Similar absences in the left hemisphere were also observed in a previous study of children aged 8 to 14 years who had CPAD21. The absence of Pb is probably not associated with left hemisphere lesions, since any pathological history was an exclusion factor in this study. Likewise, if the absences were the result of weakness in detecting the potential, absences would not be restricted just to the group with altered hearing abilities.

It was observed that individuals with altered hearing ability presented a smaller amplitude of the Na and Pa components for waves A1C3 and A2C3. This relation between impaired auditory skills and Na and Pa amplitude has also been observed in previous studies21,25. Such findings indicate that subjects with impaired auditory skills tend to have a lower neuronal recruitment in the medial geniculate body (Na), the thalamus, and primary auditory cortex (Pa) (the component generators)5. This could explain the deficit in the auditory performance of these individuals, because these regions, mainly primary auditory cortex, are associated with important auditory skills such as recognition and discrimination26. Mattson et al. (2019)27, investigating hearing difficulties in individuals aged 8 to 14 years through the AMLR, also concluded that the thalamo-cortical impairments identified by this potential could contribute to difficulties in discriminating speech sounds. No significant differences were found for the Nb and Pb components, showing that cortical regions tend to have a lower impact on altered auditory skills. A previous study21 involving CAPD, also identified greater alterations in the Na and Pa components than in the others.

In the sensitivity and specificity analysis of the AMLR, it was found that a cut-off value of 50% provided a better balance between the criteria (87% sensitivity and 93% specificity) compared to a cut-off value of 30% (93% sensitivity but only 75% specificity). This result fails to corroborate the study by Schochat et al. (2004)9, which suggested that a cut-off value of 30% offered the best performance.

For this study, a cut-off value of 30% gave good sensitivity (93%); however, it diagnosed as altered those subjects who were normal in terms of the behavioral screening of their CAP skills. On the other hand, the 50% cut-off value, despite showing a lower sensitivity (87%), gave a better specificity (93%). The findings of this study indicate that the criterion of 50% aligns better with the literature on the topic10.

It is suggested that further studies be done with larger samples and with imaging studies that can check neural integrity. Although no imaging tests were performed here, our participants were highly educated

and had no signs, symptoms, or diagnoses of pathologies in the central nervous system. Nevertheless, the results here are for alteration in auditory skills in young adults, and further work should investigate the sensitivity and specificity of the AMLR in other populations and other pathologies.

CONCLUSION

Young adults with altered hearing abilities had smaller response amplitudes in the Na and Pa components of the waves generated in the left hemisphere (A1C3 and A2C3), but there were no changes in latency. Furthermore, a 50% cut-off value showed a better balance for sensitivity and specificity in detecting Ear Effect than did a cut-off of 30%.

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VCM: conceptualization, data curation, formal analysis, investigation, methodology, visualization and original writing;

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HGM: data curation, formal analysis, original writing;

VOCN, LSS: data curation, research, methodology and writing – review and editing;

PHS: methodology, visualization and writing – review and editing;

MDS, MVG: conceptualization, data curation, formal analysis, investigation, methodology, supervision, visualization and original writing.