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Brief communication

Acoustically controlled auditory training: A monitoring program with frequency following response

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ABSTRACT

Purpose: to present a monitoring program for acoustically controlled auditory training, using the frequency following response.

Methods: a bibliographic search was conducted in the Virtual Health Library and Scientific Electronic Library Online (SciELO) databases to identify literature on monitoring acoustically controlled auditory training. Initially, 24 references were found and after evaluating them and applying the eligibility criteria, nine scientific articles were included. Then, the monitoring program for acoustically controlled auditory training was structured, using the frequency following response.

Results: the program was organized into two parts: the first focused on behavioral assessment and reassessment of auditory processing, and the second on electrophysiological assessment and reassessment, using the frequency following response.

Conclusion: the monitoring program provides a structured approach to observing the effectiveness and efficacy of acoustically controlled auditory training, supporting improved therapeutic planning and clinical guidance.

Keywords: Audiology; Electrophysiology; Cognitive Training; Hearing Disorders; Evoked Potentials, Auditory

INTRODUCTION

Central auditory processing (CAP) is the term used to describe the central auditory nervous system's (CANS) mechanism responsible for transforming, organizing, analyzing, decoding, encoding, and understanding acoustic signals[1]. Deficits in the neurobiological development of auditory skills characterize central auditory processing disorder (CAPD), which may be associated with other language and learning impairments and deficits[2].

When CAPD is detected, the recommended treatment is auditory training, which has two forms: acoustically controlled auditory training (ACAT) and informal auditory training. These training approaches use sensory stimulation strategies (bottom-up) to enhance the quality of the acoustic signal and linguistic and cognitive strategies (top-down) to improve these skills. The intervention follows the developmental hierarchy of auditory skills and commonly results in improvements due to the CANS' capacity for change and reorganization[3,4].

Children with CAPD have difficulty understanding speech in noisy environments and often need to have it repeated. They also have associated deficits in attention and auditory memory, which can lead to academic and emotional challenges. The lack of systematic evaluation can significantly compromise treatment efficacy, as CAPD is a complex condition requiring multidimensional assessments. Studies indicate that integrating electrophysiological data, such as auditory evoked potentials (AEPs), with behavioral data is essential for accurate diagnosis and appropriate follow-up[3-10].

The complexity of CAPD highlights the need for a structured program to measure improvements in auditory performance after ACAT. The treatment's effectiveness can also be documented through CAP reassessment, self-assessment questionnaires, auditory training progress, and electrophysiological measures. Various AEPs can be used to assess therapeutic efficacy, including the frequency following response (FFR)[4-10].

Electrophysiological measures, such as FFR, have shown high sensitivity and specificity in identifying changes in auditory processing, objectively assessing auditory responses and the impact of therapies[11-15]. Thus, a program integrating FFR as a monitoring tool can provide a comprehensive view of the patient's progress, ensuring that interventions are tailored to individual needs.

Studies increasingly point out ways to apply FFR to assess and monitor CAP[16-19], providing statistically significant test-retest reliability results in group evaluations and validating FFR as an electrophysiological tool for assessing auditory processing. Thus, this study aimed to propose a monitoring program for ACAT, using FFR.

METHODS

This study developed a monitoring program for ACAT (Appendix A) as part of the project titled "Analysis of the Frequency-Following Response in Children with Central Auditory Processing Disorder before and after Auditory Training." This project has been approved by the Research Ethics Committee of the Universidade Estadual de Ciências da Saúde de Alagoas (UNCISAL), AL, Brazil, under evaluation report no. 6.019.422, CAEE no. 67714923.9.0000.5011.

The study had three main steps, described as follows: (1) Literature review, (2) Development of the ACAT monitoring program, using FFR, and (3) Peer evaluation of the program.

Stage 1 – Literature Review

A bibliographic search was initially conducted to identify electrophysiological protocols used in ACAT monitoring research. They were surveyed in the Virtual Health Library (VHL) and Scientific Electronic Library Online (SciELO) databases using the following search strategy: (Central Auditory Processing Disorder OR Central Auditory Processing) AND (Evoked Potentials, Auditory OR Auditory Evoked Potential OR Potentials, Auditory Evoked OR Auditory Evoked Response OR Auditory Evoked Responses OR Evoked Response, Auditory OR Evoked Responses, Auditory OR Auditory Evoked Potentials) AND (Training Auditory). There were no restrictions on the articles' year, language, or study population. The review included studies that used AEPs to monitor ACAT and excluded duplicates or those that did not meet the established criteria.

Two reviewers evaluated titles and abstracts to select studies, followed by an individual reading of the full texts. In cases of disagreement regarding the inclusion or exclusion of a study during the selection process, a third reviewer was consulted for the final decision. Two independent evaluators extracted data from the studies using a form designed specifically for this review.

The parameters for developing the ACAT monitoring program with FFR were established based on this literature review.

The search results yielded 24 references. After applying the criteria described above and reading the full texts, nine scientific articles were included, as presented in Chart 1.

Chart 1. Articles used as reference for constructing the monitoring program

	REFERENCE
ARTICLE 1	Hayes EA, Warrier CM, Nicol TG, Zecker SG, Kraus N. Neural plasticity following auditory training in children with learning problems. Clin Neurophysiol. 2003;114(4):673-84. https://doi.org/10.1016/s1388-2457(02)00414-5 PMID: 12686276.[5]
ARTICLE 2	Wilson WJ, Arnott W, Henning C. A systematic review of electrophysiological outcomes following auditory training in school-age children with auditory processing deficits. Int J Audiol. 2013;52(11):721-30. https://doi.org/10.3109/14992027.2013.809484. PMID: 24001257.[20]
ARTICLE 3	Yamamoto MRV, Pereira LD. Acoustically controlled auditory training as an intervention option in central auditory processing disorder in severe/ profound unilateral hearing loss. Audiol., Communic. Res. 2020;259(1):e2399. https://doi.org/10.1590/2317-6431-2020-2399[21]
ARTICLE 4	Schochat E, Musiek FE, Alonso R, Ogata J. Effect of auditory training on the middle latency response in children with (central) auditory processing disorder. Braz J Med Biol Res. 2010;43(8):777-85. https://doi.org/10.1590/s0100-879x2010007500069. PMID: 20658093.[22]
ARTICLE 5	Francelino EG, Reis CF de C, Melo T. O uso do P300 com estímulo de fala para monitoramento do treinamento auditivo. Distúrb Comum.2014; 26(1):27-34[23].
ARTICLE 6	Alonso R, Schochat E. The efficacy of formal auditory training in children with (central) auditory processing disorder: behavioral and electrophysiological evaluation. Braz J Otorhinolaryngol. 2009;75(5):726-32. https://doi.org/10.1016/s1808-8694(15)30525-5. PMID: 19893943; PMCID: PMC9442236.[24]
ARTICLE 7	Filippini R, Befi-Lopes DM, Schochat E. Efficacy of auditory training using the auditory brainstem response to complex sounds: auditory processing disorder and specific language impairment. Folia Phoniatr Logop. 2012;64(5):217-26. https://doi.org/10.1159/000342139. PMID: 23006808.[7]
ARTICLE 8	Tremblay K, Kraus N, Carrell TD, McGee T. Central auditory system plasticity: generalization to novel stimuli following listening training. J Acoust Soc Am. 1997;102(6):3762-73. https://doi.org/10.1121/1.420139 PMID: 9407668.[25]
ARTICLE 9	Krishnamurti S, Forrester J, Rutledge C, Holmes GW. A case study of the changes in the speech-evoked auditory brainstem response associated with auditory training in children with auditory processing disorders. Int J Pediatr Otorhinolaryngol. 2013;77(4):594-604. https://doi.org/10.1016/j.ijporl.2012.12.032. PMID: 23357780.[26]

Source: Developed by the authors.

Stage 2 – Developing the ACAT monitoring program with FFR

The ACAT monitoring program was created after the literature review. The program was designed to be applied to children aged 7 to 12 years, diagnosed with CAPD and undergoing ACAT. It is intended to be used by a qualified speech-language-hearing pathologist with appropriate undergraduate and specialized training, prioritizing aspects of the patient's quality care.

The program was structured to include initial assessment, continuous monitoring, and final assessment, using FFR as the main electrophysiological tool to monitor the children's auditory progress during ACAT. Auditory responses are collected in the initial assessment before the training begins to establish a baseline and compare with subsequent data. Throughout the process, the speech-language-hearing pathologist periodically records the FFR, assessing changes in latency, amplitude, waveform morphology, slope, area, fundamental frequency, and harmonics – indicators of training-induced auditory plasticity. At the end of the ACAT, the FFR is re-recorded and compared with the initial measures, providing objective information on the training's effects on the children's auditory processing. Thus, the program guides clinical practice based on concrete data and provides a parameter for adjusting the treatment to ensure effective and individualized monitoring.

Stage 3 – Program assessment by peers

The study selected 10 speech-language-hearing pathologists with at least 1 year of experience in auditory training to analyze the program's content and verify whether the monitoring program's criteria had appropriate content and clear information for clinical applicability. All professionals received copies of the following documents:

a) A printed copy of the program.

b) A copy of the content assessment questionnaire.

The study authors developed the content assessment questionnaire with five yes/no questions. Its final section had space for the reviewers to make relevant comments or observations regarding the program.

A brief introduction to the research and its objectives and methods was also sent to the evaluators. The researchers adjusted the protocol – including the behavioral auditory processing assessment battery – based on the reviewers' analyses and suggestions. The program included behavioral assessment to provide a comprehensive perspective on the patient's progress. This allows for qualitative data collection, complementing the quantitative data obtained from the FFR, and ensuring a more holistic treatment response assessment.

RESULTS

The program was developed after the literature review and the professionals' assessment. All participating speech-language-hearing pathologists provided key points based on their observations and suggestions. The monitoring program has two parts, described below, and is available in Appendix A:

Behavioral assessment and reassessment

The following tests were selected for behavioral assessment and reassessment, according to the guidelines in the CAP assessment and intervention guide of the Brazilian Federal Speech-Language-Hearing Council (CFFa) (2020)[27]: Pediatric Speech Intelligibility Test (PSI), Binaural Fusion Test, recognition of familiar words in dichotic listening – Dichotic Digits Test (DDT), Duration Pattern Test (DPT), and Random Gap Detection Test (RGDT).

The diotic tests include the Five-Direction Sound Localization Test, which assesses the ability to localize sound after the percussion of a musical instrument; the Sequential Memory Test for Verbal Sounds (SMTV), which evaluates the sequential sound discrimination using the syllables /pa/, /ta/, /ka/, and /fa/; and the Sequential Memory Test for Non-Verbal Sounds (SMTNV), which evaluates sequential sound discrimination using four musical instruments played in different orders[28].

The PSI with an ipsilateral competing message requires the individual to point to the figures corresponding to the sentence they hear while ignoring the competing message (a story presented simultaneously)[29].

The DDT assesses the figure-ground ability for verbal sounds by presenting two simultaneous numbers to the right ear and another two to the left ear, overlapping the pairs[29]. The RGDT measures the ability to detect brief silence intervals, presented binaurally at different frequencies (500 Hz, 1 kHz, 2 kHz, and 4 kHz)[30]. The participant's task is to identify and signal the gaps.

Lastly, the DPT consists of short and long pure tones, separated by 300-ms intervals. Sequences of three tones are presented binaurally, and the participant must repeat the correct sequence. These tests in combination assess different aspects of auditory perception, allowing for a detailed analysis of the person's auditory skills[30].

Electrophysiological assessment – FFR

The FFR is an objective, non-invasive test that can contribute promisingly to investigating verbal sound perception disorders. This research defined the following parameters: An averaged stimulus – the syllable [da] (40 ms) – presented monaurally (first to the right ear, then to the left ear), in alternating polarity at 80 dBnHL and a presentation rate of 10.9 stimuli/second. The recording window was 74.67 ms, with a high-pass filter of 100 Hz and a low-pass filter of 2000 Hz, using two sweeps of 3000 stimuli[31]. After the waves were reproduced, the waveforms were summed with weights, and the waves were marked on the resulting trace.

The components V, A, C, D, E, F, and O were identified, and the absolute latencies, interpeak latencies, amplitudes, slope, and area were recorded for FFR waveform analysis in the time domain.

A signal processing tool is required for the frequency domain spectrum, extracting frequency responses, specifically the fast Fourier transform (FFT). The F0, F1, and F2 and their harmonics and amplitudes should be analyzed after applying the FFT.

DISCUSSION

Pediatric CAPD has been gaining attention, particularly due to its association with specific learning difficulties, attention-deficit/hyperactivity disorder (ADHD), dyslexia, and language disorders. This reflects the growing demand for quick assessment methods to provide screening and differential diagnoses and monitor therapeutic progress. Hence, protocols, scales, and screening tools are increasingly used[32,33].

The recommendations in the CFFa's guide for CAPD assessment and intervention (2020)[27] suggest that the evaluation should use behavioral auditory tests, with batteries covering auditory closure, figure-ground, interaction, binaural integration and separation, resolution, and temporal ordering. The patient's characteristics and clinical history should also be considered when defining the protocol.

ASHA (2005)[3] recommends defining the intervention plan based on the skill deficits and impairments documented in the CAPD assessment, and the patient's history, complementing it with language, neuropsychological, and psychoeducational assessment data[3]. Thus, it seems appropriate to recommend a comprehensive auditory evaluation, including the assessment of auditory acuity and central auditory function, using both behavioral and electrophysiological auditory tests, for better guidance in intervention and auditory stimulation programs[27,33].

The combination of electrophysiological data, such as the FFR, with behavioral assessments is crucial for a more complete view of the effectiveness of auditory training and changes in neural plasticity. The FFR measures the auditory system's response to sound stimuli, providing objective information about auditory processing at the neurophysiological level. On the other hand, behavioral assessments help understand how these neurophysiological responses translate into functional auditory skills in children's daily lives. This integrated approach not only enriches the evaluation but also identifies improvements in neural plasticity resulting from auditory training, providing more robust evidence of the interventions' effectiveness. The intersection of these two areas of assessment can reveal insights into children's auditory and cognitive development, contributing to a more informed and effective therapeutic approach.

Auditory training monitoring should reassess the patient with CAP behavioral and electrophysiological tests[27]. Articles in the national and international literature have used AEPs to monitor the therapeutic effects of auditory training. Studies[1,13,16,20-21,33-36] have used electrophysiological tests such as long-latency auditory evoked potentials (LLAEP/P300), middle-latency auditory evoked potentials (MLAEP), mismatch negativity (MMN), auditory steady-state response (ASSR), and FFR to ensure nonbehavioral responses that provide data on neural activity in response to stimuli. Each of these potentials uses a protocol and a parameter with specific references for the age group or population studied.

AEPs play a crucial role in therapeutic monitoring by revealing changes in neural activity associated with the auditory experience provided by auditory training. The central nervous system's ability to reorganize in response to stimuli, known as neural plasticity, changes the AEP's latency and amplitude parameters after auditory training.

Studies with FFR have become more frequent in the national and international literature, providing quantitative measures of speech stimuli's acoustic properties[37,38]. This technique identifies components in the time and frequency domains, with more consistent analyses of CAPD changes[38-40], and obtains sensitivity and specificity CAP parameters[41]. Another relevant aspect of FFR is its ability to assess the effect of auditory training in children with CAPD, revealing significant changes in post-intervention results. These findings highlight the need to consider neural plasticity in the brainstem in response to verbal stimuli[12].

The literature shows a prevalence of English tools to assess and screen children with auditory and communicative issues, whereas Brazil lacks questionnaires to assess and monitor CAP[42]. To date, the only validated and standardized instrument for the Brazilian national context is the Auditory Processing Domains Questionnaire (APDQ) by Dias and colleagues (2022)[43].

The proposed program was compared with the APDQ, highlighting that the APDQ is a self-assessment questionnaire used to identify children at risk for CAPD and differentiate them from children with ADHD or language disorders. While the APDQ is subjective and focuses on self-reports of auditory and processing difficulties, based on the parents' and teachers' perceptions of the child's auditory and cognitive behavior[43], the program is objective and focuses on continuous reassessment of auditory progress throughout auditory training. It monitors the effectiveness of with an electrophysiological and behavioral approach, involving tests such as sound localization, sequential memory, and dichotic tests.

Given the scarcity of monitoring instruments in the national literature, authors of a systematic review[44] suggested the development of new studies with greater methodological rigor to increase the dissemination and clinical applicability in our country. Thus, the protocol presented in this study is expected to provide new tools to develop and carry out scientific studies and facilitate clinical practice.

One of the challenges faced while developing the assessment program was integrating different types of assessments, such as electrophysiological and behavioral data. This requires a deep understanding of the interrelationships between these approaches for a coherent interpretation of the results. The variety of available instruments makes the selection process challenging, as it is crucial to ensure that the chosen tests are not only relevant to CAPD but also reliable and valid.

To deepen the understanding of the assessment program's effectiveness, future studies should explore its application across different populations and age groups. The diversity in demographic characteristics may influence how CAPD manifests and, consequently, how the tests should be adapted. They should also include electrophysiological parameters other than FFR, such as LLAEP and cortical response measures. Expanding the electrophysiological evaluation could provide a more comprehensive understanding of auditory capabilities and the impact of auditory training on neural plasticity in various populations. Ongoing research in this field could significantly enhance clinical practices and the adaptation of interventions to the specific needs of different groups, fostering more effective and personalized care.

CONCLUSION

The proposed FFR program can be used to monitor auditory skills in children undergoing ACAT.

The monitoring program proposes a structured observation of the effectiveness and efficacy of auditory training, facilitating better therapeutic planning and clinical guidance.

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Authors' contributions:

LDSV: Conceptualization; Data curation; Formal analysis; Methodology; Writing - Original draft; Writing - Review & editing.

IAS: Methodology; Project administration; Resources; Writing - Review & editing.

MHRC, RCCC, TNUS: Data curation; Formal analysis; Writing - Original draft.

ATLC: Supervision; Conceptualization; Data curation; Formal analysis; Validation; Visualization; Writing - Original draft; Writing - Review & editing.

Data sharing statement:

We declare for all due purposes that the research data will be shared in full and will be available after the journal approves its publication, without a time limit or access criteria, other than those provided for by the publishing journal.

APPENDIX A – ACOUSTICALLY CONTROLLED AUDITORY TRAINING: MONITORING PROGRAM WITH FREQUENCY FOLLOWING RESPONSE

PERSONAL DATA

Participant's name: ______________________________ Age: ______

Grade in school: ______________________ Date of birth: ____________

Parents/guardian's name: ____________________ Contact: ____________

COMPLEMENTARY DATA

Referred by: ______________________________________

Reason for assessment: __________________ Date of examination: __________

Speech-language-hearing pathologist in charge: _______________________

PART 1. BEHAVIORAL ASSESSMENT AND REASSESSMENTF AUDITORY PROCESSING

SIMPLIFIED BATTERY FOR ASSESSMENT OF CENTRAL AUDITORY PROCESSING

DIOTIC TEST	Before	After
Sound localization		
Sequential memory test for nonverbal sounds		
Sequential memory test for verbal sounds		

Normal values: sound localization (≥ 4 hits), sequential memory test for nonverbal sounds (≥ 2 hits), Sequential memory test for verbal sounds (≥ 2 hits)

MONOTIC TESTS Pediatric Speech Intelligibility test with ipsilateral competing message (PSI)			Before	After
	ICM (0)	ICM (-15)		
Right ear				
Left ear				

Caption: ipsilateral competing message (ICM)
Normal values: ICM (0) ≥ 80% of hits; ICM (-15) ≥ 60% of hits.

DICHOTIC TESTS Dichotic Digits Test			RESULT	
	Right ear	Left ear	Before	After
Free recall				
Directed attention				

Normal values: Please, verify the age group

TEMPORAL TESTS

DURATION PATTERN TEST			RESULTS	
	Right ear	**Left ear**	**Before**	**After**
Imitation				
Naming				

Normal values: Please, verify the age group

RANDOM GAP DETECTION TEST (RGDT)		
	SMALLER GAP (BEFORE)	**SMALLER GAP (AFTER)**
500 Hz		
1000 Hz		
2000 Hz		
4000 Hz		
MEAN		

Caption: Hertz (Hz)
Normal values: 10 ms

PART 2. ELECTROPHYSIOLOGICAL ASSESSMENT AND REASSESSMENT FREQUENCY-FOLLOWING RESPONSE

Reminder: The reference electrodes should be positioned on the left (M1) and right (M2) mastoids, the active electrode (Fz) on the central and upper portion of the forehead, and the ground electrode (Fpz) on the central and lower portion of the forehead.

REFERENCE PROTOCOL

Transducer	Insert - EAR-phones 3A
Polarity	Alternating
Intensity	80 dB SPL
Presentation	Monaural
Stimuli	Verbal stimuli (/da/) – 40 ms
Impedance between electrodes	≤ 5 kΩ
Band-pass filter	100-Hz high-pass filter and 2000-Hz low-pass filter
Capture window	74.67 ms
Number of average acquisitions	Perform two 3000-stimuli sweeps
Stimulation rate	10.9 stimuli/second

Captions: sound pressure level (SPL), milliseconds (ms), kiloohms (kΩ), Hertz (Hz).

FREQUENCY FOLLOWING RESPONSE IN THE TIME DOMAIN

Frequency following response components – V, A, C, D, E, F, and O

- ELECTROPHYSIOLOGICAL MEASURES BEFORE ACOUSTICALLY CONTROLLED AUDITORY TRAINING (ACAT)

Absolute latency							
Right ear	V	A	C	D	E	F	O
Mean							

Amplitude							
Right ear	V	A	C	D	E	F	O
Mean							

NORMAL ( ) ABNORMAL ( )

Absolute latency							
Left ear	V	A	C	D	E	F	O
Mean							

Amplitude							
Left ear	V	A	C	D	E	F	O
Mean							

NORMAL ( ) ABNORMAL ( )

Interpeak latency									
Right ear	V-A	A-C	C-D	D-E	E-F	F-O	V-C	V-E	V-O
Mean									

NORMAL ( ) ABNORMAL ( )

Interpeak latency									
Left ear	V-A	A-C	C-D	D-E	E-F	F-O	V-C	V-E	V-O
Mean									

NORMAL ( ) ABNORMAL ( )

SLOPE (Right ear) ____________________

SLOPE (Left ear)__________________

AREA (Right ear)______________________

AREA (Left ear) ___________________

- ELECTROPHYSIOLOGICAL MEASURES AFTER ACOUSTICALLY CONTROLLED AUDITORY TRAINING (ACAT)

Absolute latency							
Right ear	V	A	C	D	E	F	O
Mean							

NORMAL ( ) ABNORMAL ( )

Amplitude							
Right ear	V	A	C	D	E	F	O
Mean							

NORMAL ( ) ABNORMAL ( )

Latency							
Left ear	V	A	C	D	E	F	O
Mean							

NORMAL ( ) ABNORMAL ( )

Amplitude							
Left ear	V	A	C	D	E	F	O
Mean							

NORMAL ( ) ABNORMAL ( )

Interpeak latency									
Right ear	V-A	A-C	C-D	D-E	E-F	F-O	V-C	V-E	V-O
Mean									

NORMAL ( ) ABNORMAL ( )

Interpeak latency									
Left ear	V-A	A-C	C-D	D-E	E-F	F-O	V-C	V-E	V-O
Mean									

NORMAL ( ) ABNORMAL ( )

SLOPE (Right ear) ____________________

SLOPE (Left ear)__________________

AREA (Right ear)______________________

AREA (Left ear) ___________________

FREQUENCY FOLLOWING RESPONSE IN THE FREQUENCY DOMAIN

- ELECTROPHYSIOLOGICAL MEASURES BEFORE ACOUSTICALLY CONTROLLED AUDITORY TRAINING (ACAT)

Frequency							
Right ear	F0	F1	F2	F0	H1	H2	
Mean							

NORMAL ( ) ABNORMAL ( )

Captions: fundamental frequency (F0), first formant (F1), second formant (F2), first harmonic (H1), second harmonic (H2).

Amplitude							
Left ear	F0	F1	F2	F0	H1	H2	
Mean							

NORMAL ( ) ABNORMAL ( )

Captions: fundamental frequency (F0), first formant (F1), second formant (F2), first harmonic (H1), second harmonic (H2).

- ELECTROPHYSIOLOGICAL MEASURES AFTER ACOUSTICALLY CONTROLLED AUDITORY TRAINING (ACAT)

Frequency							
Right ear	F0	F1	F2	F0	H1	H2	
Mean							

NORMAL ( ) ABNORMAL ( )

Captions: fundamental frequency (F0), first formant (F1), second formant (F2), first harmonic (H1), second harmonic (H2).

Amplitude							
Left ear	F0	F1	F2	F0	H1	H2	
Mean							

NORMAL ( ) ABNORMAL ( )

Captions: fundamental frequency (F0), first formant (F1), second formant (F2), first harmonic (H1), second harmonic (H2).

HAVE THE WAVES IMPROVED AFTER THE ACAT? ______________________________