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ORIGINAL ARTICLE

Effect of contralateral stimulation on acoustic reflectance measurements☆,☆☆

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KEYWORDS
Hearing;
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Abstract
Introduction: Acoustic reflectance is an important tool in the assessment of middle ear afflictions, and the method is considered advantageous in relation to tympanometry. There has been a growing interest in the study of contralateral acoustic stimulation and its effect on the activation of the efferent auditory pathway. Studies have shown that the introduction of simultaneous stimulation in the contralateral ear generates alterations in auditory response patterns.
Objective: To investigate the influence of contralateral stimulation on acoustic reflectance measurements.
Methods: Case study of 30 subjects with normal hearing, of both genders, aged 18–30 years. The test and retest acoustic reflectance was conducted in the frequency range 200–6000 Hz. The procedure was repeated with the simultaneous presence of contralateral white noise at 30 dBNS.
Results: The analysis of the conditions of test, retest, and test with contralateral noise showed statistical difference at the frequency of 2 kHz ($p = 0.011$ and $p = 0.002$ in test and retest, respectively) in the right ear.
Conclusion: The activation of the auditory efferent pathways through contralateral acoustic stimulation produces alterations in response patterns of acoustic reflectance, increasing sound reflection and modifying middle ear acoustical energy transfer.

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PALAVRAS-CHAVE
Audição;
Orelha média;
Reflexo acústico;
Testes auditivos

Efeito da estimulação contralateral nas medidas de reflectância acústica

Resumo
Introdução: A reflectância acústica é citada como uma importante ferramenta na avaliação das afecções da orelha média, sendo um método considerado vantajoso em relação à timpanometria. Tem havido crescente interesse no estudo da estimulação acústica contralateral e seu efeito na ativação da via eferente auditiva. Estudos têm demonstrado que a introdução de estímulo simultâneo na orelha contralateral gera mudanças no padrão de respostas auditivas.
Objetivo: Verificar a influência da estimulação contralateral nas medidas de reflectância acústica.
Método: Estudo de casos de 30 sujeitos com audição normal, de os gêneros entre 18 a 30 anos. Foi realizado o teste e reteste de reflectância acústica no intervalo de frequência de 200 a 6000 Hz. O procedimento foi repetido com a presença simultânea de ruído branco contralateral à 30 dBNS.
Resultados: A análise entre as condições de teste, reteste e teste com ruído contralateral apresentou diferença estatística na frequência de 2 kHz ($p = 0{,}011$ em teste e $p = 0{,}002$ em reteste) em orelha direita.
Conclusão: A ativação da via auditiva eferente por meio da estimulação acústica contralateral produz mudanças nos padrões de respostas da reflectância acústica, aumentando a reflexão do som e, modificando a transferência de energia sonora da orelha média.

Introduction

The use of acoustic immittance at a frequency of 220 Hz has contributed to the clinical diagnosis of middle ear disorders, especially those associated with a change of stiffness in the system. Several authors have suggested that the use of additional frequencies besides 220 Hz can provide data on the tympanum-ossicular system behavior, especially when stimulated by high tones.[1–6]

An alternative line of research on middle ear function in adults and children has used measures of acoustic immittance in a static pressure environment with a wide range of frequencies.[7] They are the so-called admittance and reflectance tests. The acoustic reflectance is the ratio of energy reflected from a surface over the energy that reaches the surface (incident energy). This concept shows how much energy is reflected by the tympanic membrane and how much is absorbed by the middle ear. Acoustic reflectance systems can measure a wide range of frequencies; because the acoustic reflectance is mathematically related to the impedance and admittance, it is possible to derive any quantity of immittance from the reflectance measurements.

Over several years, acoustic reflectance measurements have been described as an important tool in the assessment of middle ear disorders.[7–12] Acoustic reflectance measurements have potential advantages over tympanometry, particularly in children. First, ear canal pressurization is not necessary, and thus there is no distortion in the canal. Second, the measures are performed over a range of frequencies, instead of a single frequency evaluated in tympanometry. And finally, the measures can be quickly obtained. Therefore, it is possible that the acoustic reflectance measurements can provide more information, more quickly than tympanometry in the diagnosis of middle ear dysfunctions.

The hearing system consists of auditory afferent and efferent pathways that operate jointly. The auditory efferent pathway has connections from the cortex to the most peripheral structures. In this pathway, the efferent motor neuron systems are highlighted, with the olivocochlear tract responsible for sending fibers to the spiral body and the motor neurons of the middle ear muscles.[13–16]

There has been a growing interest in the study of contralateral acoustic stimulation and its effect on the auditory efferent pathway activation. Studies have shown that the introduction of simultaneous stimulation in the contralateral ear generates changes in the auditory response patterns, both in otoacoustic emission (OAE) measurements and in auditory evoked potentials (AEP), with a reduction in response amplitude observed.[17–20] Simultaneous contralateral stimulation also has been shown to increase acoustic immittance reflex thresholds.[21,22]

The auditory efferent pathways, through the integrated action of the auditory system, modify the response of the outer hair cells and activate the reflex of the middle ear muscles. This principle gave rise to the hypothesis that acoustic reflectance, being a high-resolution measure, could identify possible changes in the middle ear energy transfer, when the efferent auditory pathway is activated through white noise in the contralateral ear.

There are no similar studies in the literature that have provided clues on the effect of this stimulation on the profile of acoustic reflectance curves. Therefore, the aim of this study is to investigate the influence of contralateral stimulation by white noise on the middle ear acoustic reflectance measurements in young adults.

Methods

This was an observational study of a contemporary cohort. The present study was developed in a laboratory of human hearing research, after being approved by the Research Ethics Committee through protocol 212/10.

Sample

Participants were recruited among the university students of the teaching and research center of the institution. The sample consisted of 30 participants, 15 males and 15 females, aged 18–30 years. To avoid influence of laterality or cerebral dominance, all subjects showed right lateral dominance according to Edinburgh Inventory.[23]

Inclusion criteria for this study were: absence of middle ear disorders detected at tympanometry (type A curve) and no history of otitis during childhood nor in the past five years; ipsilateral acoustic reflexes present at the frequencies of 500–4000 Hz; and hearing thresholds up to 20 dB.

Equipment

The following were used:

1. Protocol for identification data registry and investigation of complaints related to hearing;
2. GSI 61 – Grason Stadler Audiometer – The equipment complies with the ANSI S 3,6-1989; ANSI S3,43-1992; IEC 645-1(1992); IEC 645-2(1993); ISO 389; and UL 544 standards. Insertion earphones in a calibrated transducer for the ER-Etymotic model were used for threshold audiometry (250–8000 Hz) and white noise threshold assessment.
3. An AT235 micro-processed Middle Ear Analyzer with two tone frequencies in the immittance probe: 226 Hz was used for automatic tympanometric measures at the rate of 50 daPa/s, whereas the manual form of equipment was used for the measurements of ipsilateral acoustic reflexes.
4. MEPA3 – Middle-Ear Power Analysis – Mimosa Acoustics – used to obtain the reflectance measurements through the clinical module program MEPA 3, with the following technical characteristics:
   Frequency range: 169–6613 Hz
   Stimulus intensity: 60 dBNPS
   Sample time (window): 0.1–10 s per point
   Stimulus: ''Chirp''
   Probe: Etymotic Research ER 10C
   Latex eartips in eight adaptable sizes for children and adults

The MEPA equipment was calibrated in an acoustically treated room and the reflectance test was conducted inside the soundproof booth where audiometry was performed.

Procedures

Initially the subjects were informed about the study aims and procedures and, after agreeing to participate, they signed the informed consent.

The procedures were performed in a single session lasting approximately 20 min. Identification data registry was carried out using a specific protocol and the anamneses included complaints related to hearing and otological history in childhood and the past five years, as the subjects could not have complaints or history of otitis to be included in the study. Next, the subjects were instructed to complete the Edinburgh Inventory to assess laterality or cerebral dominance influence.

After these steps, the subjects were submitted to the following procedures:

1. Inspection of the external auditory meatus.
2. Imitanciometry consisting of tympanometry with probes of 226 and 1000 Hz and acoustic reflex assessment in the ipsilateral and contralateral modalities at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz.
3. Pure-tone threshold audiometry at the frequencies of 250–8000 Hz at 10-dB down and 5-dB up method, with starting frequency at 1000 Hz, followed by the frequencies of 2000, 3000, 4000, 6000, 8000, 500, and 250 Hz. White noise threshold assessment was performed to define the basal value for the noise input at the same intensity ratio. Thus, the level of 30 dB SL (decibel sensation level) was used for noise intensity. The noise was generated by the GSI 61 audiometer and provided through insertion phones in a calibrated transducer for the ER-Etymotic model.
4. Middle ear reflectance assessment in three steps: (A) Obtaining the reflectance curve in the frequency range 200–6000 Hz at an intensity of 60 dB SPL. Each stimulus lasted 0.1–10 s per point. Collection was carried out with the chirp acoustic stimulus. (B) Retest to confirm the obtained reflectance curve. (C) The procedure was repeated, with the simultaneous presence of contralateral noise through insertion phones at 30 dBNS in relation to the white noise threshold. In the end, three measures were obtained in each ear. Based on the three measures, the difference between the response levels collected with and without contralateral noise was calculated.

Statistical analysis

Data were automatically exported by MEPA equipment to Microsoft Excel software. To determine whether there was a response alteration at each assessed frequency with and without contralateral noise, increase or decrease was considered when the subtraction of values was different from zero.

The variables were submitted to statistical analysis and the 5% significance level was used to reject the null hypothesis for all analyses.

Results

Table 1 and Fig. 1 show the results of the comparative analysis of the different assessment conditions for the chirp stimulus.

Statistical differences were observed at the frequency of 2 kHz for the chirp stimulus in the right ear when comparing the test to the test with contralateral noise, as well as when

Table 1 Descriptive statistics of the acoustic reflectance between the comparisons of test, retest, and test with contralateral noise conditions for the chirp stimulus in the right ear.

Chirp reflectance RE		Mean	Median	Standard deviation	CV	Min	Max	*n*	CI
250 Hz	Test	91.81	93.26	5.40	6%	78.42	100.00	30	1.93
	Retest	91.64	93.29	6.25	7%	75.46	99.39	30	2.24
	With noise	91.93	93.05	5.60	6%	76.12	100.00	30	2.01
500 Hz	Test	79.01	79.88	13.37	17%	48.51	99.22	30	4.78
	Retest	79.28	79.95	13.02	16%	50.24	98.81	30	4.66
	With noise	78.79	78.81	12.83	16%	47.46	100.00	30	4.59
750 Hz	Test	61.48	60.71	17.84	29%	23.94	89.06	30	6.38
	Retest	61.29	59.78	17.72	29%	23.99	88.08	30	6.34
	With noise	61.43	60.78	17.97	29%	25.11	88.34	30	6.43
1 kHz	Test	47.32	46.85	18.10	38%	9.09	79.81	30	6.48
	Retest	47.37	47.35	17.73	37%	9.08	80.22	30	6.34
	With noise	47.59	47.05	18.02	38%	8.34	82.08	30	6.45
1.5 kHz	Test	39.96	40.65	15.80	40%	1.66	64.35	30	5.65
	Retest	39.86	41.23	15.86	40%	2.07	65.28	30	5.68
	With noise	39.85	41.09	15.81	40%	3.01	64.80	30	5.66
2 kHz	Test	40.27	45.48	17.62	44%	3.85	75.57	30	6.30
	Retest	40.30	45.61	17.91	44%	4.01	75.46	30	6.41
	With noise	41.10	45.19	17.65	43%	4.66	75.43	30	6.32
3 kHz	Test	36.68	40.06	18.73	51%	3.27	75.51	30	6.70
	Retest	36.70	39.34	18.83	51%	3.28	75.18	30	6.74
	With noise	37.01	38.14	18.72	51%	3.37	75.99	30	6.70
4 kHz	Test	45.56	47.09	17.16	38%	4.16	79.37	30	6.14
	Retest	45.96	47.12	16.83	37%	4.00	79.57	30	6.02
	With noise	45.65	46.70	16.98	37%	5.55	80.46	30	6.08
6 kHz	Test	74.50	77.02	19.32	26%	31.56	105.45	30	6.91
	Retest	74.95	78.35	19.57	26%	33.00	107.95	30	7.00
	With noise	75.05	78.40	19.64	26%	33.51	109.65	30	7.03

RE, right ear; CV, coefficient of variation; *n*, number of ears; CI, confidence interval.

comparing the retest and the test with contralateral noise, with *p*-values of 0.011 and 0.002 for the comparisons of the test and the retest, respectively.

Regarding the left ear, there was no statistical difference when comparing the test, retest, and test with contralateral noise situations for the chirp stimulus. The results are shown in Table 2 and Fig. 2.

Discussion

In the literature the middle ear is classically described as a mechanical-acoustic energy transmitter with a linear characteristic, that both allows the passage of, and some resistance to, sound.[7,24] Only at high intensities does the middle ear lose this linear characteristic, as there is a contraction of intratympanic muscles with high sound stimulus situations. The reflex action of these muscles is directly involved in auditory system protection from high intensity sounds.[24–26]

At the frequency of 2 kHz in the right ear for the chirp stimulus, a statistical difference was observed when comparing the test and retest conditions with the test condition with contralateral noise. The mean responses increased when the auditory efferent pathway was activated. The resulting inhibitory effect would act as an auditory system protection, making the system increase sound reflection. Thus, the energy transfer through the middle ear is lower, preventing damage to the auditory system and improving noise discrimination, especially in noisy environments, demonstrating that the middle ear may be the first auditory system selection filter, as previously suggested by another study.[24] It is noteworthy that these results were observed in right-handed individuals with right side dominance, confirmed by the Edinburgh Inventory. Thus, our study detected an advantage of the right when submitted to auditory efferent pathway activation, as was observed in other auditory system studies.[17,27] The discussed subject is whether the same right ear advantage would be observed in left-handed individuals and thus, studies on the subject are necessary.

The WN intensity utilized was 30 dBNS, mirroring other studies.[21,22] This intensity was used to activate the auditory efferent pathway without activating the acoustic reflexes. The contralateral suppression of the acoustic reflex can be used to verify the efferent pathway function when the auditory system is subjected to high intensity levels,[27] but under

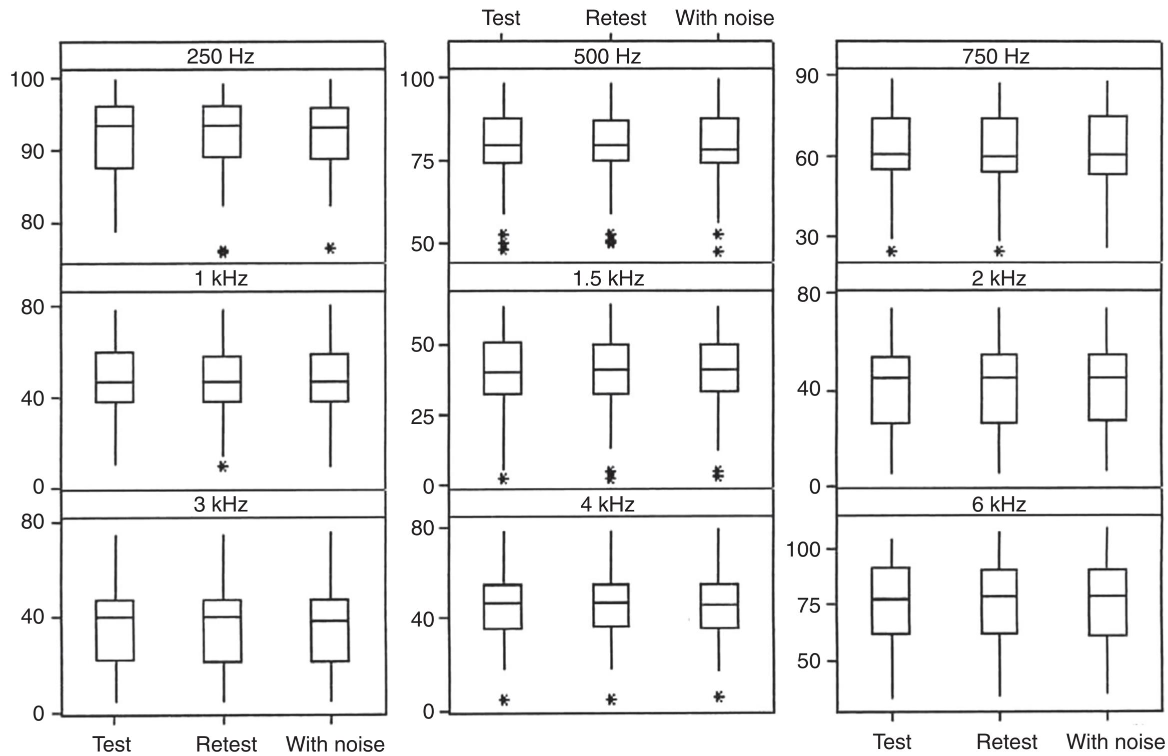

Figure 1 Box plot of comparisons of responses between test, retest, and test with contralateral noise conditions in the right ear.

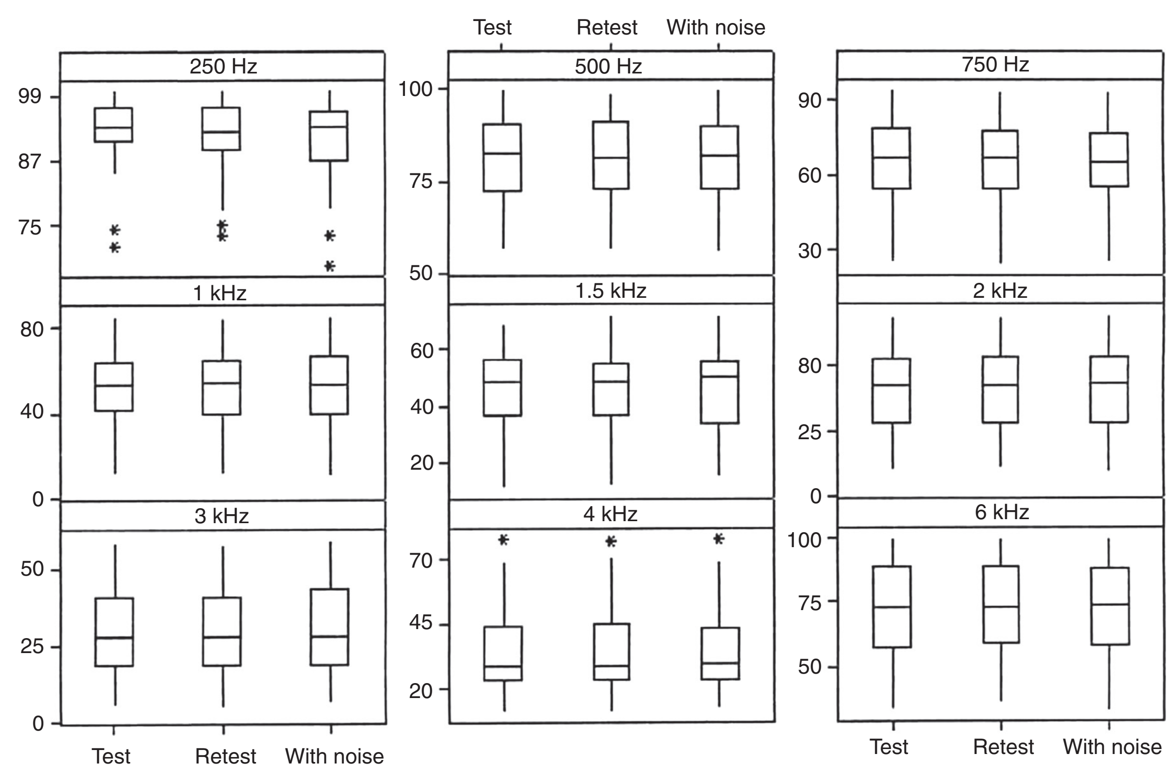

Figure 2 Box plot of comparisons of responses between test, retest, and test with contralateral noise conditions in the left ear.

Table 2 Statistical analysis of the acoustic reflectance between the comparisons of test, retest, and test with contralateral noise conditions for chirp stimulus in the left ear.

Chirp reflectance LE		Mean	Median	Standard deviation	CV	Min	Max	*n*	CI
250 Hz	Test	92.15	93.21	6.80	7%	70.95	100.00	30	2.43
	Retest	91.54	92.29	7.29	8%	72.70	100.00	30	2.61
	With noise	90.66	93.06	8.01	9%	66.98	100.00	30	2.87
500 Hz	Test	81.90	82.49	10.90	13%	56.09	100.00	30	3.90
	Retest	81.95	81.20	10.65	13%	56.12	98.78	30	3.81
	With noise	81.96	82.23	11.15	14%	55.98	100.00	30	3.99
750 Hz	Test	64.83	66.56	16.23	25%	23.91	93.91	30	5.81
	Retest	64.92	66.56	16.39	25%	23.24	93.43	30	5.87
	With noise	64.83	64.82	16.12	25%	24.44	92.96	30	5.77
1 kHz	Test	53.24	53.28	17.73	33%	11.11	85.28	30	6.34
	Retest	53.22	54.80	18.32	34%	10.78	84.79	30	6.55
	With noise	53.51	53.37	18.22	34%	9.67	85.58	30	6.52
1.5 kHz	Test	44.66	48.37	15.65	35%	9.97	68.72	30	5.60
	Retest	45.18	48.28	15.48	34%	11.20	71.86	30	5.54
	With noise	44.84	49.86	16.27	36%	14.47	71.92	30	5.82
2 kHz	Test	40.80	42.73	14.54	36%	9.43	69.17	30	5.20
	Retest	41.18	42.53	14.33	35%	10.30	69.11	30	5.13
	With noise	41.43	43.98	14.77	36%	8.69	70.00	30	5.29
3 kHz	Test	29.35	27.85	15.32	52%	5.16	59.20	30	5.48
	Retest	29.28	27.64	15.12	52%	4.99	58.19	30	5.41
	With noise	29.74	27.47	15.43	52%	6.30	59.52	30	5.52
4 kHz	Test	35.08	28.29	16.75	48%	10.24	77.98	30	5.99
	Retest	34.95	28.24	16.97	49%	10.73	77.78	30	6.07
	With noise	35.07	29.26	17.01	48%	12.12	77.87	30	6.09
6 kHz	Test	72.79	72.64	18.32	25%	33.21	100.07	30	6.56
	Retest	73.02	73.21	18.29	25%	35.86	100.00	30	6.54
	With noise	73.25	73.58	18.38	25%	32.34	100.00	30	6.58

LE, left ear; CV, coefficient of variation; *n*, number of ears; CI, confidence interval.

the influence of contralateral acoustic stimulation, changes in the latency and threshold acoustic reflex responses are observed.[21,22] Studies with OAE and AEP used contralateral stimulation level at the intensity of 60 dB HL;[20,28–30] however, a study comparing different levels of contralateral stimulation observed that an intensity lower than or equal to 50 dB HL did not affect the clinical recording of N1 and P2 waves.[30]

The influence of the auditory efferent pathway pervades the entire auditory system, ranging from the most central to the most peripheral portion. Studies with OAE, BAEP (brainstem auditory evoked potential), and medium- and long-latency AEP with contralateral acoustic stimulation provide information that there is an alteration of the responses in these procedures.[20,31–34] With the same purpose, but assessing the middle ear, some authors[21,22] associated response alterations to the auditory efferent pathway influence on that portion of the auditory system. The findings of this study suggest that the auditory efferent pathway acts on the middle ear causing changes in patterns of acoustic reflectance responses.

Conclusion

When the auditory efferent pathway is stimulated by contralateral acoustic stimulus with white noise, there is a statistical difference at the frequency of 2 kHz in the right ear for the chirp stimulus for both test and retest conditions. This effect consistency shows that the auditory efferent pathway influences acoustic energy transfer by the middle ear, with right-ear advantage and at medium frequency.

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Conflicts of interest

The authors declare no conflicts of interest.

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