BEHAVIORAL ASSESSMENT OF AUDITORY PROCESSING AFTER CRANIOENCEPHALIC TRAUMA: PILOT STUDY

Avaliação comportamental do processamento auditivo em indivíduos pós- traumatismo cranioencefálico: estudo piloto

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ABSTRACT

Purpose: to characterize the performance of individuals after traumatic brain injury in behavioral tests to evaluate auditory processing. **Method:** the participants of this research were 10 individuals with normal hearing with traumatic brain injury. They were submitted to: pure tone audiometry, speech audiometry, acoustic immittance measures (tympanometry and acoustic reflex) and behavioral evaluation of auditory processing (Sound Location Test, Verbal Sequential Memory, Non Verbal Sequential Memory, Duration Pattern Sequence Test, Dichotic Consonant-vowel, *Staggered Spondaic Word* (Portuguese version), Identification of synthetic sentences with competitive message, *Random Gap Detection Test*, Percentage Index of Speech Recognition with recording, speech test). **Results**: the test of Duration Pattern indicated the test with the largest number of alteration (60%). The test with the most satisfactory average was the Percentage Index of Speech Recognition with recording (93%) and the less satisfactory average test was related to dichotic consonant-vowel (40,56%). The reversals (70%) represented the tendency of more frequent errors in the SSW. The damage of decoding was the most prevalent (100%), followed by the organization (90%), supra-segmental (60%) and encoding-gradual loss of memory (20%). There was no damage of encoding-integration. **Conclusions:** the patients after traumatic brain injury present auditory processing disorders of varying degrees, involving the processes of decoding and organization.

KEYWORDS: Hearing; Craniocerebral Trauma; Auditory Perceptual Disorders; Hearing Tests; Hearing Disorders

INTRODUCTION

Traumatic brain injury (TBI) is defined as any trauma that leads to anatomical and/or functional impairment of the cranium, meninges, scalp, brain or its vessels.[1]

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Conflict of interest: non-existent

Cranioencephalic injuries can be classified as primary or secondary. Primary injuries occur at the time of the trauma.[2] Secondary injuries are the that ones begin after the accident, resulting from the interaction of intra and extracerebral factors that aggregate to derail the survival of encephalic cells spared by the initial trauma.[3,4]

TBI incidence is greater among males and adults under 40 years of age.[5] The principal causes of TBI include automobile, motorcycle, bicycle and firearm accidents, falls and other less common causes.[6]

Auditory processing of sensory information depends on the organic and functional integrity of the entire auditory system, which includes the peripheral portion (external, middle and internal ear and the VIII cranial nerve) and the central portion (brainstem and cortical/subcortical regions).[7]

An assessment of the central auditory nervous system (CANS), a complex system of neural pathways, is therefore crucial in individuals with TBI since there is a link to cerebral deformation after extreme acceleration and deceleration of the head. The external, middle and internal ears, as well as the auditory nerve, can be compromised by a cranial trauma. Therefore, an assessment of the integrity of the central and peripheral auditory nervous system must not be ignored in such cases.[8]

Auditory processing refers to what is done with what an individual hears.[9] It is not enough to simply possess normal hearing thresholds. It is essential that the acoustic signal is analyzed and interpreted in order to be transformed into a meaningful message. Auditory processing disorder is a specific dysfunction of the auditory processes but may also be associated with deficits of language, memory and attention, among others.[10]

Auditory processing disorders can affect communication, learning and professional and social fulfillment. Therefore, it is of fundamental importance that audiologists assess the integrity of the CANS in TBI patients for full documentation and to maximize the efficiency of treatment as well as the reconstruction of the patients' life.[9]

Considering the association between auditory perception and cranioencephalic trauma, the aim of the present study was to evaluate the performance of post-TBI individuals in behavioral tests to assess auditory processing.

METHOD

Data collection was carried out in the Neurology and Speech Pathology departments. All participants signed an informed statement of consent.

The casuistry was composed of ten individuals, eight males and two females, aged between 13 and 42 years (mean of 28 years). All of these individuals were affected by a closed head injury, of various types, and were being assessed and/or rehabilitated in two out-patients clinics of the São Paulo city hospital (Brazil). Injuries were confirmed by neurologists who performed neuroimaging examinations such as nuclear magnetic resonance or computerized tomography of the cranium.

Inclusion criteria in the present study were as follows: aged both genders between 12 and 55 years; hearing thresholds within normal limits (less than or equal to 25dBHL) between 250 and 4000Hz, and affected by a closed head injury, of various types (Figure 1).

Type of Injury
1. Not specified.
2. Fractures of the temporal bone and the right greater sphenoid wing and nasal bones.
3. Signs of front-temporal or left parietal craniotomy.
4. Not specified.
5. Diffuse axonal injury/ Frontal, temporal and parietal contusions/ punctate brain hemorrhage.
6. Diffuse injury in the parietal and left occipital lobe.
7. Left frontal bone fracture, subgaleal, frontal and right parietal hematoma and peripheral edema in the left temporal area.
8. Injury sequelae in frontal and right temporal lobe. Dilation of the ventricular system.
9. Diffuse axonal injury and frontal hematoma.
10. Left-sided contusion and diffuse axonal injury.

Figure 1 – Diagnostic impression of injuries among the participants

The basic auditory assessment consisted of the following: anamnesis, otoscopy, pure tone audiometry, speech audiometry, tympanometry and contralateral acoustic reflexes. The following auditory tests in free field (dichotic task) were used to assess auditory processing: Sound Localization Test (SLT); Verbal Sequential Memory Test (VSMT) and the Non-Verbal Sequential Memory Test (NVSMT).

Other behavioral tests were conducted in a soundproof booth under headphones with a compact disc player (TDH-39) coupled to an audiometer with two channels (GSI-61). The tests conducted were as follows: Duration Pattern Sequence Test (DPST); Dichotic Consonant-vowel Test (DCVT); Staggered Spondaic Word Test (SSW); Synthetic Sentence Identification with ipsilateral and contralateral competing message (PSI/SSI); Random Gap Detection Test (RGDT) and the Speech-in-Noise Test (SNT). A 1000 Hz calibration tone was used for the audiometry channels recorded on each of the CD's used. The tests were applied following previously published methodology.[11] The present study was approved by the Human Research Ethics Committee under protocol number 1609/09.

After collection, the data were recorded in an excel spreadsheet and submitted to the pertinent statistical analysis. The results of all behavioral tests related to auditory processing were analyzed. The results were described based on two types of analysis: the percentage of people from the group with abnormal results for each test and the mean score of the group for each test.

RESULTS

The casuistry was composed of young adults with a mean age of 28 years old and a predominance of right manual preference. Auditory processing was found to be abnormal in 100% of the participants. Severely affected auditory processing was the most common (40%), followed by moderately affected (20%) and mildly affected (20%). Therefore, 80% of individuals were affected as shown by the quantitative SSW analysis.

Among the full group of participants, abnormal results were exhibited by 60% in the DPST, 50% in the RGDT, 40% in the DCTV, 20% in the NVSMT and 10% in the SLT, VSMT, PSI/SSI and the SNT. None of the participants exhibited abnormal WRS results (Table 1).

The mean results were as follows: WRS – 93%, SNT – 89%, SLT – 84%, VSMT – 83.3%, PSI/SSI – 81%, SSW – 75.3%, NVSMT – 71.3%, DPST – 66%, DCVT – 40.56%, RGDT – 8.68% (Tables 2 and 3).

Table 1 – Percentage of individuals with normal and abnormal development in the tests conducted (N=10)

Tests	Normal	Abnormal
SLT	90%	10%
VSMT	90%	10%
NVSMT	80%	20%
PISR	100%	0
SNT	90%	10%
SSW	20%	80%
PSI/SSI	90%	10%
DCVT	60%	40%
DPST	40%	60%
RGDT	50%	50%

Legend: SLT- Sound Location Test; VSMT- Verbal Sequential Memory Test; NVSMT- Non-Verbal Sequential Memory Test; PISR- Percentage Index of Speech Recognition with recording; SNT- Speech-in-Noise Test; SSW- Staggered Spondaic Word Test; PSI/SSI- Synthetic Sentence Identification – monotic condition (FR-10); DCVT- Dichotic Consonant-vowel Test; DPST- Duration Pattern Sequence Test; RGDT- Random Gap Detection Test.

During the qualitative analysis of the SSW test in Portuguese, it was found that inversions (70%) occurred most frequently, followed by the high-low auditory effect (20%), low-high auditory effect (10%), high-low order effect (10%), low-high order effect (10%) and type-A response pattern (10%).

The gnosic process of decoding was the most prominent among the participants (100%), followed by organization (90%), non verbal (60%), and encoding/memory (20%). None of the participants exhibited abnormal results for the gnosic process of encoding/integration.

DISCUSSION

The casuistry consisted of individuals affected by TBI. Previous studies in the literature show that, in many patients, the central and peripheral auditory systems are affected by brain injuries. The population of the present study was selected. Very few studies have investigated the performance of TBI patients in behavioral tests related to the central auditory system.[12] Extensive research in various databases confirmed the scarcity of studies related to TBI and special auditory tests. Furthermore, it is important to confirm that the variety of injuries does not permit the establishment of a performance

Table 2 – Mean results of individuals in all tests conducted (N=10) without differentiation of ears

	SLT	VSMT	NVSMT	DPST	RGDT
1	100%	100%	100%	33%	*
2	100%	100%	66.60%	40%	6.25ms
3	40%	0%	33.30%	86%	13.75m
4	100%	100%	33.30%	73%	7.5ms
5	80%	66.60%	100%	50%	10ms
6	80%	100%	80%	87%	11.25ms
7	80%	66.60%	100%	90%	2ms
8	80%	100%	66.60%	43%	*
9	80%	100%	33.30%	73%	12.5ms
10	100%	100%	100%	86%	6.25ms
Mean	83.3%	81%	66%	40.56%	8.68ms

Legend: SLT- Sound Location Test; VSMT- Verbal Sequential Memory Test; NVSMT- Non-Verbal Sequential Memory Test; DPST- Duration Pattern Sequence Test; RGDT- Random Gap Detection Test.
*Patients that were unable to participate in the test.

Table 3 – Mean results of individuals in all tests conducted (N=10) with differentiation of ears

	PISR		SNT		PSI/SSI		DCVT		SSW	
	RE	LE	RE	LE	RE	LE	RE	LE	RE	LE
1*	96%	96%	76%	92%	80%	90%	12.50%	79.10%	47%	92%
2	88%	88%	96%	88%	80%	100%	50%	29.10%	65%	52%
3*	88%	88%	88%	84%	100%	80%	41.60%	41.60%	60%	67%
4	88%	84%	88%	72%	80%	100%	54.10%	16.60%	90%	30%
5	88%	96%	80%	92%	90%	90%	58.30%	20.80%	90%	92%
6	100%	100%	96%	92%	70%	70%	75%	16.60%	70%	75%
7	96%	92%	88%	88%	60%	70%	58.30%	29.10%	85%	85%
8	92%	96%	96%	92%	80%	70%	70.30%	12.50%	87%	87%
9	100%	100%	96%	96%	80%	90%	37.50%	29.10%	100%	90%
10*	92%	92%	84%	96%	70%	70%	29.10%	50%	47.50%	95%
Mean of both ears	93%		89%		81%		40.56%		75.30%	

Legend: PISR- Percentage Index of Speech Recognition with recording; SNT- Speech-in-Noise Test; PSI/SSI- Synthetic Sentence Identification test – monotic condition (FR-10); DCVT- Dichotic Consonant-vowel Test (free attention step); SSW- Staggered Spondaic Word Test; RE- Right Ear; LE- Left Ear.
*Left-handed individuals.

standard among the participants. Thus, the present study was considered to be a pilot study.

TBI can result in significant central auditory deficits, even in the absence of radiological evidence and any obvious deficit in the peripheral auditory system.[12] A total of 80% of the participants of the present study were male whereas 20% were female. Brain injuries are more common among males, particularly in the case of injuries related to automobile accidents.[5]

The casuistry consisted of individuals ranging from 13 to 42 years of age, with a mean age of 28 years. This demonstrates that young adults are part of the risk group for TBI. Only 10% of the participants of the present study exhibited abnormal results in the SLT and VSMT whereas 20% of the NVSMT results were abnormal. This finding confirms that the participants performed better in tests which did not differentiate between ears.

With the exception of the frequency pattern test (FPT), which was not used in the present study, 60% of the participants exhibited abnormal DPST results. This corroborates with previous studies[13,14], in the conclusion that various brain injuries, total or partial section of the posterior corpus callosum or any disorder in the operation of one of the hemispheres will bilaterally affect the performance in frequency pattern and duration tests.

A total of 90% of the participants performed well in the PSI/SSI test. This test was applied in another study of individuals with a single cortical injury, in monotic and dichotic conditions. The patients exhibited significant comprehension difficulties in relation to an ipsilateral competitive message, signal to noise ratios of 0dB and –10dB, as well as a contralateral competitive message (-40dB).[15]

A study of the auditory processing of athletes with brain concussions confirmed abnormalities in over half of the participants in one or more of the tests applied (FPT, DPST, PSI/SSI, SSW)[16]. Based on these results, the variation profile of the auditory processing deficit could be explained by the relatively heterogeneous profile of the injury,[17] similar to the present study. This finding is consistent in the literature in which auditory processing disorder in itself is considered quite heterogenous.[18]

A case study was conducted with a 49-year old individual who had suffered a TBI and complained of speech comprehension problems dating from the time of the accident. The behavioral assessment of auditory processing revealed the following abnormalities: figure-ground for linguistic sounds (SSW and Pediatric Speech Intelligibility (PSI) test), temporal patterns and verbal memory.[19] These abnormalities were also found in the present study. Participants performed poorly in tests involving figure-ground for linguistic sounds (SSW) and temporal patterns (FPT).

The quantitative analysis of the SSW results demonstrated that the participants had an accuracy rate of 75.3%. This fact led to a classification of moderately impaired auditory analysis, which highlights the significant difficulty of following instructions in noisy environments. The abnormality found in the qualitative SSW analysis revealed an impairment of the gnosic process of decoding, as well as error trends related to low-high order effect and high-low auditory effect.

With regard to significant error trends, it was found that 70% of the participants exhibited inversions; 20% recorded high-low auditory effect; and 10% registered low-high auditory effect, high-low order effect, low-high order effect and type-A response pattern. These results, as well as the abnormal performance in the verbal and non-verbal sequential memory tests indicate abnormalities in the memory of individuals affected by TBI, a common symptom in this population. The difference between these sequential memory tests and the SSW test is the level of complexity of the exercise. During the sequential memory tests, particularly for non-verbal sounds, the patient may benefit from the assistance of spatial clues.

Auditory processing was mildly and moderately affected in 20% of the participants whereas 40% were severely affected. This result for the severely affected participants highlights the significant difficulty of conversing in a noisy environment.

Among the categories of auditory processing disorder, the gnosic process of decoding was the most frequent (100%), followed by the gnosic processes of organization (90%), non-verbal (70%), encoding/memory (20%). No abnormalities were found related to encoding impaired by auditory-visual integration, possibly due to the ease of performing the PSI/SSI tests. This corroborates with previous studies in the literature.[20] An impaired auditory gnosic process refers to the inability to attribute meaning to the phonemic information of the language.[11]

Abnormal auditory processing was frequent in the population of the present study (100%). A behavioral assessment of auditory processing should form part of any assessment of the sequelae resulting from TBI. Furthermore, therapy for individuals with TBI and abnormal auditory processing should emphasize the training of auditory skills that underlie the often-impaired gnosic processes, thereby aiming to improve the quality of life of these patients.

It is of paramount importance that individuals affected by TBI are submitted to a battery of tests involving a behavioral assessment of auditory processing, as well as electrophysiological hearing tests. These tests should be carried out both pre and post-intervention, whether specifically auditory or not, in order to quantify the effects in terms of auditory perception.

CONCLUSION

Individuals who have suffered a traumatic brain injury exhibit auditory processing disorders of varying degrees, related to the gnosic processes of decoding and organization.

RESUMO

Objetivo: verificar o desempenho de indivíduos pós-traumatismo cranioencefálico em testes comportamentais para avaliação do processamento auditivo. **Método:** participaram da pesquisa 10 indivíduos audiologicamente normais com histórico de trauma craniano. Foram submetidos a: audiometria tonal liminar, logoaudiometria, medidas de imitância acústica (timpanometria e pesquisa dos reflexos acústicos) e avaliação comportamental do processamento auditivo (Testes de Localização Sonora, Memória Sequencial Verbal, Memória Sequencial Não Verbal, Padrão de Duração, Dicótico Consoante-Vogal, Dicótico de Dissílabos Alternados, Identificação de Sentenças Sintéticas com mensagem competitiva, Identificação de Intervalo Aleatório, Índice Percentual de Reconhecimento de Fala com gravação, Fala com Ruído Branco). **Resultados:** o teste de Padrão de Duração indicou o teste com o maior número de alteração (60%). O teste com a média mais satisfatória foi o Índice Percentual de Reconhecimento de Fala com gravação (93%) e a média menos satisfatória relacionou-se ao teste Dicótico Consoante-Vogal, com 40,56%. As inversões (70%) representaram a tendência de erros no Dicótico de Dissílabos Alternados mais frequente. O processo gnósico do tipo decodificação foi o mais predominante (100%), seguido da organização (90%), não verbal (60%), codificação-perda gradual de memória (20%). Não houve alteração no processo gnósico de codificação-integração. **Conclusão:** os indivíduos pós-traumatismo cranioencefálico apresentam transtorno do processamento auditivo de diferentes graus, envolvendo os processos gnósicos de decodificação e organização.

DESCRITORES: Audição; Traumatismos Craniocerebrais; Transtornos da Percepção Auditiva; Testes Auditivos; Transtornos da Audição

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