Original article

Comparison of the auditory process between subjects with paranoid schizophrenia and a control group. Central auditory processing in schizophrenia

Comparación del proceso auditivo en sujetos con esquizofrenia paranoide y un grupo control. Procesamiento auditivo central en la esquizofrenia

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Abstract

Introduction The prevalence of schizophrenia in Mexico is between 1% and 5%, predominating in males. Seventy percent of those affected present auditory hallucinations involving some brain structures shared with Central Auditory Processing (CAP). The objective of the study was to compare the dichotic auditory responses in subjects with paranoid schizophrenia and a control group.

Methods We conducted a comparative observational study in two groups with seven subjects each with and without paranoid schizophrenia, all of whom provided m of signed informed consent. The auditory study was carried out, and six tests that evaluated CAP were performed.

Results Normal audiometric thresholds in both groups that were better for the control group in the left ear, significant differences in acute frequencies, responses of five dichotic tests better for left ear in both groups. With a significant difference in binaural fusion in right ear ($p = 0.011$), while the test with dichotic digits showed better results in the left ear, with mixed responses and without omissions for the left ear.

Discussion The lower response in the left ear of dichotic digits for the cases could be due to a low reception of external stimuli or incapacity for identifying and inhibiting irrelevant stimuli, indicating deterioration of the executive functions (working memory and attention).

Conclusions The results do not determine a disorder of the CAP and could be associated with a deficit of working memory, cognition, and attention on being evaluated in a larger sample.

Key Words: Central auditory process, paranoid schizophrenia, dichotic tests.

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Resumen

Introducción: La prevalencia de la esquizofrenia en México se encuentra entre 1% y 5%, predominando en hombres. El 70% de los afectados presentan alucinaciones auditivas que involucran algunas estructuras cerebrales compartidas con el Procesamiento Auditivo Central.

Objetivo: El objetivo del estudio fue comparar las respuestas auditivas dicóticas en sujetos con esquizofrenia paranoide y un grupo de control.

Métodos: Llevamos a cabo un estudio observacional comparativo en dos grupos con siete sujetos, uno con y otro sin esquizofrenia paranoide –todos ellos proporcionaron su respectivo consentimiento informado firmado. Además del estudio auditivo, se realizaron seis pruebas que evaluaron la CAP.

Resultados: Los umbrales audiométricos normales en ambos grupos fueron mejores para el grupo control en el oído izquierdo, con diferencias significativas en las frecuencias agudas y respuestas de cinco pruebas dicóticas mejores para el oído izquierdo en ambos grupos. Con una diferencia significativa en la fusión binaural en el oído derecho ($p = 0.011$), mientras que la prueba con dígitos dicóticos mostró mejores resultados en el oído izquierdo, con respuestas mixtas y sin omisiones para el oído izquierdo.

Discusión. La respuesta más baja en el oído izquierdo de los dígitos dicóticos para los casos podría deberse a una baja recepción de estímulos externos o incapacidad para identificar e inhibir estímulos irrelevantes, lo que indica un deterioro de las funciones ejecutivas (memoria de trabajo y atención).

Conclusiones: Los resultados no determinaron trastorno de CAP y podrían asociarse con un déficit de la memoria de trabajo, la cognición y atención al ser evaluados en una muestra más grande.

Palabras clave: Proceso auditivo central, esquizofrenia paranoide, pruebas dicóticas.

Introduction

The Central Auditory Nervous System (CANS) is a complex system with multiple components and levels, whose organization interacts in its majority in parallel and in sequence, and which is anatomically constituted of nuclei, brainstem pathways, subcortex, primary auditory cortex, the association cortex, and the corpus callosum. The greater part of its process is unconscious, producing what is known as the perceptual event.[1]

In 1996, the American Speech-Language-Hearing Association (ASHA) published the definition of the Central Auditory System (CAP) as follows: "All of those auditory mechanisms

and processes responsible for the following behavioral phenomena: the localization and lateralization of the sound; auditory discrimination; temporal aspects (resolution, masking, integration, and ordering), and auditory performance on encountering conditions of degradation of the acoustic signal," which are applicable to verbal as well as non-verbal signals,[2] and its disorders were defined during the UJD/ Callier Center Consensus Conference of Bruton in the year 2000, as a deficit in the processing of information related specifically with the auditory modality, exacerbated in unfavorable acoustic environments, which can be associated with auditory difficulties, difficulties in understanding speech, and difficulties in the development of language and learning,[3] with many aspects of audition (lateralization, localization, tone, and time) are measured by the mechanisms and structures of neural decoding; thus, these can be altered in the face of pathology of the Central Nervous System (CNS) (dyslexia, attention deficit, aphasia, epilepsy, Alzheimer disease) or age-related changes.[4,5]

Reports in thee literature have related brain lesions with a CAP Disorder (DCAP), situating these in the temporal lobes, in the thalamus, in the basal ganglia, and in brainstem structures; thus, a cortical injury can affect auditory processing, generally in a bilateral manner, and a lesion or neuropathology in the left and/or right temporal lobe can give rise to alterations in the temporal processing of information. An injury of the right temporoparietal area can result in a bilateral deficit of the spectral analysis of a sound signal. Counterlateral deficits of the dichotic audition and in low-redundancy discrimination tests have been reported after cortical injuries.[6]

Diagnosis of a DCAT has been achieved by conducting a basic auditory evaluation and a complete clinical history, considering the sociodemographic factors that can exert an influence on the results, such as age, academic level, cognitive abilities, treatment, and the social and cultural environment, as well as one of several tests that can be behavioral auditory with manipulation of acoustic stimuli directed toward evaluating particular auditory functions (monoaural tests of speech understanding, of dichotic speech, of temporal patterns, or of binaural interaction), or electrophysiological tests. The former correspond to audiological tests with manipulation of acoustic stimuli directed toward the auditory function in particular.[7] The electrophysiological tests include Brainstem Auditory Evoked Potentials (BAEP), Middle Latency Auditory Evoked Potentials (MLAEP), Auditory Evoked Potentials of Late Latency (AEPLL) or those related with the event, the P300 test, and the Mismatch Negativity (MMN) test; additionally employed are techniques of structural neuroimaging, such as Computed Axial Tomography (CAT) and Magnetic Resonance (MR), and also functional neuroimaging techniques including SPECT, PET, and RMf.

The Diagnostic and Statistical Manual of Mental Disorders in its fifth edition (DSM-5) defines schizophrenia as a psychotic disorder that presents one of more of the following characteristics: deliria; hallucinations; disorganized thought (discourse); behavioral disorganization (including catatonia), and negative symptoms.[8] Of the symptoms considered as positive for schizophrenia, hallucinations are highlighted, which are alterations in perception that occur without an external stimulus, the most common of these being auditory (voices that make comments, that insult, that give orders, etc.) and whose prevalence is reported in 70%,[9] with hallucinations described as a mental

phenomenon, transitory, whose heterogeneity renders it difficult to identify their neurobiological bases. The subtypes of schizophrenia are defined by the symptomatology predominant at the time of the evaluation (paranoid, disorganized, catatonic, undifferentiated, and residual). The paranoid subtype, that which is included in the present study, is characterized by the presence of clear delirious ideas or hallucinations, within the context of relative conservation of the cognitive capacity and the affectivity.[10]

Verbal hallucinations are a common symptom of this illness and the neurocognitive and neurobiological mechanisms still remain under debate. Some studies suggest that hearing voices has a multifactorial explanation that includes a local deficit of the left auditory cortex and the connection between the frontal and temporoparietal areas related with language, as well as the pathways of the interhemispheric junction.[11] There also exists a hypothesis that these are aberrant perceptions of the language in which receptive areas of the latter are involved in the left hemisphere and that these interfere with the processing of external sounds that require carrying on their processing in these areas. Hyperexcitibility has been demonstrated, by means of RMf, of the language at the time of the hallucination and, when the latter is severe, there is a response reduction in the left temporal cortex.[12] With the use of Positron Emission Tomography (PET), it has been demonstrated that the same neuronal networks are activated as those in normal musical perception.[13] Other studies reveal that anosognosia (lack of consciousness of the hallucination) is related with injuries to the frontal lobes, to the visual association cortex, and to other neuronal substrates;[14] with respect to the spatial location of the hallucination (inside or outside of the head) with the right temporoparietal junction. It has also been theorized that this can be the result of the deficit in the understanding of the limits between exterior and interior space, and that the abnormal laterality in motor areas of the brain can be attributed to the lack of discrimination of whether the speech is generated internally or externally.[14,15]

During the last two decades when PET and RMf have been utilized, the latter have discovered that the anterior cingulate cortex and the insular cortex, the cerebellum, the thalamus, and the cerebral networks that intervene in attention, perception, and memory, as well as the areas of speech and perception in both hemispheres, are related with auditory hallucinations.[16] Likewise, vocal-consonant dichotic syllables are an indicator of knowing the lateralization of the language, with an advantage of 85%-90% for the right ear in general population. In schizophrenia, the dichotic digits test demonstrates diminished or absent lateralization for the right ear.[17] The correlation between the severity of the hallucination and left-hemisphere alterations is directly proportional: the greater the severity, the greater the interference in the perception of language sounds.[18]

The disadvantage of the right ear entertains possible explanations; it is related with the dysfunction of left-hemisphere areas that are specialized in the processing of stimuli associated with language, alteration in left-hemisphere activation for specific tasks, and the disinhibition of the flow of information of the right hemisphere to the left, as well as the presence and severity of the positive symptoms of schizophrenia.[19, 20] Other studies report a probable predominance of these alterations in masculine gender.[21]

Due to the reports in the literature that suggest that patients with paranoid schizophrenia present auditory hallucinations with greater frequency and severity because they possess deficits in the auditory cortex, and alteration in brain connections that are necessary for language. The objective of the present study was to identify and compare alterations in the Central Auditory Process (CAP) utilizing a recording developed at the Centro de Ciencias Aplicadas y Desarrollo Tecnológico of the Universidad Nacional Autónoma de México (UNAM) and the Instituto Nacional de Rehabilitación (INRehab), which contains six tests in the Spanish language that include the following: the binaural fusion test; the filtered word test; the compressed bisyallabic test; the noise word test; the dichotic digits test, and the music test.

Materials and Methods

We conducted a comparative observational study, obtaining a census sample of seven subjects who complied with the study inclusion criteria in the period comprising September 2014 and February 2015, with a diagnosis of paranoid schizophrenia, who were treated at the Hospital Psiquiátrico Fray Bernardino Álvarez, both sexes, older than 18 years of age, without other chronic-degenerative, neurological, or psychiatric pathologies, or cranioencephalic trauma.

To make up the group of cases and the control group, we included subjects of both sexes, older than 18 years of age, who were apparently healthy, who had signed informed consent.

We performed a clinical history and an otoscopic examination, a tonal audiometry utilizing an Interacoustics-brand Equinox 2.0 Audiometer, an impedanciometry with AT235 Interacoustics equipment, both calibrated according to ANSI S3.6 and S3.26 regulations, and with the application of the psychoacoustic tests within a sound-proofed chamber, utilizing a compact disk with voice recordings in the Spanish language within the socio-educative context prevalent in Mexico, elaborated at the Acoustic Laboratories of the Centro de Ciencias Aplicadas y Desarrollo Tecnológico (CCADT) of the UNAM, with six tests related with sound closure and tests of integration and binaural dissociation,[22] in the following sequence: the binaural fusion test, which presented bisyllabic words in complementary form in both ears, separating these words into low and high components from a cut-off at 1,200 Hz whose slope is of 46 dB/octave. The interstimulus interval was of 2 s, applying lists of 25 items; the filtered word test, which presented monosyllables that were 50 dB above the threshold for the ear-under-evaluation, and the contralateral ear was masked with white noise that was 30 dB/s under the level of the stimulus utilized for the tested ear. Twenty-five items were evaluated, and the results were registered; the compressed bisyllabic test, which compressed the stimuli to 75% of the original stimulus, which were presented monaurally.

The subjects were instructed to repeat the words presented. The monoaural tests were performed through TDH39 earphones at 50 dB above the tonal audiometric threshold obtained previously for 1 kHz, and masked with contralateral white noise of at least 30 dB with respect to the white-noise stimulus; the noise word test, which presented 25 words to the ear evaluated at 50 dB above the 1,000-Hz threshold, as well as ipsilateral white noise 10 dB under the stimulus utilized. The percentage of correct response was registered; the dichotic digits

test, in the divided-attention modality, which presented different digits, simultaneously, in one-digit-pair, two-digit-pair, and three-digit-pair segments, the subject, is instructed to indicate the number of each pair, the pair of greatest intensity, or the most important. The right, left, mixed, and omission responses were registered, and the music test, which presented 20 series (each composed of two melodies), 10 for each ear of 50 dB, above the 1-kHz threshold, utilizing white noise to mask the contralateral ear. The subject was instructed to identify whether the melodies presented the same or different tones, and a percentage was obtained for the correct responses for each ear.

The correct-response percentage was obtained for each test and per subject for each group. A database was elaborated with the SPSS ver.19 statistical software package.

Descriptive statistics were utilized for the statistical analysis, showing the median and the range, and, for comparisons, the Mann-Whitney *U* test was employed, due to the sample size.

Results

A voluntary sample of seven subjects with paranoid schizophrenia was studied who referred auditory hallucinations, compared with an apparently healthy control group, their ages had an average of the cases of 38±10 years, and for the controls, one of 24.85±4.7 years, with greater homogeneity for the latter. More male subjects participated in both groups, including five (71.42%) cases and four (57.14%) controls. We applied a tonal audiometry to all participants, in which all obtained auditory thresholds of less than 20 dB in seven measured frequencies, with a lower average for the right ear in both groups, and a better average for both ears in the control group. The tympanometry demonstrated normal type-A curves at a greater proportion for the groups of cases, with right-ear predominance (Table I).

Table I
Demographic and auditory characteristics of the studied subjects

CHARACTERISTICS			CASES	CONTROLS
	Age	Average of the SD	38± 10.26	24.85±4.7
	Sex	Masculine	5 (71.42%)	4 (57.14%)
		Feminine	2 (28.57%)	3 (42.85%)
Average of Audible Tones (AAT)				
		Right ear	16.41±3.37 dB	11.42±13.61 dB
		Left ear	19.75±5.37 dB	12.13±4.33 dB
Tympanometry				
Right ear		Jerger A curve	7(100%)	5(71%)
		Jerger As curve		2(29%)
		Jerger As curve		
Left ear				
		Jerger A curve	6(86%)	5(71%)
		Jerger As curve		2(29%)
		Jerger AD curve	1(14%)	

Due to the small sample size, a comparison was conducted for the ears of the auditory threshold of both groups, considering the median descriptors and range, in which the latter exhibited greater dispersion for the data of the control group in both ears, obtaining a significant difference in 250-dB frequencies for the right ear with a $p = 0.038$ and for the left ear of 0.011, 0.004, 0.011 at the 2,000- 4,000-, and 8,000-Hz frequencies, respectively (Table II).

Table II
Comparison of the results of the tonal audiometry of subjects with paranoid schizophrenia and their controls

Audiometric frequencies	Right ear		Mann-Whitney U	Left ear		Mann-Whitney U
	Median (range)	Median (range)		Median (range)	Median (range)	
125 dB	15(20)	10(5)	0.128	10(30)	10(5)	0.165
250 dB	15(10)	10(10)	.038*	15(10)	10(15)	0.259
500 dB	15(5)	10(15)	0.209	20(15)	15(10)	0.383
1000 dB	15(10)	15(20)	1.000	15(15)	15(10)	0.165
2000 dB	15(25)	15(20)	0.259	20(40)	5(20)	0.011*
4000 dB	20(40)	10(15)	0.053	20(50)	10(20)	0.004*
8000 dB	20(5)	5(20)	0.128	20(40)	10(20)	0.011*

*P ≤ 0.005.

The results of five dichotic tests showed, in the binaural fusion test, a greater median and lesser dispersion in the right-ear responses of the control group, with a significant difference of $p = 0.011$. The filtered word, the compressed bisyllables, and the noise word tests obtained higher values in the median of the left ear of both groups, as well as lesser dispersion, and the music test obtained similar medians for both groups in both ears, but a lesser dispersion in the left ear (Table III).

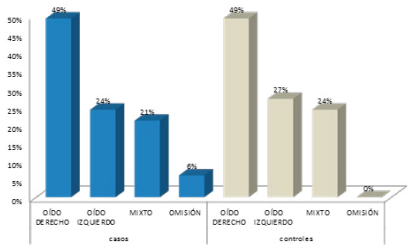
Table III
Comparison of the results of five Dichotic Tests between subjects with paranoid schizophrenia and the control group

Dichotic tests	Descriptives	Right ear		Mann-Whitney U	Left ear		Mann-Whitney U
		Cases	Controls		Cases	Controls	
Binaural fusion							
	Median	23	24		25	24	
	Range	15	3	0.011*	1	6	0.053
Filtered word							
	Median	19	18		22	21	
	Range	10	7	0.805	6	7	0.383
Compressed bisyllables							
	Median	19	22		24	25	
	Range	7	7	0.301	2	2	0.177
Noise word							
	Median	24	24		25	25	
	Range	2	3	0.943	1	2	0.530
Music							
	Median	10	10		10	10	
	Range	2	2	1.000	1	1	0.710

* P value = 0.05.

With regard to the dichotic digits test, the percentage of responses for the right ear in both groups was the same, while the percentage of responses in the left ear and in mixed responses was discretely higher for the left ear of the control group, as well as a total absence of omissions (Figure 1).

Figure 1
Comparison of the responses in the Dichotic Digits Test between subjects with paranoid schizophrenia and controls



Discussion

Our results derive from a small sample of subjects with paranoid schizophrenia, while it was estimated that there were 21 million subjects who presented the disease worldwide according to the World Health Organization (WHO) (2001),[23] among whom the masculine gender predominated, and 50% had no access to specialized medical service. In Mexico, the prevalence of paranoid schizophrenia is reported as ranging from 1%-5%, occupying third place in mental diseases,[24] and predominating in masculine gender at a 2:1 ratio. Age-at-onset in males is earlier than in females but both are found at the productive age, the presentation of rises requiring hospitalizations 4 to 5 per year, and there being few resources for their care, there is little access for those requiring monitorized treatment in a hospital, all of the demographic data coincided in the subjects included in the study, whose profile is similar to that of the control group.

The results in the audiometric and tympanometric studies revealed greater dispersion in the group of cases, even though both groups are shown to fall within the normal limits prior to being exposed to the dichotic-stimuli evaluation.[25] This could be due to problems that involve the attention and concentration of the illness.

The dichotic digits test provides a measure of the central auditory function. Even when there are peripheral losses, these tests evaluate the mechanisms of interhemispheric integration in children as well as in adults, where the response pattern in normal subjects demonstrates an advantage of the right ear.[26] If there were an alteration in left hemispheric activation, this could interfere with the execution of specific tasks and in the disinhibition of the flow of information

of the right hemisphere to the left one, causing the disadvantage of the right ear in subjects with schizophrenia, in addition to the presence of the severity of the positive symptoms of the illness.

Likewise, this test permits the measurement of the lateralization of language, with an advantage for the right ear in general population and a diminution or absence of responses for subjects with schizophrenia. In this study, the advantage for the right ear was for both groups. The differences were found in favor of the control group in terms of mixed responses and the absence of omissions.[27, 28] This has been explained by other authors, who attribute it to attentional alterations than can manifest themselves in lower receptivity toward external stimuli or in the incapacity to identify and inhibit irrelevant stimuli, indicating deterioration of the function of short-term memory and simple attention in subjects with schizophrenia.[29]

The binaural interaction tests require the participation of both ears to achieve auditory closure of when the sound signal differs with respect to time, frequency, and intensity, this occurring at the level of the encephalic- stem level. Therefore, lesions in the latter would exhibit alterations in the binaural fusion test,[30] while the monoaural tests, such as the filtered word test,[31] the noise word test, and the compressed bisyllables test, evaluate abilities of speech recognition under conditions of degradation, a finding not unearthed in this study. The results solely show a greater percentage of correct responses for the control group and a disadvantage for the right ear with respect to the left in both groups. The latter coincides with that found by other authors, where there is the continuous presentaron of stimuli (letters or numbers) that continue to degrade, rendering difficult their identification. Subjects with schizophrenia demonstrate poor execution on encountering the diverse varieties of dichotic tests.[32]

According to other authors, when there are significant differences in the contralateral ear of a same group, these differences are associated with lesions of the temporary lobe and of the brainstem, where the deficit can be contralateral, ipsilateral, bilateral, and with normal results. Therefore, imaging studies are required for corroboration. In this study, both groups behaved similarly; however, the disadvantage of the right ear with its contralateral has been identified by other authors as a deficit of the left hemisphere that is present in subjects with schizophrenia associated with positive symptoms.[33] Thus, the sample must be enlarged in order to corroborate these findings.

Finally, the music test, which evaluated the perception of sounds, revealed similar results in both groups in terms of number of correct responses as well as their dispersion and with discrete improvement in the left ear.

Conclusions

The number of subjects included in the study is small. Thus, the sample requires being larger and paired. The results of the auditory closure test and of the integration and binaural dissociation tests, which entail the ordered repetition of a series of number or syllables and which require conditions of attention, were lower compared with those of the control group, where the significant differences did not determine a disorder of the central auditory process and can be associated with a deficit of the working memory, cognition, and attention. Therefore, the application is recommended of instruments that evaluate these aspects.

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