Differences on interhemispherical auditory integration between female and male: preliminary study

Diferenças na habilidade de integração auditiva inter-hemisférica entre os gêneros feminino e masculino: estudo preliminar

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ABSTRACT

Purpose: To evaluate the interhemispherical auditory integration ability between female and male individuals. **Methods:** Participants were 30 individuals – 15 female and 15 male – aged between 18 and 25 years, without hearing complaints and with hearing within normal limits. Data collection was carried out using the non-verbal dichotic test, the dichotic digits test, and suppressive transient otoacoustic emissions. **Results:** In the non-verbal dichotic test, in the stage of right attention, there was difference between genders regarding the number of correct responses in the right ear. In the dichotic digits test, in binaural integration, there was difference between genders regarding the percentage of correct responses in the right ear. In the stage of directed attention, there was a tendency towards difference between genders on the percentage of correct responses in the left ear. Among female subjects, there was a tendency towards difference between right and left ears in the non-verbal dichotic test, free attention stage, and there was difference between ears in selective attention. In the dichotic digits test, in binaural integration, there was a tendency towards difference between ears. **Conclusion:** Differences were observed between male and female individuals in some abilities, while in others there was similarity of responses.

Keywords: Corpus callosum; Auditory cortex; Auditory perception; Hearing tests; Auditory pathways

INTRODUCTION

The anatomical and/or functional differences between female and male individuals are object of study for many researchers. Behavioral studies suggest some differences between men and women in the temporal cortex, the Broca's area and the corpus callosum, mainly due to its role in communication between the two cerebral hemispheres.

To process the sound information, detection and interpretation of sounds are necessary. The acoustic stimuli received by the peripheral system are encoded and, then, transformed into internal representations which will be analyzed and integrated by the central auditory nervous system[1,2].

The auditory system consists of afferent and efferent auditory pathways. The efferent auditory system emerges from the cortex to the cochlea. All efferent fibers are organized at the level of the superior olivary complex. From this point, descend toward the cochlea, tract by means of two distinct tracts: the lateral olivocochlear tract and the medial olivocochlear tract[3].

The lateral olivocochlear tract, composed of unmyelinated fibers, is ipsilateral and projected from the lateral region of the superior olivary complex to the inner hair cells. The medial olivocochlear tract, composed of myelinated fibers, is projected ipsilaterally and contralaterally, of the medial region of the superior olivary complex, to the outer hair cells[4].

From the superior olivary complex the ascending fibers cross from one cerebral hemisphere to the other. The message received by ear is directed to the hemisphere ipsilateral through of the ipsilateral pathways, and to the contralateral hemisphere, through of the contralateral pathways. So, auditory information coming from the right ear crosses to the left hemisphere while the information coming from the left ear crosses to the right

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hemisphere and crosses the corpus callosum to again get to the left hemisphere[5].

Many authors refer to the hemispheric specialization for the decoding of acoustic signals. The left hemisphere is considered responsible by the analysis of linguistic sounds, related to speech and language. The right hemisphere is considered responsible by the decoding of non-linguistic sounds, as music and rhythm[6-9].

The observed differences in operation of each of the cerebral hemispheres are related to asymmetries at the intersection of the pyramidal tracts. This understanding of the role of the cerebral hemispheres in decoding acoustic signals is consistent with attentional models and polarity of hemispheric functional specialization. That differences in hemispheric processing of the verbal and non-verbal stimuli are related to the processing mode, in other words, holistic/synthetic or analytic[10].

Although the existence of two cerebral hemispheres, there is no dominance relationship among them, on the contrary, they work together, using of the millions of nerve fibers that constitute the cerebral commissures, that are responsible for putting them in constant interaction[11].

The cerebral hemispheres are connected by the corpus callosum. The corpus callosum is the largest of the three commissural fibers that make the integration among symmetrical areas of the two hemispheres. It consists of about 300 to 800 million inter-hemispheric fibers, descendants fundamentally from the cerebral cortex. The posterior portion of the corpus callosum, splenium, is responsible for auditory, visual and auditory-visual integration among the hemispheres[12-15].

There are some neurophysiological and anatomical differences in men and women brains. One of these differences can be observed in the corpus callosum, whose posterior portion is more bulbous and wider in the female brain[16].

Since the first reports on the differences in the corpus callosum of men and women, there are studies that confirm and contest these differences. It is observed that there is a consensus that, probably, there is little difference in the size of the corpus callosum in favor of women[16].

Some researchers argue that these differences restricted to the posterior region of the commissural fibers (splenium). In a relationship of the proportionality, it is observed that there are more nerve fibers in a commissure greater than in a lower commissure. Thus, there is, potentially, better connection between the two cerebral hemispheres[16].

Many studies point to the cerebral cortex as the most developed, evolved and differentiated portion of the nervous system, even that the functional studies of the cerebral cortex are still insufficient for obtaining this knowledge. The difficulty may lie in the anatomical differences and, consequently, functional among individuals[13].

For years science has researched this difference in various fields, among them the neuroscience. Initially, researchers have attempted to attribute the behavioral and cognitive differences between men and women to anatomical differences, and a classic example is the size of the brain. In recent studies, some researchers have tried to assess whether the auditory cortex of women is larger and more symmetrical than man. There is still no consensus, since there is great variability within and among individuals as to size and location of the auditory cortex primary and secondary[17,18].

The objective of this study was to evaluate the ability to integrate interhemispheric auditory information in female and male genders. Thus, this research is justified by the possibility of understanding and determining the relationship between the anatomical differences and / or functional and performance of men and women in central auditory tests.

METHODS

The procedures in this study were approved by the Research Ethics Committee of Pontifícia Universidade Católica de Minas Gerais (PUC Minas), under protocol number 0342.0.213.000-10 (Resolution 196/96 National Health Council – CONEP).

This study was characterized by a pilot study, of descriptive typology, and qualitative and quantitative analysis. Fifteen female and 15 male individuals were invited to participate in the research. The sample, then, consisted of 30 individuals, young adults, aged 18 to 25 years.

The participants of the research were selected in undergraduate courses offered in the building of the Continued Education Institute – IEC at Pontifícia Universidade Católica de Minas (PUC Minas) and in the social environment of the researchers. The subjects of this research were selected by means of the non-random sampling technique, of the type convenience sampling.

The participants of the research were communicated personally about the objectives of the research, the absence of damage to your health, the guarantee of confidentiality of their identities or any other characteristics which could identify them, and on the roadmap of the research. Being properly informed, all signed the Consent Term.

The data collection was carried in the Clinical Center for Speech – Language Pathology and Audiology of PUC Minas. All the individuals were submitted to basic audiologic evaluation. This evaluation consisted of: anamnesis, otoscopy, pure tone audiometry, logoaudiometry, tympanometry and research of acoustic reflexes.

In the anamnesis the individual provided information as personal data, audiological history and health-related aspects. The anamnesis was conducted with the same protocol used in the Clinical Center for Speech – Language Pathology and Audiology of PUC Minas.

To perform the visual inspection of the external auditory canal (otoscopy) was used otoscope, of the brand TK®, model 22. The Pure tone audiometry and logoaudiometry were performed in acoustically treated booth and with two-channel audiometer, model Midimate 622, of the brand Madsen Electronics®, using phone TDH-39 and bone vibrator B-71. The tympanometry and the research of acoustic reflexes were performed through the middle ear analyzer, model AZ7, of the brand Interacoustics®.

Inclusion criteria to the study group were the absence of hearing complaints, and results within normal range in audiometry and immittance test. We considered individuals with audiological assessment within the normal range those who presented pure tone thresholds by air conduction to 25 dBHL, in the frequencies of 250 Hz to 8 kHz, and pure tone thresholds by bone conduction to 15 dBHL, in the frequencies of de 500 Hz to 4 kHz, with difference between the thresholds of air conduction and bone conduction less or equal to 10 dB; tympanometric curve type A and presence of acoustic reflexes in the frequencies of 500 Hz, 1, 2 and 4 kHz.

Then, the individuals were submitted to research of transient evoked otoacoustic emissions and the suppression of transient otoacoustic emissions.

The transient otoacoustic emissions were performed with non-linear stimulus, type click, with intensities from 80 e 85 dBSPL. The transient otoacoustic emissions were taken initially without contralateral noise, and then, with contralateral noise with the order not to change the placing the probe during the two test cases.

The transient otoacoustic emissions were performed by otoacoustic emission analyzer model ILO version 6, of the brand Otodynamics®. To investigate the effect of suppression of transient otoacoustic emissions was used broadband noise transmitted by the two-channel audiometer, model Midimate 622, of the brand Madsen Electronics®, by means of the phone TDH-39, in the intensity of 60 dB SPL.

The transient evoked otoacoustic emissions were found to be present when the amplitude of the frequencies of 1 and 1.4 kHz were greater or equal to 3 dB, and of the frequencies of 2, 2.8 and 4 kHz, were greater or equal to 6dB, reproducibility having values greater than 50% and values of stability of the adjustment of the probe greater than 70%. Only individuals who had transient evoked otoacoustic emissions present were included in the study.

For the effect of suppression observed the variation of the response of amplitude in the presence of noise, in relative the response of amplitude in the absence of noise. The value of the suppression referring to the action of the olivocochlear system is given by the difference of the values obtained in the conditions with and without contralateral stimulation, in each ear, and that value determines whether or not suppression. So, if the value is positive, there suppression and if it is negative or zero, there is no suppression in the emission amplitudes[20]. In this study we chose to by considering a minimum variation of 0.5 dB SPL.

Then, the participants of the study were submitted the dichotic listening tests. The task of dichotic stimulation was composed by materials of nature non-verbal, non-verbal dichotic test, and of nature verbal, dichotic digits test.

The dichotic tests are available in Compact Disc (CD)[19] and to its realization used a two-channel audiometer, model Midimate 622, of the brand Madsen Electronics®, coupled to a CD player, of the brand Coby®. The tests were applied in acoustically treated booth, the intensity of 50 dBNS, as from the average of pure tone thresholds by air conduction, in the sound frequencies of 500 Hz, 1 and 2 kHz.

The non-verbal dichotic test started presenting the sound to individual so take it, by demonstration, to associate each sound heard the figure corresponding. These sounds are combined in pairs and presented one by one in each ear, simultaneously, a total of 12 pairs[19].

The non-verbal dichotic test assesses selective attention, by means of a task of binaural separation (free attention, right attention and left attention). In the stage free attention, each individual was instructed to point at any of the figures that represented the sounds presented. In the stage of right attention, each participant was instructed to point at the corresponding figure of sound heard in the right ear. In the stage left attention, each individual was instructed to point at the corresponding figure of sound heard in the left ear[19].

The answers given by participants were transcribed onto a sheet of records, circling the corresponding word the sound indicated by the same. In case of error, beside the pair of sound, was recorded name of the sound shown by the participant. The results were presented in number of hits[19].

The dichotic digits test is the presentation of two digits in each ear, simultaneously. The list of digits consists of 20 pairs of digits representing disyllables of Portuguese language. This test assesses the tasks of binaural integration and binaural separation (attention directed to the right and attention directed to the left). In the stage of binaural integration, each individual was instructed to repeat all the digits presented, independently of the order. In the stage of binaural separation, each individual was instructed to repeat the digits heard only in the right ear (attention directed to the right) and, then, only the digits heard only in the left ear (attention directed to the left)[19].

The results were recorded on a score sheet containing identification data and the lists that comprised the test. In the stage of binaural integration, no record was made when the subject correctly identified the digits presented and, in case of error, omission or substitution of digits, this was indicated by a dash in the corresponding digit. In the stage of binaural separation, digits identified were circled. The results were presented in percentage of correct. Each stimulus correctly identified corresponded to 2.5% and was computed by ear, in three stages of the test[19].

After the assessments, the data were tabulated and analyzed statistically by Chi-square test and hypothesis of proportion test. For both tests, were adopted the significance level of 5%.

RESULTS

In the non-verbal dichotic test, in stage of free attention, there was no difference between the number of hits of the right ear (p=0.439) and of the left ear (p=0.269), between genders: in the female gender, 11 (73.33%) participants and in the male gender, nine (60.00%) participants. Most of the participants of both genders presented of six to 12 hits in the right ear. In the left ear, it was observed that 10 (66.67%) participants of the female gender had up to five hits, as in the male gender there was a balanced distribution of the number of hits: seven (46.67%) participants had up to five hits and eight (53.33%) participants presented of six to 12 hits.

In the stage of right attention, was difference in the number of hits of the right ear (p=0.046), between the genders studied (Table 1).

In the stage of left attention, there was no difference in the number of hits of the left ear (p=1.000), between the female

Table 1. Performance of the genders in the non-verbal dichotic test, right attention stage

Gender	Until 11 hits (%)	12 hits (%)	Total	p-value
Female	7 (46.67)	8 (53.33)	15 (100%)	0.046*
Male	2 (13.33)	13 (86.67)	15 (100%)	
Total	9 (30.00)	21 (70.00)	30 (100%)	

* Significant value (p≤0.05) – Chi-square test

and male genders. In both genders, 14 (93.33%) participants had 12 hits.

In the dichotic digits test, in the stage of binaural integration, that was difference in percentage of hits of the right ear (p=0.001), between the genders studied (Table 2).

In the stage of binaural integration, there was no difference in percentage of hits of the left ear (p=0.439), between the female and male genders. It was observed in 11 (73.33%) participants of the female gender and nine (60.00%) participants of the male gender, in other words, most of the participants of both genders presented 95% or 100% of hit.

In the stage of attention directed to the right, there was no difference in percentage of hits of the right ear (p=1.000), between the genders studied. Both in the female gender as in the male gender, 14 (93.33%) participants presented 95% or 100% of hits.

In the stage of attention directed to the left, there was a trend to difference in percentage of hits of the left ear (p=0.068), between the genders (Table 2).

In the research of the suppressive effect (positive), it was observed that there was no difference to the frequencies of 1.0 kHz (p=1.000), 1.4 kHz (p=1.000), 2.0 kHz (p=0.682), 2.8 kHz (p=0.450) and 4.0 kHz (p=0.462) in the right ear, between the genders studied. In the left ear, it was observed that also there was no difference to the frequencies of 1.0 kHz (p=1.000), 1.4 kHz (p=1.000), 2.0 kHz (p=1.000), 2.8 kHz (p=0.264) and 4.0 kHz (p=1.000), between the female and male genders.

In the separate analysis of the data for each gender, it was found that in the female gender there was a trend to difference between the right ear and left ear in the non-verbal dichotic test, in the stage of free attention (p=0.066) (Table 3).

In the stage of selective attention (right attention and left attention) was difference between the right ear and left ear, in the female gender (p=0.035) (Table 3).

In the dichotic digits test, in the stage of binaural integration, there was a trend to difference between the right ear and left ear, in the female gender (p=0.100) (Table 3).

In the stage of binaural separation (attention directed to the right and attention directed to the left) there was no difference between the right ear and left ear, in the female gender (p=0.598).

In the research of the suppressive effect (positive), it was observed that there was no difference to the frequencies of 1.0 kHz (p=1.000), 1.4 kHz (p=1.000), 2.0 kHz (p=1.000), 2.8 kHz (p=0.264) and 4.0 kHz (p=0.714) between the right ear and left ear, in the female gender.

In the male gender there was no difference between the right ear and left ear in the non-verbal dichotic test, in the stage of free attention (p=1.000), neither in the stage of selective attention (p=1.000). In the dichotic digits test also there was no difference between the right ear and left ear, in the stage binaural integration (p=0.715), neither in the stage of binaural separation (p=1.000). In the research of the suppressive effect (positive), also there was no difference to the frequencies of

Table 2. Performance of the genders in the dichotic digits test

Gender	Binaural integration right ear		Directed attention to the left	
	<95% hits n (%)	95 a 100% hits n (%)	<95% hits n (%)	95 a 100% hits n (%)
Female	0 (0)	15 (100)	3 (20.00)	12 (80.00)
Male	8 (53.33)	7 (46.67)	0 (0)	15 (100)
p-value	0.001*		0.068#	

* Significant values (p≤0.05) – Chi-square test
# Values with tendency towards statistical significance (p≤0.10)

Table 3. Performance of the ears in the dichotic tests of the female gender

Hits	DNV-free attention		DNV-selective attention		DD-binaural integration		DD- directed attention	
	Até 5	6 a 12	Até 11	12	<95%	95/100%	<95%	95/100%
OD	4	11	7	8	0	15	1	14
OE	10	5	1	14	4	11	3	12
p-value	0.066#		0.035*		0.100#		0.598	

* Significant values (p≤0.05) – Hypothesis test of proportions
# Values with tendency towards statistical significance (p≤0.10)
Note: DNV = non-verbal dichotic; DD = dichotic digits; OD = right ear; OE = left ear

1.0 kHz (p=1.000), 1.4 kHz (p=1.000), 2.0 kHz (p=1.000), 2.8 kHz (p=0.450) and 4.0 kHz (p=0.452), between the right ears and left.

DISCUSSION

The researches involving the dichotic tests present various results. However criterion should be taken to compare the dichotic tests, because different dichotic tests presented different results. There are studies that observed trend for the best performance of the female gender in dichotic task with consonant and vowel(7). Otherwise, there are studies that point to differences between the genders in consonant-vowel test only to synthetic stimulation. For speech stimulus no difference was observed(8).

Some studies show that male gender has a tendency to right ear advantage in comparison to female gender. However, other studies had not observed this trend, reporting no differences between genders(9,14).

Of the studies performed with dichotic listening for non--verbal stimuli, some evidenced preference for the left ear, and others, observed symmetry of responses to stage of binaural separation (free attention, right attention and left attention). However the studies performed with dichotic listening for verbal sounds, reported preference for the left hemisphere and, thus, observed advantage of the right ear(6,11).

The advantage of the left ear for processing of non-verbal sounds may indicate a preference for the right hemisphere for this dichotic task. A research has already reported a preference for the left hemisphere, in the processing of the information for verbal sounds in dichotic listening. So, the processing of non-verbal sounds would be conducted, generally, by the right hemisphere, unlike the analytical processing that the left hemisphere realizes for verbal sounds(10,11).

The role of the olivocochlear tract, in auditory performance, is not yet fully set, but some functions have been attributed to olivocochlear medial tract, such as: auditory attention, location of the sound source, improvement in the detection of acoustic signals in the presence of noise, improvement in hearing sensitivity and protection function(3,4).

In view of that there was no difference between the suppressive effect between the genders female and male and nor between the ears in the several genders, it can be stated that the absence of dominance of the suppression in the right ear and in the left ear can mean the existence no of the hemispheric dominance and, consequently, absence of advantage of one of the ears(4,19).

The perceptual asymmetry can be justified by the structural and cognitive models, that seek to explain the advantage of the right ear and the consequent disadvantage of the left ear in the dichotic tests.

In the structural model, the information presented in the right ear is transmitted directly to the left hemisphere. In situations of monotic listening, any pathway, ipsilateral or contralateral, is able to transmit the neural signal. However, during dichotic stimulation the ipsilateral pathway is suppressed favoring the contralateral pathway that has greater number of fibers. The disadvantage of the left ear is justified by the longer time of transmission of the verbal information presented in this ear, since must be transported, through the corpus callosum, of the right hemisphere to be processed in the left hemisphere. Thus, the left ear need greater participation of the corpus callosum to be efficient in the processing of verbal information(10,11,15,18).

The cognitive detach model refers to the importance of attention, working memory and speed of information to process sound in dichotic listening situations. As consequence of the left hemispheric dominance to processing the speech, most individuals have better attention to stimuli heard by the right ear. This allows that these individuals make use predominant of automatic acoustic processing of the stimulus. In the dichotic task, listening to the left, the stimuli are suppressed by the stimuli of the right ear. So, to direct the listening to the left ear, it is necessary greater activation and involvement of cognitive functions, which differ between individuals(14).

Often if asserts the female superiority in the verbal domain (left hemispheric dominance) and the male superiority in visual-spatial tasks (right hemispheric dominance). The verbal skills and the visual-spatial abilities were the subject of many studies on the cognitive differences between men and women. However, the results revealed minimal differences only in a part of the individuals(11,16,17).

The differences observed in various domains (verbal and non-verbal) depend, probably, more on strategies of use of cognitive capabilities than on their own capabilities. This has consequences on the brain organization that might be different among men and women, but that could also be identical. Thus, the difference is more related to brain function – and not to the anatomy – more accurately on the solicitation of the various brain structures, mainly the two cerebral hemispheres, that could differ according to the processing strategies, and are variables of one individual to another, mainly among men and women(6,11,14).

The present study found different results, both for the non--verbal dichotic test as for the dichotic digits test. Some results coherent, and other non-coherent with the literature consulted.

The processing of the sound information is a complex mechanism that involves peripheral structures, as the auricular pavilion, and central structures, as the auditory cortex. Each of these structures performs a specific role in the auditory system. In due of the complexity of the system, becomes impracticable assign a single function the given structure. The system acts as a whole and, possibly, a skill can be attributed to various structures(2).

So, the task of selective attention, though it is one of the attribution of the efferent auditory system, has other anatomical structures involved, as the reticular formation. When the ascending reticular pathway is stimulated, the cortex selects the information to be treated with priority. So, this can be one of the mechanisms involved in selective attention and, consequently, in the dichotic listening task(2).

This assumption can justify the findings of this study, but, the differences between the genders and the asymmetry between the ears in the female gender should be considered with caution, so new studies with larger samples should be performed.

CONCLUSION

The results of the present study were inconclusive. The female gender, whose posterior portion of the corpus callosum is wider and more bulbous, did not present better interhemispheric auditory integration ability compared to the male gender. Hence, it cannot be assumed that neurophysiological and anatomical differences between female and male genders were determinant for the performance in central auditory tests.

RESUMO

Objetivo: Avaliar a habilidade de integrar informações auditivas inter-hemisféricas em indivíduos do gênero feminino e do gênero masculino. **Métodos:** Participaram da pesquisa 30 indivíduos, 15 do gênero feminino e 15 do gênero masculino, na faixa etária de 18 a 25 anos, todos sem queixa auditiva e com audição dentro dos padrões de normalidade. A coleta de dados foi realizada por meio dos testes dicótico não verbal e dicótico de dígitos e pela pesquisa do efeito supressor das emissões otoacústicas transientes. **Resultados:** No teste dicótico não verbal, na etapa de atenção, houve diferença entre os gêneros estudados no número de acertos da orelha direita. No teste dicótico de dígitos, na etapa de integração binaural, houve diferença entre os gêneros na porcentagem de acertos da orelha direita. Na etapa de atenção direcionada, houve tendência à diferença na porcentagem de acertos da orelha esquerda entre os gêneros estudados. No gênero feminino houve tendência à diferença entre as orelhas direita e esquerda no teste dicótico não verbal, na etapa de atenção livre, e houve diferença entre as orelhas na etapa de atenção seletiva. No teste dicótico de dígitos, na etapa de integração binaural, houve tendência à diferença entre as orelhas. **Conclusão:** Observou-se diferenças entre os gêneros feminino e masculino em algumas habilidades e, em outras, houve similaridade de respostas.

Descritores: Corpo caloso; Córtex auditivo; Percepção auditiva; Testes auditivos; Vias auditivas

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