http://dx.doi.org/10.23925/2176-2724.2018v30i1p43-51

ARTICLES

Auditory sensory deprivation and its relation with auditory evoked potentials of long latency

Privação sensorial auditiva e sua relação com os potenciais evocados auditivos de longa latência

Privación sensorial auditiva y su relación con los potenciales evocados auditivos de larga latencia

*Mirtes Bruckmann**
*Dayane Domeneghini Didoné**
*Michele Vargas Garcia**

Abstract

Objective: To verify whether auditory sensory deprivation time of up to five years, in individuals with mild to moderate sensorineural hearing loss may influence the Long-Latency Auditory Evoked Potential (LLAEP) responses. **Methods:** Prospective, cross-sectional, and quantitative study. Were assessed 14 subjects, aged 52 to 76 years, with symmetric mild or moderate sensorineural hearing loss, who were waiting for a hearing aid program and had between two and five years of auditory sensory deprivation. For the presentation of the LLAEP, verbal stimuli were used and the potentials N1, P2 and P300 were analyzed. **Results:** The mean age of the subjects was 63.5 years and the time of hearing deprivation was 3.3 years. There was a difference between the number of normal and altered subjects for N1, with a higher number of normal individuals, whereas for P2 and P300 there was no difference. When comparing the normal and altered outcome in the potentials with age and time of deprivation, there was no significant difference. **Conclusion:** The time of hearing deprivation between two and five years in individuals with mild or moderate sensorineural hearing loss did not influence the results of the LLAEP.

Keywords: Hearing; Auditory Evoked Potentials; Aged; Hearing Loss; Sensory Deprivation.

*Universidade Federal de Santa Maria, Santa Maria, Rio Grande do Sul, Brazil.

Authors' contributions:
MB - responsible for tabulating the data, statistical analysis and preparation of the manuscript.
DDD and MGV - responsible for collecting data, preparing and reviewing the manuscript

Correspondence address: Mirtes Bruckmann - mirtes.bruckmann@gmail.com
Received: 14/02/2017
Accepted: 17/02/2018

Resumo

Objetivo: verificar se o tempo de privação sensorial auditiva de até cinco anos em indivíduos com perda auditiva neurossensorial de grau leve ou moderado pode influenciar nas respostas dos Potenciais Evocados Auditivos de Longa Latência (PEALL). **Métodos:** Estudo prospectivo, transversal e quantitativo. Foram avaliados 14 sujeitos, com idade entre 52 e 76 anos, com perda auditiva neurossensorial de grau leve ou moderado simétrico, que estavam na fila de espera de um programa de concessão de próteses auditivas e possuíam entre dois e cinco anos de privação sensorial auditiva. Para apresentação do PEALL foram utilizados estímulos verbais e foram analisados os potenciais N1, P2 e P300. **Resultados:** A média de idade dos sujeitos foi de 63,5 anos e do tempo de privação auditiva foi de 3,3 anos. Houve diferença entre o número de sujeitos normais e alterados para N1, sendo maior o número de normais, já para P2 e P300 não houve diferença. Ao comparar o resultado normal e alterado nos potenciais com a idade e tempo de privação, não houve diferença significativa. **Conclusão:** O tempo de privação auditiva entre dois e cinco anos em indivíduos com perda auditiva neurossensorial de grau leve ou moderado, não influenciou nos resultados dos PEALL.

Palavras-chave: Audição; Potenciais evocados auditivos; Idoso; Perda auditiva; Privação sensorial.

Resúmen

Objetivo: verificar si el tiempo de privación sensorial auditiva de hasta cinco años en individuos con pérdida auditiva neurosensorial de grado leve o moderado puede influir en las respuestas de los Potenciales Evocados Auditivos de Larga Latencia (PEALL). **Métodos:** estudio prospectivo, transversal y cuantitativo. Fueron evaluados 14 sujetos, con edad entre 52 y 76 años, con pérdida auditiva neurosensorial de grado leve o moderado simétrico, que estaban en línea de espera de un programa de concesión de prótesis auditivas y tenian entre dos y cinco años de privación sensorial auditiva. Para la presentación del PEALL fueron utilizados estímulos verbales y fueron analizados los potenciales N1, P2 y P300. **Resultados:** el promedio de edad de los sujetos fue de 63,5 años y del tiempo de privación auditiva fue de 3,3 años. Hubo diferencia entre el número de sujetos normales y alterados para N1, el mayor número siendo normales, ya para P2 y P300 no hubo diferencia. Al compararse el resultado normal y alterado en los potenciales con la edad y tiempo de privación, no hubo diferencia significativa. **Conclusión:** el tiempo de privación auditiva entre dos y cinco años en individuos con pérdida auditiva neurosensorial de grado lele o moderado, no influyó en los resultados de los PEALL.

Palabras claves: Audición; Potenciales evocados auditivos; Adulto mayor; Pérdida auditiva; Privación sensorial.

Introduction

Hearing loss consists of a decrease in auditory acuity and presents difficulties to the wearer[1]. It is common that with the passing of the age, the subjects initiate the process of degeneration of the cochlea, acquiring a peripheral hearing loss, which causes a decrease in the capacity of communication[2,3].

There are different degrees of hearing loss and, even in mild hearing loss, there is a need for diagnosis and early intervention in the elderly[4], since in addition to the peripheral hearing loss, the elderly usually have a cerebral cortex level degeneration and a decrease in the number of neurons due to aging[5], which can lead to associated central auditory processing disorder (APD), and further impairs speech comprehension[6]. Still, there is the possibility of a cognitive deficit as a function of hearing loss[7,8], which reinforces the importance of rehabilitation as early as possible.

Among the problems caused by auditory sensory deprivation are changes in abilities involving attention, cognition and memory[9]. These abilities are also part of the APD of the individual, which can be evaluated by means of behavioral and electrophysiological tests, in the latter case, Cortical Potentials or Long-Latency Auditory Evoked Potentials (LLAEP), which can be performed in the evaluation of hearing impaired individual[10] and help to understand how sensorineural hearing loss can alter brain processes for auditory detection and discrimination.

The LLAEP can be subdivided into exogenous potentials (P1, N1, P2, N2), influenced mainly by the physical characteristics of the stimulus (intensity, frequency and duration)[11], and endogenous (P300) influenced by internal events related to the cognitive function of the subject[12,13].

The presence of N1, for example, suggests physiological evidence of the arrival of the stimulus to the supratemporal auditory cortex and demonstrates that the stimuli are audible by the individual, that is, the initial decoding of the stimulus[14,15]. The P2 wave is related to the ability to discriminate the characteristics of sounds[14] and P300 is related to cognitive function, which requires tasks to varying degrees of complexity. The response of P300 is related to fundamental aspects of mental function: perception and cognition[12-17]. Thus, the LLAEP allows the neuroelectric measurement in each way of the auditory path and the precise observation of the information processing in time, in milliseconds (ms)[14].

The LLAEP is able to provide information on both the auditory pathway and cognitive aspects, because at the moment the subject performs the P300, for example, he will need his attention, cognition and memory skills to perform the task that the test proposes. In it, the subject will need the memory ability to count a different stimulus and keep the count of these; attention to perceive this stimulus in the middle of several equal stimuli, being the memory and attention two abilities totally related to the cognitive aspects of the subject, that needs to understand and to carry out the task of the test[10,13,17].

The auditory deprivation time caused by hearing loss is directly related to decreased neural function or plasticity. In this way, individuals who delay the demand for auditory rehabilitation will have fewer answers regarding experiences and modifications of the environment[18]. One of the ways of treating hearing loss is the use of the Personal Hearing Amplification Device that amplifies both environmental sounds as well as speech, warning and danger signals. Thus, the assessment of LLAEP in patients with mild to moderate hearing loss becomes important as a tool for the neurophysiological evaluation of central auditory pathway processes. Obviously, the full assessment should involve behavioral and electrophysiological testing. However, electrophysiological assessment can serve as a screening for subsequent testing in this population, as well as being an "objective" measure, facilitating the assessment of these auditory abilities.

Electrophysiological measures can provide information on how efficient the brain is to recognize differences in speech stimuli and measure its reaction time for it. Such information may contribute to the elaboration of rehabilitation strategies for subjects with hearing loss[15].

Thus, it is understood that it is important to observe the physiological function of the auditory pathway at the cortical level through auditory sensory deprivation, and to know the time of deprivation that can actually harm the subjects with hearing loss. Therefore, the objective of this study was to verify if auditory sensory deprivation time of up to five years in individuals with mild or moderate sensorineural hearing loss may influence the responses of the LLAEP.

Method

The study was characterized as being a prospective, transversal and quantitative research. The procedures were initiated after the approval of the research project in the Ethics and Research Committee on Human Beings of the Universidade Federal de Santa Maria, under the protocol number 25933514.1.0000.5346. All subjects invited to participate in the study were guided by their own free participation, instructed on the procedures to be performed and followed the precepts of resolution 466/12.

The subjects were selected from a database of a Regional Health Coordination and invited by telephone to participate in the research. In this telephone contact they received brief information about the purpose of the research and the tests that would be carried out. For those who agreed to participate, they were asked to take the updated tonal audiometry on the date of the examination.

When accepting to participate in the study, they were scheduled to perform the LLAEP evaluation at the Electrophysiology Ambulatory Clinic of the

Hospital Universitário de Santa Maria - HUSM, and on that occasion they signed the Informed Consent Term, which authorized their voluntary participation in the study research, which also included all the procedures to be performed. The exams had a predetermined day and time.

To compose the sample, the subjects needed to meet the following eligibility criteria: have mild or moderate sensorineural hearing loss[19] and symmetric; being on the waiting list of the hearing aid concession program (having two to five years of auditory sensory deprivation); be literate; do not have neurological changes or syndrome; never made use of AASI; have no middle ear changes.

Initially, 330 charts were selected for analysis. Of those, 84 were excluded from subjects with asymmetric hearing loss and 215 from subjects with moderately severe, severe and profound hearing loss[19].

Thus, there were left 31 records of subjects with mild or moderate hearing loss who were contacted by telephone and invited to participate in the study, but nine did not attend on the day of the evaluation, five had deprivation time greater than 10 years and three had time of deprivation less than two years, totaling 14 subjects who were part of the final sample, six of them were female gender and eight were of the male gender, in the age range of 52 to 76 years.

The investigation of the time of hearing deprivation, that is, how long the subject perceived the hearing loss, or that it was diagnosed, was performed by anamnesis.

The LLAEP registration was performed on the "SmartEP" equipment by Intelligent Hearing Systems (IHS) of two channels. The examination was conducted in a quiet room and the subjects stayed awake, sitting in a comfortable chair.

Before the insertion of the electrodes, the skin was cleaned with abrasive paste, and the surface electrodes were fixed with electrolytic paste and micropore adhesive tape on the forehead (Fpz = earth electrode), cranial vertex (Cz = active electrode), and in the earlobes (reference electrodes: A1 = left ear and A2 = right ear), according to the international system standard 10-20. The impedance of the electrodes remained less than or equal to 3 Kohms.

For the presentation of the sound stimuli, ER-3A insertion phones were placed in the subjects, who were instructed to pay attention to the different stimuli (rare stimulus) that would appear randomly in the middle of a sequence of equal stimuli (frequent stimulus). The participant was asked to mentally count the rare stimuli and to respond at the end of the test the number of stimuli counted, which were always around 60. For this it was also checked previously if the subjects could count up to 60.

Before starting the registration, a brief training was conducted to guarantee the understanding of the procedure and discrimination of the presented stimuli. The intensity of presentation of the stimuli was of 80 dBnNA, considered audible and comfortable to all participants.

The stimulus used was verbal, in which the frequent was the syllable /ba/ and the rare stimulus, the syllable /di/, presented binaural form, in a paradigm of the rare-type type, with probability of 80% of frequency stimuli and 20% of rare ones, in a total of 300 stimuli, of alternating polarity, with presentation rate of 1 stimulus per second and band pass filter: 1-25 Hz. These stimuli are part of the software of the Smart EP equipment and the same have duration of 170050 usec for the stimulus /ba/ and 209525 usec for the /di/. The artifacts were controlled during the test so that they did not interfere with the recording of the responses.

Among the exogenous potentials, the potential N1 and P2 and the endogenous potential P300 were analyzed. The latency of the N1 and P2 components was marked on the frequent stimulus tracing and the P300 component was marked on the rare stimulus tracing. For the classification of these potentials in normal and altered, we considered the reference criteria cited in a study[20] that also used this same set of stimuli and the same protocol as the current study, also in the Smart EP, where N1 occurred on average of 108.55 ms (± 18.05), P2 at 184.9 ms (± 25.15) and P300 at 327.05 ms (± 61.3). The current study used the same methodology of the mentioned study, which evaluated adult subjects. Thus, in addition to using this reference, we also considered the age of participants over 60 years of age in the current study, for the classification in normal and altered in P300, since the literature refers to a latency increase of around 2.85 ms every year from this age goup[13].

At the end of the exam the subjects received guidelines regarding the results and those who presented changes were sent to conduct behavioral evaluation of auditory processing.

The results were arranged in an Excel spreadsheet and analyzed by a professional of the area, being considered significant results when p≤0.05 with 95% confidence interval. The statistical tests used were the Equality Test of Two Proportions for the distribution of potentials in normal and altered the Mann-Whitney test to compare potentials for age and time of deprivation.

Results

The mean age of participants was 63.5 years with a minimum of 52 and a maximum of 76 years. In relation to the time of auditory sensorial deprivation, it varied from two to five years according to the inclusion criteria, with a mean of 3.3 years.

In Table 1, there is the distribution of N1, P2 and P300 for the classification of normal and altered. Note that there are a greater number of normal subjects in the potentials, however, only in N1 there is a significant difference, with normal majority. It is worth mentioning that the subjects classified as altered in the P300, showed absence of this potential in all cases.

In Tables 2, 3 and 4, the results (normal or altered) of the N1, P2 and P300 potentials are consecutively compared with the variables age and time of deprivation, where it is observed that there was no statistical significance for age and time of deprivation in the three potentials. However, Table 3 shows a tendency of P2 to undergo influences of deprivation time. Still, Figures 1, 2 and 3 represent the medians and respective quartiles of Tables 2, 3 and 4 in comparing the potentials results with age and deprivation time.

Table 1. Distribution of N1. P2 and P300 to normal and altered

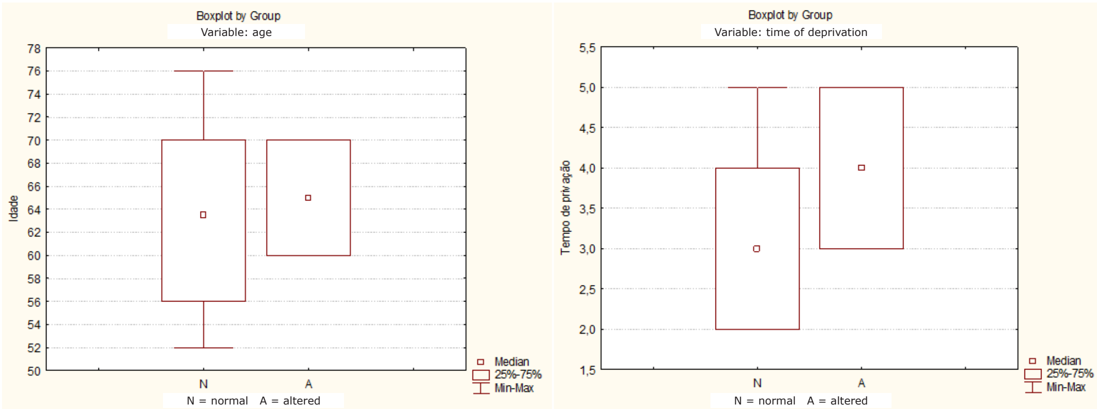
Potential	Classification	N	%	P-value
N1	Normal	12	85.7%	<0.001
	Altered	2	11.8%	
P2	Normal	9	64.3%	0.131
	Altered	5	29.4%	
P3	Normal	9	64.3%	0.131
	Absent	5	29.4%	

Caption: N: number of subjects.
Equal Two-Proportion Test (p≤0.05)

Table 2. Compares N1 for age and deprivation time

N1	Age		Time of Deprivation	
	Altered	Normal	Altered	Normal
Average	65.0	63.3	4.0	3.3
Standard Deviation	7.1	7.5	1.4	1.1
N	2	12	2	12
IC	9.8	4.2	2.0	0.6
P-value	0.782		0.396	

Caption: N: number of subjects; CI: confidence interval.
Mann-Whitney test (p≤0.05)

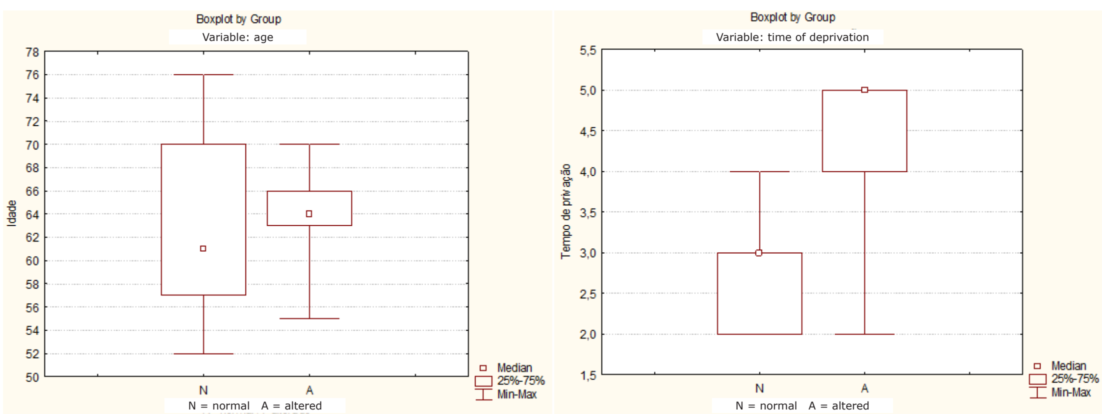


Picture 1. Compares N1 for age and time of deprivation

Table 3. Compares P2 for age and time of deprivation

P2	Age		Time of Deprivation	
	Altered	**Normal**	**Altered**	**Normal**
Average	63.6	63.4	4.2	2.9
Standard Deviation	5.5	8.3	1.3	0.8
N	5	9	5	9
IC	4.8	5.4	1.1	0.5
P-value	0.946		0.054	

Caption: N: number of subjects; CI: confidence interval.
Mann-Whitney test (p≤0.05)

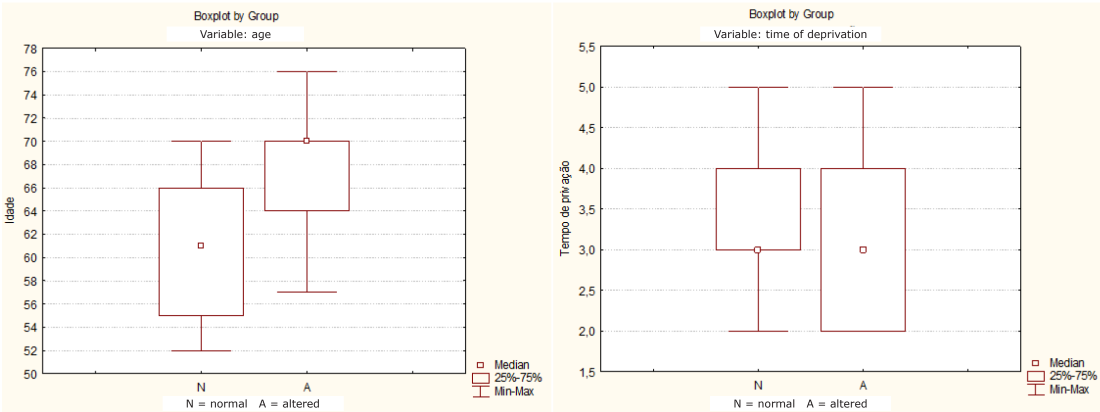


Picture 2. Compares p2 for age and time of deprivation

Table 4. Compares P300 for age and time of deprivation

P300	Age		Time of deprivation	
	Absent	**Normal**	**Absent**	**Normal**
Average	67.4	61.3	3.2	3.4
Standard Deviation	7.2	6.6	1.3	1.1
N	5	9	5	9
IC	6.3	4.3	1.1	0.7
P-value	0.121		0.680	

Caption: N: number of subjects; CI: confidence interval.
Mann-Whitney test (p≤0.05)



Picture 3. Compares P300 for age and time of deprivation

Discussion

Even though the literature points out that cortical potentials can be performed in individuals with larger hearing loss[10,21], it was chosen for the mild and moderate degree in this study, because better communication with these individuals was possible, since the contact would be by phone and to understand if these degrees of loss with little time of deprivation would already be able to influence the LLAEP, considering that these subjects usually took a little longer to seek treatment because they did not realize the loss. In addition, the literature indicates that mild and moderate hearing loss is already capable of producing a deceleration of the brain processes involved in the identification and discrimination of sound stimuli, reflecting in an increase in the latency of cortical potentials[15].

In this study, in addition to considering the lowest degrees of hearing loss, subjects with a deprivation time greater than 10 and less than two years were excluded in order to make the results more reliable. However, this methodology influenced the sample size, since the majority of subjects in the waiting queue had hearing loss of higher degrees or greater deprivation times.

Regarding the percentage of subjects with normal or altered potentials, it was noted that there was a significant difference only for the N1 potential, in which there were a greater number of normal individuals and in the other potentials, they did not present a difference, presenting a number close to normal and altered individuals (Table 1). This result can be justified by the fact that component N1 represents the detection of the stimulus in the auditory cortex, which represents the arrival of the acoustic stimulus in the central auditory system, evidencing the adequate audibility of the stimuli by the participants of the present study. In relation to P300, the absence of this potential, which classified subjects as altered, may have occurred due to impairments in the attention of the subjects to sound stimuli.

A study[22] compared three groups of elderly individuals between 60 and 85 years of age and normal thresholds or hearing loss up to 40/50 dBHL in the frequencies up to 2 KHz, but with hearing losses of varying degrees between 3 and 6 KHz (mean 0 to 39; to 59, from 60 to 120 dBHL) and did not observe differences between the groups regarding P300 latency, the mean of the groups being within the expected values for the age, i.e., the authors concluded that the P300 was not very sensitive for age-related changes. It is also noted that P300 did not change due to peripheral hearing loss in these subjects. However, the study does not report the time of hearing deprivation or whether the subjects used Personal Hearing Amplification Device or not.

Other researchers[15] conducted a study to observe the cortical detection of speech sounds in adults with sensorineural hearing loss. Contrary to previous authors, they concluded that sensorineural hearing loss had a greater influence on the latency of N2 and P300 (posterior) potentials, causing an increase, than in N1 and MMN (previous). Thus, they suggested that hearing loss implies greater impact the higher the cognitive level processed, and that causes physiological changes in the cortex, which causes it to have longer latency and reaction times. However, in the same way as the previous study, it does not report the time of auditory sensory deprivation of the evaluated subjects, which makes comparisons and analyzes difficult.

When comparing the age and the deprivation time with the latencies found in the potentials, it is verified in this study that there was no influence of these variables on the evaluated potentials (Tables 2, 3 and 4), which differs from other studies in which the authors present the possibility of recording changes in the morphology, latency and amplitude of the cortical auditory powers due to the deprivation of the auditory[23-25]. However, there is a tendency for P2 to be influenced by deprivation time (Table 3). Though, a study[26] which analyzed P1, N1 and P2 in adults and compared with the elderly (with and without hearing loss), verified an increase in N1 and P2 latency in the elderly group, regardless of hearing conditions, suggesting that even before auditory impairment, aging itself may interfere with these potentials.

In a study conducted in individuals with symmetric bilateral hearing loss and unilaterally prosthesis, it was verified that P300 latency in the deprived ear was statistically higher than that recorded in the ear, but this study analyzed subjects with loss of up to 70 dBHL[27]. In another study it was also verified the association of the presence or absence of P300 with the time of auditory deprivation[10]. However, this study compared those who were rehabilitated up to five years of age or after that age, to severe or profound grade losses.

Regarding the ages of the subjects there are studies that affirm that due to structural changes in the auditory pathway, P300 latency begins to increase in the second or third decade of life. For this reason, age was taken into account in the interpretation of the values obtained as already referenced in the methodology[13,21]. However, most subjects presented values within normal for adults, disagreeing with the studies cited.

The absence of influence of age and time of auditory deprivation on the cortical potentials in this study can be justified by the small sample size, however it is known that sensory deprivation brings negative consequences to hearing abilities[28] and consequently to cortical potentials[24,27]. Perhaps a larger sample or greater hearing loss in this same period of deprivation or even those same degrees of hearing loss with a longer deprivation can demonstrate such results in future correlations.

In addition, it is known that the range of normality of LLAEP can be considered extensive when compared to other electrophysiological assessments, which makes it difficult to characterize normal and altered cross-sectional studies. In the literature there is also a disagreement about the cortical potentials being affected or not by the subjects' age, which can be caused by the size of the samples, paradigms used and even the placement position of the electrodes[25].

Even though from this study no influence of the time of auditory deprivation with cortical potentials has been identified, it is important that there is awareness of the use of hearing aids as early as possible, aiming at greater stimulation of the auditory pathways and improving cerebral plasticity.

Conclusion

The time from two to five years of auditory sensory deprivation in subjects with mild to moderate sensorineural hearing loss, did not interfere in the latency values of cortical potentials N1, P2 and P300.

References

1. Crispim KGM, Ferreira AP. Prevalência de deficiência auditiva referida e fatores associados em uma população de idosos da cidade de Manaus: um estudo de base populacional. Rev CEFAC. 2015; 17(6): 1946-56. http://www.scielo.br/scielo.php?pid=S1516-18462015000801946&script=sci_abstract&tlng=pt

2. Baraldi GS, Almeida LC, Borges ACC. Evolução da perda auditiva no decorrer do envelhecimento. Rev Bras Otorrinolaringol. 2007; 73(1): 64-70. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0034-72992007000100010

3. Paiva KM, Maciel PMA, Cintra LG. Compreendendo o idoso usuário de próteses auditivas. Ciênc saúde coletiva. 2011; 16(6): 2927- 34. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1413-81232011000600030

4. Veras RP, Mattos LC. Audiologia do envelhecimento: revisão da literatura e perspectivas atuais. Rev Bras Otorrinolaringol. 2007; 73(1): 128-34. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0034-72992007000100021

5. Nordon DG et al. Perda cognitiva em idosos. Rev Fac Ciênc Méd Sorocaba. 2009; 11(3): 5-8. https://revistas.pucsp.br/index.php/RFCMS/article/viewFile/1874/1288

6. Lima IMS, Miranda-Gonsalez EC. Efeitos da perda auditiva, escolaridade e idade no processamento temporal de idosos. Rev CEFAC. 2016; 18(1): 33-9. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-18462016000100033

7. Kopper H, Teixeira AR, Dorneles S. Cognitive Performance of a Group of Elders: Influence of Hearing, Age, Sex, and Education. Int Arch Otorhinolaryngol. 2009; 13(1): 39-43. http://www.arquivosdeorl.org.br/conteudo/acervo_eng.asp?Id=586

8. Lin FR, Yaffe K, Xia J, Xue Q, Harris TB, Purchase-Helzner E. et al. Hearing Loss and Cognitive Decline in older adults. Jama Intern Med. 2013; 173(4): 293-9. http://jamanetwork.com/journals/jamainternalmedicine/fullarticle/1558452

9. Pinheiro MMC, Iório MCM, Miranda EC, Dias KZ, Pereira LD. A influência dos aspectos cognitivos e dos processos auditivos na aclimatização das próteses auditivas em idosos. J Soc Bras Fonoaudiol. 2012; 24(4): 309-15. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S2179-64912012000400004

10. Reis ACMB, Frizzo ACF, Isaac ML, Garcia CFD, Funayama CAR, Iório MCM. P300 em indivíduos com perda auditiva sensorioneural. Braz j otorhinolaryngol. 2015; 81(2): 126-32. http://www.scielo.br/scielo.php?pid=S1808-86942015000200126&script=sci_arttext&tlng=pt

11. Frizzo ACF, Alves RPC, Colafêmina JF. Potenciais evocados auditivos de longa latência: um estudo comparativo entre hemisférios cerebrais. Rev Bras Otorrinolaringol. 2001; 67(5): 618-25. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0034-72992001000500004

12. Duarte JL, Alvarenga KF, Banhara MR, Melo ADP, Sás RM, Costa Filho OA. Potencial evocado auditivo de longa latência-P300 em indivíduos normais: valor do registro simultâneo em Fz e Cz. Braz J Otorhinolaryngol. 2009; 75(2): 231-6. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0034-72992009000200012

13. Cóser MJS, Cóser PL, Pedroso FS, Rigon R, Cioqueta E. P300 Auditory Evoked Potential Latency In Elderly. Braz J Otorhinolaryngol. 2010; 76(3): 287-93. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1808-86942010000300003

14. Regaçone SF, Gução ACB, Giacheti CM, Romero ACL, Frizzo ACF. Potenciais evocados auditivos de longa latencia em escolares com transtornos especificos de aprendizagem. Audiol Commun Res. 2014;19(1):13-8. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S2317-64312014000100004

15. Oates PA, Kurtzberg D, Stapells D. Effects of sensorineural hearing loss on cortical event-related potential and behavioral measures of speech-sound processing. Ear Hear. 2002; 23(5): 399-415. https://www.ncbi.nlm.nih.gov/pubmed/12411773

16. Duarte JL, Alvarenga KF, Costa OA. Potencial cognitivo p300 realizado em campo livre. Rev Bras Otorrinolaringol. 2004; 70(6): 781-6. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0034-72992004000600013

17. McPherson DL. Late potentials of the auditory sistem. San Diego: Singular Publishing Group; 1996.

18. Kappel V, Moreno ACP, Buss CH. Plasticidade do sistema auditivo: considerações teóricas. Braz j otorhinolaryngol. 2011; 77(5): 670-4. http://www.scielo.br/scielo.php?pid=S1808-86942011000500022&script=sci_arttext&tlng=pt

19. Lloyd LL, Kaplan H. Audiometric interpretation: a manual of basic audiometry. University Park Press: Baltimore; 1978.

20. Didoné DD, Oppitz SJ, Folgearini J, Biaggio EPV, Garcia MV. Auditory Evoked Potentials with Different Speech Stimuli: a Comparison and Standardization of Values. Int Arch Otorhinolaryngol. 2016; 20(2): 99-104. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1809-48642016000200099

21. Miranda EC, Pinheiro MMC, Pereira LD, Iorio MCM. Correlation of the P300 evoked potential in depressive and cognitive aspects of aging. Braz J Otorhinolaryngol. 2012; 78(5): 83-9. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1808-86942012000500013

22. Samelli AG et al . Avaliação auditiva periférica e central em idosos. Rev Bras de Geriatr e Gerontol. 2016; 19(5): 839-49. http://www.scielo.br/pdf/rbgg/v19n5/pt_1809-9823-rbgg-19-05-00839.pdf

23. Purdy SC, Kelly AS, Thorne PR. Auditory evoked potentials as measures of plasticity in humans. Audiol Neurootol. 2001; 6(4): 211-5. https://www.ncbi.nlm.nih.gov/pubmed/11694730

24. Tremblay KL, Kraus N. Auditory training induces asymmetrical changes in cortical neural activity. J Speech Lang Hear Res. 2002; 45(3): 564-72. https://www.ncbi.nlm.nih.gov/pubmed/12069008

25. Stenklev NC, Laukli E. Cortical Cognitive Potentials in Elderly Persons. J Am Acad Audiol. 2004; 15(6): 401-14. https://pdfs.semanticscholar.org/7d97/d0eeb09fb329ec370c8966beaa503d5587c4.pdf

26. Tremblay KL, Piskosz M, Souza P. Effects of age and age-related hearing loss on the neural representation of speech cues. Clin Neurophysiol. 2003; 114(7): 1332-43. https://www.ncbi.nlm.nih.gov/pubmed/12842732

27. Wieselberg MB, Iorio MCM. Adaptação de prótese auditiva e a privação da audição unilateral: avaliação comportamental e eletrofisiológica. Braz J Otorhinolaryngol. 2012; 78(6): 69-76. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1808-86942012000600012

28. Amorim RMC, Almeida K. Estudo do benefício e da aclimatização em novos usuários de próteses auditivas. Pró- Fono. 2007; 19(1): 39-48. http://www.scielo.br/scielo.php?pid=S0104-56872007000100005&script=sci_abstract&tlng=pt