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Musical and temporal auditory skills in cochlear implant users after music therapy

Habilidades auditivas musicais e temporais em usuários de implante coclear após musicoterapia

Janaina Patricio de Lima[1]
Sônia Maria Simões Iervolino[2]
Eliane Schochat[3]

Keywords

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ABSTRACT

Purpose: Verify the performance of musical perception and temporal auditory resolution and ordering skills in pre- and post-music therapy patients with cochlear implants (CI). **Methods:** Study participants were 11 postlingual CI users with mean age of 47.64 years. All individuals underwent 10 weekly music therapy sessions. Auditory assessment was conducted using the Montreal Battery of Evaluation of Amusia (MBEA) and the Frequency Pattern Test (FPT). All participants were submitted to a placebo condition prior to music therapy and were evaluated at three different times. **Results:** Significant improvement was observed in the subtests of contour and melody memory after music therapy. No placebo effect or difference in the FPT was observed after music therapy. **Conclusion:** Music therapy is a useful tool to improve musical skills in adult postlingual users of CI.

Descritores

Audição
Perda Auditiva
Implante Coclear
Musicoterapia
Plasticidade Neuronal
Música

RESUMO

Objetivo: Verificar o desempenho das habilidades de percepção musical e das habilidades auditivas temporais de resolução e ordenação pré e pós-musicoterapia em pacientes pós-linguais usuários de implante coclear. **Método:** Participaram do estudo 11 indivíduos (média de idade: 47,64 anos) pós-linguais implantados, que foram submetidos a 10 sessões de musicoterapia, sendo uma por semana. Para a avaliação auditiva, foram utilizados o teste *Montreal Battery Evaluation of Amusia* e o teste de padrão de frequência (TPF). Todos os participantes passaram por um momento placebo antes da musicoterapia e foram avaliados em três momentos distintos. **Resultados:** Foi observada melhora significativa nos subtestes das habilidades musicais de contorno e melodia após musicoterapia. Não foi observado efeito placebo e nem diferença do TPF após a musicoterapia. **Conclusão:** A musicoterapia foi uma ferramenta útil para melhorar as habilidades auditivas musicais em indivíduos adultos pós-linguais usuários de IC.

Endereço para correspondência:
Janaina Patricio de Lima
Rua José Benedito Salinas, 68
apto.152B, São Paulo (SP), Brasil.
E-mail: janapatricio@yahoo.com.br

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Study conducted at the Faculdade de Fonoaudiologia, Irmandade de Santa Casa de Misericórdia de São Paulo, São Paulo (SP), Brasil.
[1] Universidade de São Paulo – USP - São Paulo (SP), Brasil.
[2] Irmandade de Santa Casa de Misericórdia de São Paulo - São Paulo (SP), Brasil.
[3] Curso de Fonoaudiologia, Universidade de São Paulo – USP - São Paulo (SP), Brasil.

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INTRODUCTION

Cochlear Implant (CI) is an electronic device that directly stimulates the auditory nerve, transforming the acoustic signal into an electrical signal that will be transmitted through the auditory pathways to the cerebral cortex[1,2]. This device is able to provide the necessary characteristics for speech comprehension, but presents limitations to reproduce and provide all the fine temporal characteristics of the acoustic stimulus. One of the frequent complaints of CI users is the lack of musical quality. In addition to the technical limitations of the CI, some personal characteristics may affect this perception, such as individual's deprivation time, pathology, number of activated electrodes, and type and mode of stimulation.

According to the American Speech-Language-Hearing Association – ASHA[3], the temporal aspects of hearing include masking, integration, order/sequence, and resolution skills. Temporal ordering is closely associated with the importance of speech and music[4,5]. The ability to recognize, identify, and sequence the auditory patterns involves a variety of processes, from the ipsilateral and contralateral auditory pathways of the stimulated ear to the two cortical hemispheres and the corpus callosum[6,7].

Musical aspects involve skills with spectral and temporal characteristics. Researchers[8] have developed the Montreal Battery of Evaluation of Amusia (MBEA), which assesses six aspects of musical perception: Contour, Interval, Scale, Rhythm, Meter, and Melody memory. This battery has been used in studies with individuals with amusia, which is characterized by the presence of some deficit in musical perception. This test presents satisfactory sensitivity and specificity and is thus useful in assessing musical abilities[9].

Hearing therapy is an attempt to improve the performance of CI users. Even with the technical limitations of the CI, the training of auditory skills can assist users with achieving better performance in situations of difficult listening comprehension as well as in musical activities[10]. Music therapy is one of the approaches to hearing therapy. The use of music therapy is described in the specific scientific literature as a way to stimulate auditory processing in the most diverse pathological conditions[11,12]. The process of interpreting music in the human brain is extremely complex, involving several of its areas, including that of language processing. The basic concepts of music, such as pitch and intensity, are perceived in the primary auditory area, whereas the more robust concepts, such as musical phrases, are processed in the secondary and association areas, which closely overlap the areas of language[13,14]. In addition, there is participation of the limbic system, which is associated with the emotions transmitted by music[13]. Thus, the use of music for brain stimulation, in an attempt to improve auditory performance, should be considered especially in the approach in which the patients perform tasks and actively participate in the therapeutic process.

Therefore, this study aimed to characterize the musical and temporal auditory skills of CI users and verify whether music therapy can be a tool capable of stimulating and promoting the improvement of these skills.

METHODS

This study was approved by the Research Ethics Committee of the Irmandade de Santa Casa de Misericórdia de São Paulo under protocol no. 1.226.566. Study participants were 11 individuals (five men and six women) aged 25-68 years (mean of 47.64 ±14.36) presented with bilateral, severe or profound, postlingual, sensorineural hearing loss, who were users of cochlear implant (CI) for at least one year, had not previously studied music formally, and presented auditory threshold with CI in the open field of at least 40 dBNA at the 500, 1k, 2k, 3k, and 4k Hz frequencies. The patients were not undergoing Speech-language Pathology (SLP) therapy at the time of the study. All participants signed an Informed Consent Form (ICF) prior to study commencement.

Table 1 shows the individual characteristics of the individuals that comprised the study sample (n = 11).

Table 1. Characterization of the study sample

Individual	Age	Gender	Processor / Strategy	Etiology	Duration of deafness (yrs)	Time wearing device (yrs)	Age when CI was activated (yrs)
1	67	M	Opus2/FS4	idiopathic	47	3	64
2	29	F	Freedom/Ace	syphilis	7	3	26
3	55	F	N6/Ace	otosclerosis	40	11	44
4	34	M	N6/Ace	ototoxic	29	5	29
5	52	M	Opus2/FS4	meningitis	40	2	50
6	54	F	Harmony/HiRes120	idiopathic	30	6	48
7	25	M	N5/ace	idiopathic	19	2	23
8	51	F	Harmony/HiRes 120	meningitis	42	17	34
9	51	F	N5/Ace	familiar	39	11	40
10	38	F	Naída/HiRes Optima	idiopathic	30	1	37
11	68	M	Naída/HiRes Optima	idiopathic	28	3	65
Mean (SD)	47.6 (±14.3)	N/A	N/A	N/A	31.9 (±11.5)	5.8 (±5.0)	41.8 (±14.1)

Caption: SD = standard deviation; N/A = not applicable; N5 = Nucleus 5; N6 = Nucleus 6; M = male; F = female

Initially, the participants were submitted to anamnesis, pure-tone and vocal audiometry, and functional gain audiometry. The short version of the Montreal Battery of Evaluation of Amusia (MBEA)[8,9] was used to assess musical perception. This musical test is composed of six subtests that evaluate the discrimination of Scale (Subtest 1), Contour (Subtest 2), Interval (Subtest 3), Rhythm (Subtest 4), Meter (Subtest 5), and Melody memory (Subtest 6), that is, it covers both the spectral (scale, contour, and interval) and temporal (rhythm and meter) aspects of music. This evaluation enables the diagnosis of different musical deficits. The frequency range of the excerpts of the presentations ranges from 247 to 988 Hz using piano tones.

The Frequency Pattern Test (FPT) was chosen[15] for the assessment of discrimination and temporal ordering. In this test, each stimulus lasts 200 ms, and the interval between stimuli is 150 ms. The frequencies of 1122 Hz and 880 Hz were used for the high- and low-pitched tones, respectively.

Participants were assessed at three different times: Evaluation 1, preceded any intervention, performed after the anamnesis; Evaluation 2, performed after the placebo period, prior to music therapy; and Evaluation 3, final assessment, conducted after the music therapy. The patients were using their cochlear implants at all times of assessment and auditory training.

All individuals underwent a period of placebo activity. The objective of this phase was to evaluate the test-retest effect and thus provide greater transparency to the research. This placebo training consisted of requiring the participants to watch a television or listen to a radio news report twice weekly for four weeks. At the end of each week, the examiner asked questions about the reports in order to confirm the accomplishment of the activity. The contacts were made via telephone, cell phone message and, when not possible, through some family member and/or caregiver.

After the placebo phase and Evaluation 2, the participants underwent musical training. This training was composed of activities prepared by the researcher, use of software, and home assignments. The activities prepared by the researcher during therapy included exercises of discrimination and ordering of pitch and duration of tones, perception of rhythm and meter, recognition of melodic contour and timbre, training of temporal resolution, understanding of music lyrics with and without visual support, and use of a musical keyboard to play familiar children's songs. Activities on the musical keyboard were performed in all therapy sessions. Children's songs such as the Brazilian nursery rhyme "*atirei o pau no gato*" (I threw the stick in the cat) were chosen for these activities. The choice for this type of songs is due to the fact that they are popularly known and have a short sequence. The face-to-face, 40-min long sessions were held in a quiet environment, always with the therapist's monitoring, once a week for 10 weeks. Participants who used conventional contralateral hearing devices, used only cochlear implants during therapy.

Finally, after training, all participants were reassessed (Evaluation 3).

RESULTS

For comparison between the intervention periods (Placebo and Training), the Wilcoxon signed-rank test was applied[16]. To complement descriptive analysis, a confidence interval was used to verify the variance of the mean in a given probability. A 95% confidence interval at 5% significance level ($p<0.05$) was adopted for all statistical analyses.

Table 2 shows the performance of each participant in the Montreal Battery of Evaluation of Amusia (MBEA) at Evaluations 1 and 2 (placebo period). Results of the MBEA for Evaluations 1 and 2 are presented in percentage. No statistically significant difference was observed between these two evaluations conducted during the placebo period by the Wilcoxon signed-rank test, except for Subtest 5 (z=-2.103; p=0.04).

Table 3 describes the performance in the Frequency Pattern Test (FPT) at Evaluations 1 and 2 (placebo period).

Table 4 presents the performance of each participant in the MBEA at Evaluations 2 and 3. Results of the MBEA for Evaluations 1 and 2 are presented in percentage. Results of the Wilcoxon signed-rank test showed statistically significant difference between these two evaluations conducted during the placebo period for Subtests 2 and 6 (z=-2.103; p=0.04).

Table 5 shows the performance in the FPT at Evaluations 2 and 3.

Table 2. Descriptive statistics of the individuals' performance in the MBEA specific musical test during the placebo period

	Subtest 1 (%)		Subtest 2 (%)		Subtest 3 (%)		Subtest 4 (%)		Subtest 5 (%)		Subtest 6 (%)	
Evaluations	1	2	1	2	1	2	1	2	1	2	1	2
N	11	11	11	11	11	11	11	11	11	11	11	11
Mean	45.18	44.00	35.64	26.45	39.82	32.55	43.36	29.00	54.00	60.27	47.18	45.73
Standard deviation	25.18	23.44	26.87	25.80	26.89	23.62	35.34	36.21	29.53	32.46	27.21	25.72
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	80.00	66.00	80.00	60.00	73.00	73.00	86.00	93.00	86.00	93.00	86.00	78.00
p-value	0.73		0.11		0.20		0.11		**0.04***		0.68	

*statistically significant [separar essa linha da próxima]
Caption: N = number of participants; MBEA = Montreal Battery of Evaluation of Amusia

Table 3. Descriptive statistics of the individuals' performance in the FPT during the placebo period

	FPT (%)	
Evaluations	1	2
N	11	11
Mean	25.45	29.09
Standard deviation	32.05	33.60
Minimum	0.00	0.00
Maximum	90.00	100.00
p-value	0.38	

Caption: FPT = Frequency Pattern Test; N = number of participants

Table 4. Descriptive statistics of the individuals' performance in the MBEA specific musical test during evaluations 2 and 3

	Subtest 1 (%)		Subtest 2 (%)		Subtest 3 (%)		Subtest 4 (%)		Subtest 5 (%)		Subtest 6 (%)	
Evaluations	2	3	2	3	2	3	2	3	2	3	2	3
N	11	11	11	11	11	11	11	11	11	11	11	11
Mean	44.00	54.18	26.45	54.18	32.55	43.45	29.00	42.18	60.27	59.55	45.73	62.18
Standard deviation	23.44	20.90	25.80	11.79	23.62	30.82	36.21	42.42	32.46	21.17	25.72	17.67
Minimum	0.00	0.00	0.00	33.00	0.00	0.00	0.00	0.00	0.00	21.00	0.00	43.00
Maximum	66.00	73.00	60.00	73.00	73.00	80.00	93.00	100.00	93.00	86.00	78.00	100.00
p-value	0.33		**0.01***		0.37		0.37		1.00		**0.01***	

*statistically significant [separar essa linha da próxima]
Caption: N = number of participants; MBEA = Montreal Battery of Evaluation of Amusia

Table 5. Descriptive statistics of the individuals' performance in the FPT during evaluations 2 and 3

	FPT (%)	
Evaluations	2	3
N	11	11
Mean	29.09	32.73
Standard deviation	33.60	29.36
Minimum	0.00	0.00
Maximum	100.00	80.00
p-value	0.72	

Caption: N = number of participants; FPT = Frequency Pattern Test

DISCUSSION

The Montreal Battery of Evaluation of Amusia (MBEA) was applied to assess the musical perception skills in the participants of this study. This test was developed by Peretz et al.[8] and was initially used to evaluate individuals with amusia. This test, which has been previously applied in Cochlear Implant (CI) users, presents the important advantage of not requiring the use of familiar songs, which, in addition to being influenced by long-term memory, also limit the linguistic aspect.

Table 2 shows the results of participants in the MBEA subtests at Evaluations 1 and 2. Statistically significant difference was observed only in Subtest 5, which assesses the aspect of meter, between Evaluations 1 and 2, that is, during the placebo period. As it can be observed, there was a large variation of results between the participants, with a minimum of zero in all subtests at Evaluations 1 and 2. The MBEA has a "strategic item" that refers to two very different stimuli; therefore, if the participant responds to this item wrongly (considering both sounds as the same), the entire subtest is zeroed. This may have influenced the difference observed. In addition, the MBEA is a behavioral test that can be influenced by the attention and motivation of the participants.

Table 4 shows the performance of each participant in the MBEA after music therapy. Improvement was observed in 5 (scale, contour, interval, rhythm, and melody memory) of the 6 subtests assessed. Statistically significant differences were observed in Subtests 2 (contour) and 6 (melody memory). Researchers[17] observed effect of music therapy in postlingual adult patients, with greater recognition of simple and complex melodies in the group submitted to musical training compared with that of the control group. Another survey[18] also reported improvement in the perception of melodic contour in children with CI submitted to music therapy, corroborating the findings of the present study, in which general improvement in the musical skills of postlingual adult CI users was found.

Regarding the performance in each subtest of the MBEA, higher scores were observed in Subtest 5 compared with the other subtests at Evaluations 1 and 2, although without statistically significant difference between them (p=0.41). Subtest 5 assesses the meter ability. These findings partially corroborate those of another study[19], which reported higher scores on the Rhythm and Meter subtests in 12 patients with CI. In the present study, only the Subtest Meter excelled the others.

Table 4 also shows that the best score was obtained in Subtest 6, followed by Subtests 5 (meter), 2 (contour), 1 (scale), 3 (interval), and 4 (rhythm) after music therapy, but without statistically significant differences. These data are not in agreement with those of a previous study[19], which revealed that the spectral aspects (scale, contour, and interval) were less perceived than the temporal aspects (rhythm and metric) by CI users.

It is also possible to observe that the mean of the study participants' results for this test, even after music therapy, is below standard compared with that of normal-hearing listeners, which show approximately 80% of correct responses[9]. This factor can be explained not only by the individual characteristics of CI users, but also by the limitations of the processors available. It is known that there is a limitation of fine temporal resolution in CI users, both in the spectral and temporal aspects. CI extracts the most relevant information from the acoustic signal for speech comprehension; however, for music, there is loss of essential information that characterizes the musical elements of sound, distorting and modifying the music[20,21].

Enhanced technologies in the processors regarding the extraction of information on sound, position of the electrode beam in the cochlea, and design of the electrode beam could improve recognition of fine temporal structure in the sounds processed in the CI, and therefore of musical perception. Moreover, the combination of electrical and acoustic stimulation would also assist with this perception[20].

Table 3 shows that there was no statistically significant difference in the results between Evaluations 1 and 2 regarding the performance of the study participants in the Frequency Pattern Test (FPT) during the placebo period. The same was observed in the post-music therapy evaluation (Table 5). It is possible to observe that the scores obtained by the CI users of this study at all the evaluations are significantly lower than the standard for normal-hearing individuals, which show 75% of correct responses.

The findings of this study corroborate those of a Brazilian research[22] that used the FPT in children with CI and normal-hearing listeners, and also found lower scores in the first compared with the latter. In contrast, another group of researchers[23] did not detect statistically significant difference between these two populations.

Studies suggest that auditory ability for temporal ordering involves several processes, including peripheral auditory pathways and the cortical hemispheres[6,7]. A mean of sensory deprivation (duration of deafness) of 31.9 years was found in this study (Table 1). Even with the use of conventional hearing devices before CI, there was a limitation of reception of the total perception of musical sound aspects. Sensory deprivation results in degeneration of the auditory nerve fibers and cortical reorganization, when other sensory areas recruit that region that is not being stimulated[24,25]. This factor may justify the low scores obtained in the FPT and MBEA by the study participants, but it is a small sample and, as previously reported, several factors can simultaneously influence the auditory performance of CI users.

CONCLUSION

Results of the present study show improvement in the musical skills of postlingual Cochlear Implant (CI) users after music therapy; however, no improvement in the Frequency Perception Test (FPT) was observed in these individuals.

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Author contributions

JPL: study design, collection, analysis and interpretation of data, and writing of the manuscript; SMSI: data collection; ES: adviser, study design, analysis and interpretation of data, and writing of the manuscript.