Original Article

Artigo Original

Pitch-matching scanning: comparison of musicians and non-musicians' performance

Triagem da afinação vocal: comparação do desempenho de musicistas e não musicistas

Felipe Moreti[1]
Liliane Desgualdo Pereira[2]
Ingrid Gielow[1]

Keywords

Voice
Music
Auditory perception
Hearing tests
Speech, language and hearing sciences

ABSTRACT

Purpose: To develop a simple and quick-to-apply procedure for pitch-matching scanning that contains vocal imitation tasks of musical sounds of different tones and the temporal ordination of three different tones; to verify its applicability, by comparing the performance of musicians and non-musicians. **Methods:** Participants were 32 adults of both genders without vocal, hearing and/or auditory processing complaints. They were equally divided into two groups: musicians group – MG and non-musicians group – NMG. All participants underwent the Pitch-matching Scanning that included musical stimuli compatible with men and women singing vocal range gathered into two types of tasks: isolate tones and three-tone sequences**.** Participants were instructed to listen to them and to reproduce them vocally. Voice samples were recorded, analyzed acoustically, and right and wrong matches for the two tasks were characterized. The variables regarding the comparison between groups and types of tasks were statistically analyzed. **Results:** A difference was found between groups, and the MG presented greater number of right matches in both tasks. **Conclusion:** The Pitch-matching Scanning was developed and was sensitive to evaluate and compare the performance between groups. Thus, it can be used as a tool for pitch-matching tracking. Musicians presented better performance than non-musicians in the Pitch-matching Scanning.

Descritores

Voz
Música
Percepção auditiva
Testes auditivos
Fonoaudiologia

RESUMO

Objetivos: Elaborar um procedimento simples e de rápida aplicação contendo tarefas de imitação vocal de sons musicais de diferentes tons e de ordenação temporal de três tons; verificar sua aplicabilidade, comparando o desempenho de musicistas e não musicistas. **Métodos:** Participaram 32 indivíduos adultos, de ambos os gêneros, sem queixas vocais, auditivas e/ou de processamento auditivo, que foram divididos igualmente em dois grupos: grupo musicistas – GM e grupo não musicistas – GNM. Todos passaram pela Triagem da Afinação Vocal, que incluiu estímulos musicais compatíveis com a tessitura vocal de homens e mulheres, agrupados em dois tipos de tarefas: tons isolados e sequências de três tons. Os participantes foram instruídos a ouvir os tons apresentados e reproduzí-los vocalmente. As emissões vocais foram gravadas, analisadas acusticamente e os acertos e erros cometidos nos dois tipos de tarefas foram caracterizados. As variáveis referentes à comparação entre os grupos e os tipos de tarefas foram analisadas estatisticamente. **Resultados:** Houve diferença na comparação entre os dois tipos de tarefas para o GNM, o que não ocorreu com o GM. Foram observadas diferenças na comparação entre os grupos, sendo que o GM apresentou um maior número de acertos nos dois tipos de tarefas. **Conclusão:** A Triagem da Afinação Vocal foi criada e mostrou-se sensível para avaliação e comparação do desempenho entre grupos, podendo ser utilizada como instrumento de rastreamento de afinação vocal. Musicistas apresentaram melhor desempenho que não musicistas na Triagem da Afinação Vocal.

Correspondence address:
Felipe Moreti
R. Visconde de Mauá, 347, Vila Assunção, Santo André (SP), Brasil, CEP: 09030-530.
E-mail: felipemoreti@uol.com.br

Received: 8/9/2011

Accepted: 3/15/2012

Research performed at the Department of Speech-Language Pathology and Audiology, Universidade Federal de São Paulo – UNIFESP – São Paulo (SP), Brazil, as a prerequisite for accomplishing the Undergraduate Program in Speech-Language Pathology and Audiology. Presented at 20th Brazilian Speech-Language Pathology and Audiology Congress, Brasília; 2012.
(1) Department of Speech-Language Pathology and Audiology, Universidade Federal de São Paulo – UNIFESP – São Paulo (SP), Brazil; Centro de Estudos da Voz – CEV – São Paulo (SP), Brazil.
(2) Department of Speech-Language Pathology and Audiology, Universidade Federal de São Paulo – UNIFESP – São Paulo (SP), Brazil.
Conflict of interests: None

INTRODUCTION

Pitch-matching comprises the reproduction of isolated notes; it can follow a criteria for evaluating and comparing, given that the context and culture are taken into consideration[1,2]. Pitch-matching inaccuracy in singing can be defined as the lack of ability to vocally reproduce a melodic interval between notes, making it different from the suggested stimulus. Possible causes for pitch-matching inaccuracy may be relate to musical perception difficulty, lack of vocal control or the combination of these factors[2]. Therefore, it is worth highlighting that innate neural mechanisms and cultural experience[1] as well as emotions[3] determine the behavioral response for musical stimuli[4].

In order for the music to be considered as a specific mental representation, its cerebral representation and its interference in the linguistic processing must be known. Music is greatly connected to the language functions[5], due to the involvement of both cerebral hemispheres in its comprehension. Melody and harmony are connected to the right hemisphere[6] while spoken language production and comprehension and musical rhythm are tasks of the left hemisphere[7].

In order to accurately reproduce what is heard it is necessary to have good listening abilities[8], which requires not only a good hearing detection, but also an efficient sensorial processing. It is believed that the processing of auditory information works adequately in individuals that accurately match pitches and it works inadequately in individuals that inaccurately match pitches[9].

Failure in accurate pitch-matching may occur due to perception, processing, memory, language and/or production problems. Such problems may have causes of organic, cognitive, functional and behavioral nature or may be related to a combination of these aspects[10].

Considering the plasticity of the central nervous system, it is thought that for the majority of the cases accurate pitch-matching can be developed by means of specific training. Thus, a simple and quick-to-apply procedure related to pitch-matching scanning could aid the evaluation and the follow-up of neurologic processing abilities of musical sounds in singers that have an eventual inaccurate pitch-matching complaint. Hence, such procedure would enable the guidance of a specific auditory training.

Based on the above mentioned, the purposes of this research were to design a Pitch-matching Scanning procedure and to verify its applicability, by comparing the performance of musicians and non-musicians.

METHODS

The study was approved by the Research Ethics Committee of Universidade Federal de São Paulo (CEP-UNIFESP number 0729/06). All participants signed the Consent Term according to the demands of the 196/96 act (BRAZIL. Act MS/CNS/CNEP number 196/96 of October 10th 1996).

Design of the Pitch-matching Scanning instrument

Based on the tessitura of female and male voice classification[11], middle notes were selected for the scanning tasks so that they would be comfortable to individuals belonging any singing classification, and not to benefit or impair any singing voice types. In order not to have differences regarding male and female difficulties for the tone intervals presented, the stimuli selected varied an exact octave between the genders.

After the selection, the stimuli were grouped into two types of tasks: Task 1: presentation of five isolated tones; and Task 2: presentation of five 3-tone sequences (Chart 1). The two tasks of the scanning were produced with a piano and were registered into a CD in 4 tracks (Task 1 for male, Task 2 for male, Task 1 for female and Task 2 for female).

Chart 1. Selected stimuli for the Pitch-matching Scanning

Task	Order of stimuli		Men	Women
Task 1	First stimulus		E^3	E^4
	Second stimulus		$G\#^3$	$G\#^4$
	Third stimulus		F^3	F^4
	Fourth stimulus		B^3	B^4
	Fifth stimulus		$D\#^3$	$D\#^4$
Task 2	First sequence	First stimulus	E^3	E^4
		Second stimulus	A^3	A^4
		Third stimulus	$F\#^3$	$F\#^4$
	Second sequence	First stimulus	G^3	G^4
		Second stimulus	$D\#^3$	$D\#^4$
		Third stimulus	F^3	F^4
	Third sequence	First stimulus	D^3	D^4
		Second stimulus	G^3	G^4
		Third stimulus	E^3	E^4
	Fourth sequence	First stimulus	D^3	D^4
		Second stimulus	F^3	F^4
		Third stimulus	A^3	A^4
	Fifth sequence	First stimulus	$A\#^3$	$A\#^4$
		Second stimulus	$F\#^3$	$F\#^4$
		Third stimulus	E^3	E^4

Casuistic

A total of 32 volunteers participated in the study: 16 musicians (musicians group – MG), of which 13 were female and 3 were male, aged between 19 to 48 years and mean of 26.05 years; and 16 non-musicians (non-musicians group – NMG), of which 13 were female and 3 were male, aged between 21 to 55 years and mean of 26.12 years.

The individuals from the MG were all singers that belonged to the same university choir. They had rehearsals twice a week, each rehearsal was 3-hour long and the activities performed at the rehearsals consisted of musical theory, vocal warm-up and vocal technique as well as routine singing activities with musical scores reading. The mean period of singing in the choir for the MG was 1.4 years. The MG was composed only by people that had been going regularly to the choir for the past six months. Some individuals not only participated in the choir but also performed other activities related to music such as singing

teaching, vocal coaching, musical instruments playing, both amateurs and professionals. Individuals that did not meet these criteria were considered non-musicians and were assigned to the NMG. Both groups comprised individuals that belonged to the institution in which the research was carried out and all the individuals underwent an initial interview for identification of possible vocal, hearing and/or auditory processing complaints that were considered as exclusion criteria.

Administration of the Pitch-matching Scanning

The scanning was administered individually to the participants in a quiet environment. The sound stimuli were presented under free-field conditions at a comfortable loudness to the participants. For Task 1, the individuals should listen to the five isolate musical tones and, by means of vocal imitation, they repeated them one by one, right after the stimulus was presented. For Task 2, the individuals should listen to the five 3-tone sequences and repeat them one by one, by means of vocal imitation, right after the sequence was presented.

The vocal reproductions were directly captured into a portable computer by means of a head-mounted microphone that had a straight outcome curve, placed at 45º and five centimeters away from the mouth of the participant. The samples were recorded with the Sound Forge Software, 4.5c version and imported to the Vocalgrama Software, 1.8i (CTS Informática).

Data analysis

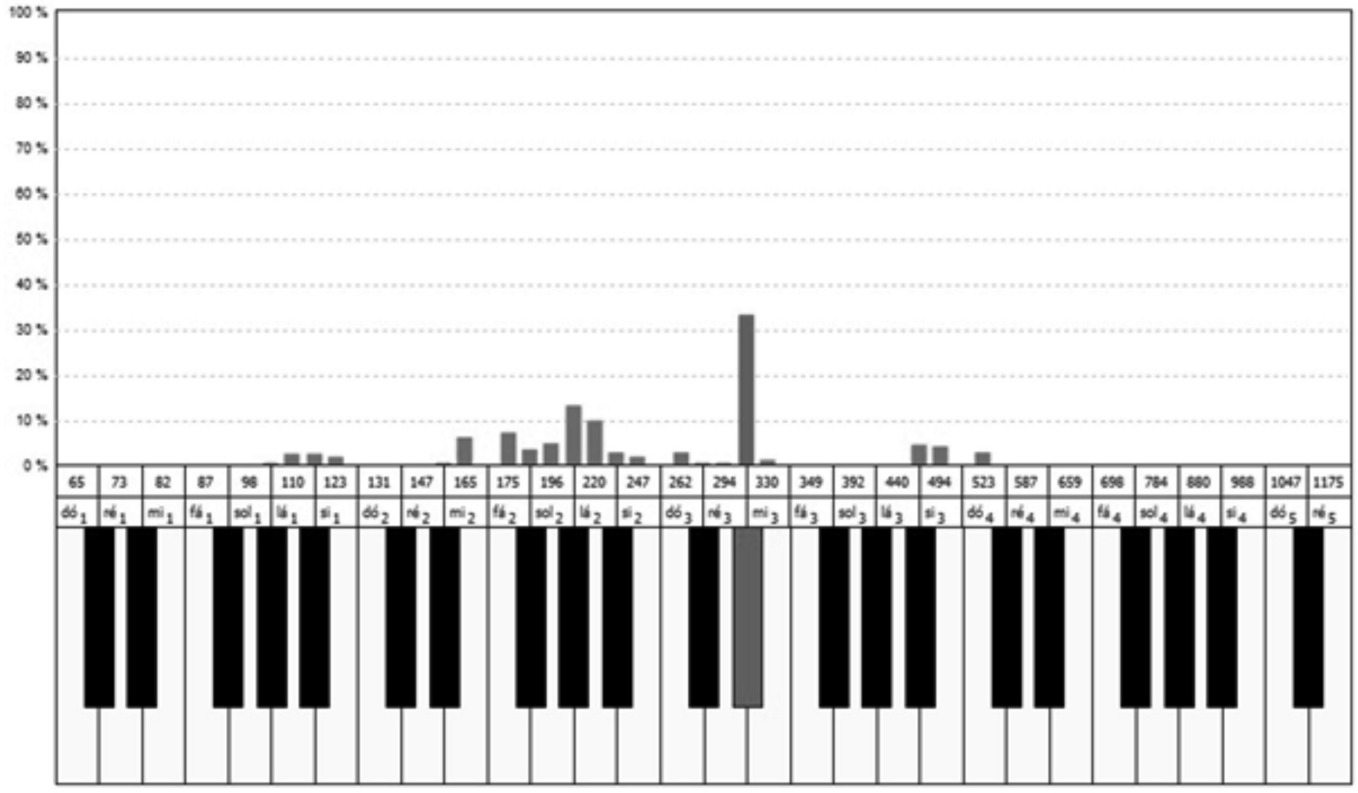
All voice samples were submitted to computerized acoustic analysis by means of the Vocalgrama Software. The vocal production of the individual was compared to the original tone presented. A right match was considered as such, when the vocal reproduction of the note presented had the same fundamental frequency, in other words, an accurate pitch-matching. In cases that the vocal reproduction and the original tone presented had distinct frequencies, the match was considered wrong (Figures 1 and 2).

For the statistical analysis we decided to describe the characteristics measured by employing the frequency and the percentage of right matches by clusters. The analyses performed were Tests for Equality of Two Proportions and the Mann-Whitney test. Significance level was 5% (0.05).

RESULTS

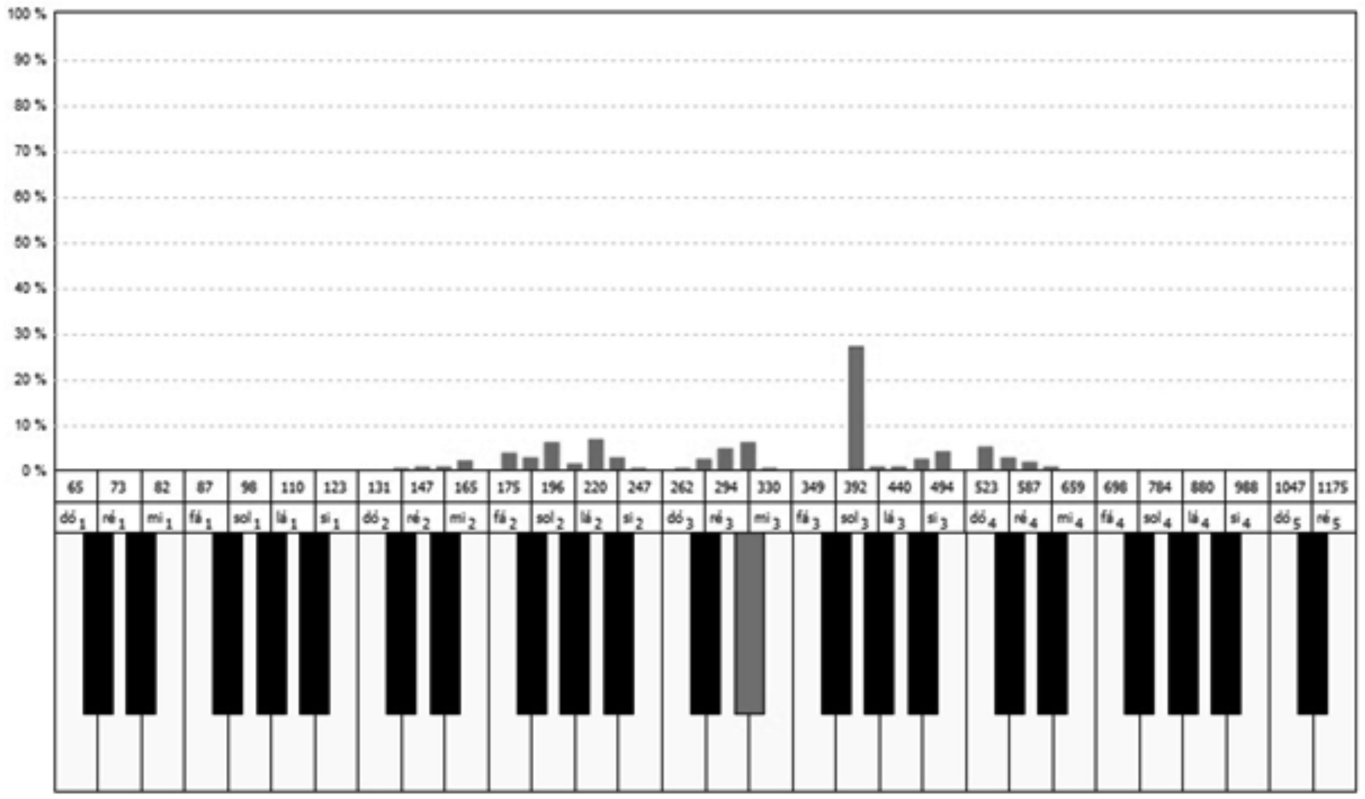
The Pitch-matching Scanning was designed based on the male and female tessitura and middle tones were used for both genders in the two types of tasks: reproduction of isolate tones and temporal ordination of three tones.

There was a difference in the comparison of Task 1 between the groups and the MG had a higher number of right matches (Table 1).



Note: Correct tuning – tone produced D#4 (gray button) and predominant percentage bar of the frequency histogram show that the vocal reproduction (D#4) was similar to the tone produced (Vocalgrama 1.8i – CTS Informática)

Figure 1. Example of the computerized acoustic evaluation of a correct tuning in the Pitch-matching Scanning



Note: Incorrect tuning – tone produced D#4 (gray button) and predominant percentage bar of the frequency histogram show that the vocal reproduction (G4) was different from the tone produced (Vocalgrama 1.8i – CTS Informática)

Figure 2. Example of the computerized acoustic evaluation of an incorrect tuning in the Pitch-matching Scanning

Table 1. Performance of musicians and non-musicians in Task 1 (single tones) of the Pitch-matching Scanning

		MG		NMG		p-value
		n	%	n	%	
E^3/E^4	Wrong matches	0	0.0	8	50.0	0.001*
	Right matches	16	100.0	8	50.0	
$G\#^3/G\#^4$	Wrong matches	1	6.3	11	68.8	<0.001*
	Right matches	15	93.8	5	31.3	
F^3/F^4	Wrong matches	3	18.8	12	75.0	0.001*
	Right matches	13	81.3	4	25.0	
B^3/B^4	Wrong matches	2	12.5	12	75.0	<0.001*
	Right matches	14	87.5	4	25.0	
$D\#^3/D\#^4$	Wrong matches	3	18.8	13	81.3	<0.001*
	Right matches	13	81.3	3	18.8	

*Significant values ($p \leq 0.05$) – Equality of Two Proportions Test
Note: MG = musicians group; NMG = non-musicians group

There was a difference between the groups for all the 3-tone sequence reproductions, again with the MG having a higher number of right matches (Table 2).

For the intra-group comparison regarding Tasks 1(five isolate tones) and 2 (five 3-tone sequences), a difference was found only for the NMG, with more wrong than right matches for this group. Moreover, for the Task 2 the rate of wrong matches was higher (Table 3).

DISCUSSION

The purpose of this research was to design a procedure entitled Pitch-matching Scanning and to verify its applicability by comparing the performance of musicians and non-musicians. The administration procedure of the Pitch-matching Scanning included the discrimination and vocal reproduction of isolate tones and the temporal ordination of some tones, always by means

Table 2. Performance of musicians and non-musicians in Task 2 (sequences of three tones) of the Pitch-matching Scanning

			MG		NMG		p-value
			n	%	n	%	
First sequence	E^3/E^4	Wrong matches	1	6.3	13	81.3	<0.001*
		Right matches	15	93.8	3	18.8	
	A^3/A^4	Wrong matches	1	6.3	11	68.8	<0.001*
		Right matches	15	93.8	5	31.3	
	$F\#^3/F\#^4$	Wrong matches	1	6.3	13	81.3	<0.001*
		Right matches	15	93.8	3	18.8	
Second sequence	G^3/G^4	Wrong matches	3	18.8	13	81.3	<0.001*
		Right matches	13	81.3	3	18.8	
	$D\#^3/D\#^4$	Wrong matches	2	12.5	13	81.3	<0.001*
		Right matches	14	87.5	3	18.8	
	F^3/F^4	Wrong matches	1	6.3	13	81.3	<0.001*
		Right matches	15	93.8	3	18.8	
Third sequence	D^3/D^4	Wrong matches	3	18.8	12	75.0	0.001*
		Right matches	13	81.3	4	25.0	
	G^3/G^4	Wrong matches	3	18.8	11	68.8	0.004*
		Right matches	13	81.3	5	31.3	
	E^3/E^4	Wrong matches	3	18.8	14	87.5	<0.001*
		Right matches	13	81.3	2	12.5	
Fourth sequence	D^3/D^4	Wrong matches	2	12.5	14	87.5	<0.001*
		Right matches	14	87.5	2	12.5	
	F^3/F^4	Wrong matches	4	25.0	14	87.5	<0.001*
		Right matches	12	75.0	2	12.5	
	A^3/A^4	Wrong matches	3	18.8	12	75.0	0.001*
		Right matches	13	81.3	4	25.0	
Fifth sequence	$A\#^3/A\#^4$	Wrong matches	1	6.3	12	75.0	<0.001*
		Right matches	15	93.8	4	25.0	
	$F\#^3/F\#^4$	Wrong matches	2	12.5	14	87.5	<0.001*
		Right matches	14	87.5	2	12.5	
	E^3/E^4	Wrong matches	2	12.5	14	87.5	<0.001*
		Right matches	14	87.5	2	12.5	

* Significant values (p≤0.05) – Equality of Two Proportions test
Note: MG = musicians group; NMG = non-musicians group

Table 3. Right and wrong matches made by musicians and non-musicians in Tasks 1 and 2 of the Pitch-matching Scanning

		Right matches		Wrong matches	
		Task 1	Task 2	Task 1	Task 2
MG	Mean	4.44	4.00	0.56	1.00
	Median	5	4.5	0	0.5
	SD	0.73	1.26	0.73	1.26
	p-value	0.420			
NMG	Mean	1.50	0.50	3.50	4.50
	Median	1	0	4	5
	SD	1.67	1.21	1.67	1.21
	p-value	0.022*			

* Significant values (p≤0.05) – Mann-Whitney Test
Note: MG = musicians group; NMG = non-musicians group; SD = standard deviation

of dichotic listening. This procedure involves the physiologic mechanism of discrimination of sound patterns related to the temporal ordination abilities (non-verbal gnostic process)[12].

Musicians had more right matches for isolate tones than non-musicians (Table 1). It is known that musicians have better frequency perception and discrimination than non-musicians[13-17] and the lack of musical exposure may be one of the causes for a possible pitch-matching inaccuracy[2].

During the task that involved the reproduction of a sound sequencing of frequency patterns, musicians also showed a better performance when compared to non-musicians (Table 2). Since every sound sequence perception involves more auditory abilities, if compared to isolate tone perception, individuals usually present better performance for simpler tasks as they demand less from central capabilities[12]. It is known that musical experience enhance auditory perception, both of duration and frequency, given that musicians are superior to non-musicians

when perceiving and detecting irregularities of rhythmic sequences and refined manipulations of tone variations[18-20].

When comparing isolate tone tasks with tone sequencing, both groups had more right matches at the isolate tone task and, for the NMG, the sequencing task turned out to be more difficult (Table 3), showing that it seems that musical learning, either formal or informal, helps the individual to overcome this greater difficulty that is the sound sequencing[13-17]. This fact corroborates the study that concluded that the longer the sequence of auditory stimuli for the sequencing task, the more difficult the activity becomes, since it involves a greater number of auditory abilities[12] and a greater auditory processing refinement[21].

Many people that do not sing in tune process musical information correctly, however they are unable to produce a desired tone. The estimate is that 3.3% of the population has some type of deficit related to musical processing and that at least 1% of them has amusia or tone deafness[10].

The term inaccurate pitch-matching may suggest a parallel to the visual phenomenon of color blindness and therefore, the study of inaccurate pitch-matching would bring about insights for the study of auditory processing. There are even two different descriptions for inaccurate pitch-matching: inability to sing in tune due to difficulties with musical perception (auditory processing) and inability to sing in tune due to difficulties associated with vocal production. It is very difficult to establish what deficiency generates the problem when you start with the final result[22].

Musical learning contributes to the development of the neurologic processing of acoustic events and can help with activities such as speaking, reading, singing, and so on. Therefore, a musical training, either formal or informal, helps to attenuate the difficulties of temporal ordination. That is why it is important and necessary to have a simple and quick-to-apply instrument in order to evaluate and follow up the progress of either trained or non-trained abilities of auditory processing.

CONCLUSION

The Pitch-matching Scanning was developed and it showed to be sensitive to evaluate and compare the performance between the groups and it can be used as an instrument for pitch-matching tracking. Musicians present better performance than non-musicians in the Pitch-matching Scanning.

ACKNOWLEDGEMENTS

We would like to acknowledge Maestro Eduardo Fernandes, who is the conductor of UNIFESP Choir, for his encouragement, care, friendship and collaboration in the area of music for the development of this research, as well as, for allowing us to collect the data of the musicians group with the singers of the UNIFESP Choir.

REFERENCES

1. Schueller M, Bond ZS, Fucci D, Gunderson F, Vaz P. Possible influence of linguistic musical background on perceptual pitch-matching tasks: a pilot study. Percept Mot Skills. 2004;99(2):421-8.
2. Sobreira S. Desafinação vocal. 2a ed. Rio de Janeiro: Musimed; 2003.
3. Petrini K, Crabbe F, Sheridan C, Pollick FE. The music of your emotions: neural substrates involved in detection of emotional correspondence between auditory and visual music actions. PLoS One. 2011;6(4):e19165.
4. Ríos AA, Rezende AG, Pela SM, Ortiz KZ, Pereira LD. Teste de padrão harmônico em escuta dicótica com dígitos – TDDH. Rev Soc Bras Fonoaudiol. 2007;12(4):304-9.
5. Brown S. Are music and language homologues? Ann N Y Acad Sci. 2001;930:372-4.
6. Hough MS, Givens GD, Cranford JL, Downs RC. Behavioural and electrophysiological measures of auditory attention in right hemisphere brain damage. Aphasiology. 2007;21(9):831-43.
7. Bamiou DE, Campbell NG, Musiek FE, Taylor R, Chong WK, Moore A, et al. Auditory and verbal working memory deficits in a child with congenital aniridia due to PAX6 mutation. Int J Audiol. 2007;46(4):196-202.
8. Estis JM, Dean-Claytor A, Moore RE, Rowell TL. Pitch-matching accuracy in trained singers and untrained individuals: the impact of musical interference and noise. J Voice. 2011;25(2):173-80.
9. Ishii C, Arashiro PM, Pereira LD. Ordering and temporal resolution in professional singers and in well tuned and out of tune amateur singers. Pro Fono. 2006;18(3):285-92.
10. Heresniak M. The care and training of adult bluebirds: teaching the singing impaired. J Singing. 2004;61(1):9-25.
11. Lacerda O. Classificação das vozes. In: Lacerda O. Compêndio de teoria elementar da música. 12a ed. São Paulo: Ricordi; 1961. p.125-8.
12. Cedolin L, Delgutte B. Spatiotemporal representation of the pitch of harmonic complex tones in the auditory nerve. J Neurosci. 2010;30(38):12712-24.
13. Nascimento FM, Monteiro RA, Soares CD, Ferreira MI. Temporal sequencing abilities in musicians violinists and non-musicians. Arq Int Otorrinolaringol. 2010;14(2):217-24.
14. Estis JM, Coblentz JK, Moore RE. Effects of increasing time delays on pitch-matching accuracy in trained singers and untrained individuals. J Voice. 2009;23(4):439-45.
15. Micheyl C, Delhommeau K, Perrot X, Oxenham AJ. Influence of musical and psychoacoustical training on pitch discrimination. Hear Res. 2006;219(1-2):36-47.
16. Rammsayer T, Altenmuller E. Temporal information processing in musicians and non-musicians. Music Perception. 2006;24(1):37-48.
17. Kishon-Rabin L, Amir O, Vexler Y, Zaltz Y. Pitch discrimination: are professional musicians better than non-musicians? J Basic Clin Physiol Pharmacol. 2001;12(2):125-43.
18. Kalakoski V. Effect of skill level on recall of visually presented patterns of musical notes. Scand J Psychol. 2007;48(2):87-96.
19. Pallesen KJ, Brattico E, Bailey CJ, Korvenoja A, Koivisto J, Gjedde A, et al. Cognitive control in auditory working memory Is enhanced in musicians. PLoS One. 2010;5(6):e11120.
20. Bidelman GM, Krishnan A, Gandour JT. Enhanced brainstem encoding predicts musicians' perceptual advantages with pitch. Eur J Neurosci. 2011;33(3):530-8.
21. Erickson ML, Perry SR. Can listeners hear who is singing? A comparison of three-note and six-note discrimination tasks. J Voice. 2003;17(3):353-69.
22. Mawhinney T. "Tone-deafness" and low musical abilities – an investigation of prevalence, characteristics and tractability [thesis]. Kingston, Ontario, Canadá: Queen's University; 1986.