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Measurement of listening effort using of a dual-task paradigm of Brazilian Portuguese: a pilot study

Mensuração do esforço auditivo com o uso de um paradigma de tarefa dupla do Português Brasileiro: estudo-piloto

Keywords

Hearing
Listening Effort
Auditory Perception
Auditory Tests
Memory
Cognition

ABSTRACT

Purpose: To measure listening effort using of a dual-task paradigm of working memory and analyze the clinical significance of the normal-hearing individuals' performance. **Methods:** Participants were 10 young adults with similar socio-cultural level, aged 18-30 years, of both genders, classified as normal-hearing individuals based on the quadritonal average (500, 1000, 2000 and 4000 Hz). The participants were submitted to audiological anamnesis, meatoscopy, and pure tone audiometry. Listening effort was measured using a dual-task paradigm comprising the tasks of speech perception and working memory with logatomes, real words, and meaningless sentences. Prior to measurement, the dual-task paradigm was carried out in audiometric booth in order to train the participants to perform the tasks properly. After the training stage, this paradigm was conducted under two different hearing situations with white noise: signal-to-noise ratios of +5 and -5dB. **Results:** Performance comparison per ear, right or left, for the two signal-to-noise ratios significantly influenced the speech perception tasks with logatomes and meaningless sentences in both ears; however, significant difference was observed only for the right ear in the tasks of listening effort and working memory. **Conclusion:** Listening effort can be measured using the paradigm proposed, and this instrument was proven sensitive for the quantification of this auditory parameter.

Descritores

Audição
Esforço Auditivo
Percepção Auditiva
Testes Auditivos
Memória
Cognição

RESUMO

Objetivo: Mensurar o esforço auditivo com o uso de um paradigma de tarefa dupla de memória operacional e analisar a significância clínica do desempenho de indivíduos normo-ouvintes. **Método:** Participaram 10 adultos jovens, entre 18 e 30 anos, de ambos os gêneros, normo-ouvintes classificados segundo a média quadritonal (500, 1000, 2000 e 4000Hz) e com nível sociocultural similar. Os participantes foram submetidos à anamnese audiológica, meatoscopia e audiometria tonal limiar. Para a mensuração do esforço auditivo, utilizou-se um paradigma de tarefa dupla, composto por tarefas de percepção de fala e memória operacional de logatomas, palavras reais e sentenças sem sentido. Anteriormente à mensuração, o paradigma de tarefa dupla foi realizado no silêncio com o intuito de treinar os participantes a desempenharem as tarefas adequadamente. Após a fase de treinamento, este paradigma foi realizado em duas situações de escuta distintas, nas relações sinal/ruído de +5 e -5dB, com o ruído do tipo *White Noise*. **Resultados:** A comparação do desempenho por orelha, direita ou esquerda, nas duas relações sinal-ruído demonstrou efeito significante para as tarefas de percepção de fala de logatomas e sentenças sem sentido em ambas as orelhas, porém para a tarefa de esforço auditivo e memória operacional houve diferença significante apenas para a orelha direita. **Conclusão:** Foi possível mensurar o esforço auditivo com o uso do paradigma proposto e este instrumento demonstrou ser sensível para a quantificação deste parâmetro auditivo.

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INTRODUCTION

In the scientific literature, especially regarding international scope, the theme listening effort has been studied in the areas of audiology and cognitive psychology in order to establish a consensus in terms of the definition, the best measurement method and cognitive resources involved in this auditory parameter. Some authors define "listening effort" as the amount of cognitive resources needed for the recognition of acoustic signals, especially speech[1].

Other authors[2] define it as "the deliberate allocation of mental resources to overcome obstacles in the pursuit of goals when performing a task, more specifically when tasks involve listening", regarding the distinction between the demand of a certain listening situation and the effort that a particular listener exerts.

Authors[3-5] stated that, over the last two decades, research on auditory-cognitive interactions has been of great interest and relevance for the understanding of processes related to hearing in general and to speech perception, especially in challenging listening conditions, with background noise[6]. The interaction between the working memory and the amount of effort expended during speech perception tasks in different listening situations, that is, with manipulation of signal-to-noise ratio (SNR) has been one of the themes investigated in this interaction.

According to the literature, individuals with higher working memory capacity expend less listening effort in speech perception tasks with manipulation of signal-to-noise ratios[7,8], since even for tasks that estimate listening effort successfully, there will be alterations in terms of the number of elements that any individual can remember and repeat, since this subtype of memory is a limited system[7,9,10].

To understand speech in noisy environments, both individuals with normal hearing and those with some degree of hearing loss will require the activation of several cognitive resources responsible for processing and interpreting auditory information and higher levels of attention and memory to well perform the tasks that measure listening effort, and/or speech perception in everyday situations in which the listening conditions are adverse[11,12].

Researches have shown that even for adults with normal hearing, noise and reverberation were damaging aspects to the good performance in tests whose task was to memorize the items heard and to recall them later[11,13-15].

Although the development of different methods for measuring listening effort in the international scenario, little is known about this measurement at the national level. One of the possible explanations for this fact would be the non-systematicity of the empirically used methods as an index of listening effort.

Some authors have quantified listening effort through behavioral methods, such as dual task paradigms[16,17]. These paradigms consist of two tasks, in which the primary task is speech perception of stimuli with different degrees of extension (logatomes, words, sentences) and difficulty, since familiarity with the presented vocabulary will interfere with the test result; and the secondary task, which may be the recall of speech stimuli previously heard by the individual being assessed. Both tasks, primary and secondary, are performed concomitantly.

Research conducted using this behavioral method has applied the span tests, which evaluate the amount of listening effort expended based on the individual's memory performance in recalling previously mentioned stimuli in the primary task of speech perception[9].

The alteration in performance of the secondary task at different levels of difficulty of the primary task reflects a change in the cognitive resources for speech processing, that is, listening effort. This interpretation assumes that the performance on both primary and secondary tasks requires the allocation of some common cognitive resources for each task. As cognitive resources are limited, greater listening effort and greater demand of cognitive resources for the speech perception task will be expended.

From the explained above, the objective of this study was to measure listening effort with the use of a dual task paradigm of working memory and to analyze the clinical significance of the normal hearing individuals' performance. It was hypothesized with this research that the dual task paradigm used would be a sensitive instrument for listening effort measurement through manipulation of working memory.

Moreover, conducting a pilot study will enable a verification of possible inconsistencies in this instrument for measuring listening effort, analyzing the performance of individuals in performing different tasks that compose the test, and verifying the clinical significance of the results.

METHODS

This study was submitted to the Research Ethics Committee of the Faculty of Philosophy and Sciences of the Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP) – Marilia and approved (CAAE: 90328318.0.0000.5406). The place of study development was the Centro de Estudos de Educação e da Saúde – CER II of the Faculty of Philosophy and Sciences of the Universidade Estadual Paulista, Campus of Marília, São Paulo - Brazil.

The study design was clinical, observational, cross-sectional, with a convenience sample. This is a pilot sample, in which all participants signed the Informed Consent Form (ICF) and agreed to the procedures conducted.

Casuistry

This was a convenience sample, composed of 10 young adults, normal hearing individuals, aged 18 to 30 years, of both genders, with similar sociocultural level, recruited in public universities of the municipality. The sociocultural level was considered similar due to the fact that all participants were egresses of public education and were regularly enrolled in public institutions of higher education. The exclusion criteria adopted were: I) to have hearing loss and/or history of conductive impairments; II) to have a history of neurological or psychiatric impairments; III) to present obstruction of the external auditory meatus.

Audiological assessment

The audiological assessment consisted of audiological anamnesis, meatoscopy and pure tone audiometry. Initially, the audiological anamnesis was applied, composed of questions regarding general health and specific to auditory problems. Subsequently, the meatoscopy was carried out to verify the presence of any obstruction, which prevented the continuity of assessment.

Pure tone audiometry was carried out in order to determine the participants' hearing threshold. The hearing thresholds were tested by air in frequencies from 250Hz to 8000Hz and the audiograms were classified based on the World Health Organization[18], considering as a criterion of normality the quadritonal average (500, 1000, 2000 and 4000Hz) equal or less than 25 dB. This procedure was conducted in an acoustic booth, using the Grasson-Stadler audiometer, model GSI-61 and supra-aural TDH50 headphones.

Table 1 presents the characterization of the sample regarding age group and quadritonal average of the ears, presented in mean and standard deviation values.

Measurement of listening effort

After the audiological assessment, the participants' listening effort was measured through application of a behavioral measurement, referenced as a dual task paradigm composed of a primary task of speech perception and a secondary task of memory/working memory. This instrument has three parts, as follow: I) speech perception of logatomes; II) listening effort and working memory (set of real words); III) perception of meaningless sentences. The dual task paradigm is available in Table 2.

To perform this paradigm, the speech stimuli were presented by the same evaluator in order to avoid biases related to the distinct characteristics of speech emission, in an acoustic booth and speakerphone.

The first part of the instrument entitled "speech perception of logatomes" is consisted of two lists of words composed of the structure "vowel + consonant + vowel" whose consonants are isolated by the vowel "A" such as "ANHA", "ALA "," ARA ", among others. The objective of this part, besides the speech perception task, is to verify if the participant emits

Table 1. Characterization of participants of the pilot study

Nº	Gender	Age (years)	Quadritonal average of RE (500, 1000, 2000, 4000Hz)	Quadritonal average of LE (500, 1000, 2000, 4000Hz)
1	F	25	1.25	2.50
2	F	24	11.25	6.25
3	F	20	2.50	1.25
4	M	24	1.25	1.25
5	F	20	2.50	3.75
6	F	26	2.50	1.25
7	M	25	1.25	1.25
8	F	25	6.25	5.00
9	M	19	8.75	7.50
10	M	27	3.75	6.25
Mean	-	23.5	4.12	3.62
SD	-	2.65	3.30	2.33

Caption: SD = Standard Deviation; RE = Right ear; LE = Left ear; Hz = Hertz; F = Female; M = Male

Table 2. Instrument that measures listening effort through a dual task paradigm

PART I – SPEECH PERCEPTION OF LOGATOMES					
	List 1	Intensity of consonant (dB)	List 2	Intensity of consonant (dB)	Frequency of consonant (Hz)
1	**AMA**	35	**ANA**	35	**250**
2	**ALA**	40	**ANHA**	40	**250**
3	**ABA**	25	**APA**	25	**500**
4	**ALHA**	35	**ARA**	35	**750**
5	**ARRA**	25	**AKA**	30	**1500**
6	**AKA**	30	**AGA**	25	**1500**
7	**AJA**	25	**ACHA**	25	**2500**
8	**ADA**	25	**ATA**	25	**4000**
9	**AZA**	20	**ASSA**	20	**4000**
10	**AVA**	15	**AFA**	15	**6000**

Caption: Hz = Hertz; dB = Decibel

Table 2. Continued...

PART II – LISTENING EFFORT AND WORKING MEMORY: SET OF REAL WORDS		
SET I		
CAMA	JANA	CHAMA
BALA	MANHA	CANA
SET II		
FALA	BANHA	PALHA
CALHA	CARA	CAPA
LAMA	TAPA	CHAPA
SET III		
FARRA	FACA	JARRA
JACA	JOGA	TAXA
TALHA	FAIXA	FALHA
SALA	FRONHA	DAMA
SET IV		
CADA	FAÇA	NADA
PARA	BATA	PLAZA
SOFA	DADA	PATA
TAÇA	VAZA	LAÇA
CASA	BRAVA	TRUFA

PART III – SPEECH PERCEPTION OF MEANINGLESS SENTENCES

1. A Flor azul da mulher estava dentro da **dama.**

2. O cachorro do quintal costuma brincar na **bala**.

3. O menino bebeu tudo daquela **farra**.

4. As crianças comeram tanto até ficarem cheias de **taça**.

5. A cor da minha blusa é rosa igual minha **manha**.

Caption: Hz = Hertz; dB = Decibel

the acoustic clue received in a reliable way or emits like a real word, performing auditory closure through use of the contextual clue, for example, for the logatome "ALA", the participant emits as the real word "FALA". This part provided data regarding participants' listening effort in perceiving the consonants with different amounts of acoustic energy, in the different signal-to-noise ratios.

Participants were instructed to repeat each logatome heard and the repetitions were scored from one to four points, such as (1) "omission", (2) "correct answer", (3) "negative substitution" (replacement of the logatome's consonant, for example, ("ALA" for "ABA"), and (4) "positive substitution" (repetition of words performing auditory closure, such as "ALA" for "FALA"). The summation of these points determined the amount of listening effort expended, in which the scores of 10-15 points "no listening effort"; 15-25, "minimum listening effort"; 25-35, "medium listening effort"; and 35-40, "maximal listening effort".

The second part of the instrument, entitled "listening effort and working memory", is composed of four sets of real words, that is, words that have meaning derived from the logatomes that make up the first part of the instrument. Each set of real words has three series of words, with a different number of words in each series. During the test, participants heard to each series of words and, in the end, they should remember and repeat the first word heard in each series.

- Set I: composed of three series of two words each;
- Set II: composed of three series of three words each;
- Set III: composed of three series of four words each;
- Set IV: composed of three series of five words each.

Regarding the task complexity, the subsequent sets were only presented by memorizing the first word of each series. As far as the participants memorized the words, the next sets were presented. The repetition of the sets were scored as percentage, from 0% to 100%, in which, "0% - It was not possible to measure listening effort (absence of correct answers)"," 25% - Maximum listening effort and severe degree of working memory ability" - (memorization of the first words of each series of Set I, equivalent to one set), "50% - Medium listening effort and moderate degree of working memory ability - (memorization of the first words of each series of Sets I and II, equivalent to two sets)", "75% - Small listening effort and preserved degree of working memory ability - (memorization of the first words of each series of Sets I, II and III, equivalent to three sets)," and "100% - Minimum listening effort and higher degree of working memory ability – (memorization of the first words of each series of Sets I, II, III and IV, equivalent to four sets).

The third and last part of the instrument is called "speech perception of meaningless sentences". At this stage, the participant should repeat five sentences and then recall the last word of each sentence. This part is composed of five sentences, in which the last word of each sentence presented is a derivation of logatomes of the first part of this instrument. This part aimed to assess the participants' working memory capacity and the amount of listening effort expended based on their performance in the memorization task for long term speech stimuli. In this part of the test, the more sentences the participants emitted correctly, the more words they remembered, the better their speech perception skills and working memory capacity would

be, and consequently the less the amount of listening effort would be expended.

The repetitions of words and their memorization were also scored as percentage, from 0% to 100%, these scores being categorized as "0% - It was not possible to measure listening effort (absence of correct answers)", "20% - Maximum listening effort and very severe degree of working memory ability (one-word memorization)", "40% - Large listening effort and severe degree of working memory ability (two-word memorization)", "60% - Medium listening effort and moderate degree of working memory ability (three-word memorization)", "80% - Small listening effort and preserved degree of working memory ability (four-word memorization)" and "100% - Minimum listening effort and higher degree of working memory ability (five-word memorization)". The way of filling the score of the three parts of the proposed dual task paradigm is shown in Chart 1.

The logatomes, real words and meaningless sentences were presented monoaural, at an intensity of 40 dBSL above the tritonal average (500, 1000 and 2000 Hz), with competitive noise White Noise type, presented in two signal-to-noise ratios + 5dB and -5dB. In order to train the participants, before the

Chart 1. Answer sheet of the instrument that measures listening effort through a dual task paradigm

LIST 1 (RE)	Omission	Correct answer	Negative substitution	Positive substitution	Score Signal-to-noise ratio	
					+5dB	-5dB
AMA	1	2	3	4		
ALA	1	2	3	4		
ABA	1	2	3	4		
ALHA	1	2	3	4		
ARRA	1	2	3	4		
AKA	1	2	3	4		
AJA	1	2	3	4		
ADA	1	2	3	4		
AZA	1	2	3	4		
AVA	1	2	3	4		
Total List 1						
LIST 2 (LE)	Omission	Correct answer	Negative substitution	Positive substitution	Signal-to-noise ratio	
					+5dB	-5dB
ANA	1	2	3	4		
ANHA	1	2	3	4		
APA	1	2	3	4		
ARA	1	2	3	4		
AKA	1	2	3	4		
AGA	1	2	3	4		
ACHA	1	2	3	4		
ATA	1	2	3	4		
ASSA	1	2	3	4		
AFA	1	2	3	4		
Total List 2						

SCORE PART I: SPEECH PERCEPTION OF LOGATOMES			
10-15 points	15-25 points	25-35 points	35-40 points
No listening effort	Minimum listening effort	Medium listening effort	Maximal listening effort

PART II: LISTENING EFFORT AND WORKING MEMORY														
Ear	Signal-to-noise ratio	Set I			Set II			Set III			Set IV			Correct answers (%)
		1	2	3	1	2	3	1	2	3	1	2	3	
RE	+5													
RE	-5													
LE	+5													
LE	-5													

Score:
0% - It was not possible to measure listening effort (absence of correct answers);
25% - Maximum listening effort and severe degree of working memory ability - (memorization of the first words of each series of Set I, equivalent to one set);
50% - Medium listening effort and moderate degree of working memory ability - (memorization of the first words of each series of Sets I and II, equivalent to two sets);
75% - Small listening effort and preserved degree of working memory ability - (memorization of the first words of each series of Sets I, II and III, equivalent to three sets);
100% - Minimum listening effort and higher degree of working memory ability – (memorization of the first words of each series of Sets I, II, III and IV, equivalent to four sets);

Caption: RE = Right ear; LE = Left ear; SNR = Signal-to-Noise Ratio; dB = Decibel

Chart 1. Continued...

PART III: PERCEPTION OF MEANINGLESS SENTENCES AND WORKING MEMORY												
RE/LE	SNR	Sentences					Words					Correct answers (%)
		1	2	3	4	5	1	2	3	4	5	
RE	+5						BALA ( )	TAÇA ( )	MANHA ( )	FARRA ( )	DAMA ( )	
RE	-5						FARRA ( )	MANHA ( )	BALA ( )	DAMA ( )	BALA ( )	
LE	+5						DAMA ( )	BALA ( )	FARRA ( )	TAÇA ( )	MANHA ( )	
LE	-5						TAÇA ( )	DAMA ( )	BALA ( )	MANHA ( )	FARRA ( )	

Score:
0% - It was not possible to measure listening effort (absence of correct answers);
20% - Maximum listening effort and very severe degree of working memory ability;
40% - Large listening effort and severe degree of working memory ability;
60% - Medium listening effort and moderate degree of working memory ability;
80% - Small listening effort and preserved degree of working memory ability;
100% - Minimum listening effort and higher degree of working memory ability.

Caption: RE = Right ear; LE = Left ear; SNR = Signal-to-Noise Ratio; dB = Decibel

Table 3. Mean and standard deviation values of participants' scores for the three parts of the dual task paradigm in two listening situations

Instrument to measure listening effort	Ear	SNR +5dB		SNR -5dB	
		Mean	SD	Mean	SD
Speech perception of logatomes (Part I)	RE	20.80	0.87	21.90	1.30
	LE	21.20	1.07	23.00	2.48
Listening effort and working memory (Part II)	RE	1.80	1.16	0.50	0.67
	LE	1.90	1.57	0.10	0.30
Perception of meaningless sentences (Part III)	RE	3.90	0.83	3.10	1.64
	LE	4.20	0.74	3.30	0.90

Caption: RE = Right ear; LE = Left ear; SD = Standard deviation; SNR = Signal-to-Noise Ratio; dB = Decibel

beginning of the measurement of listening effort, the dual task paradigm was carried out in quiet. Regarding that the sample of this study consisted of normal hearing individuals, it was decided to start the measurement of listening effort by the right ear to keep uniformity of the procedure and the left ear was assessed in sequence, in the three constituent parts of the dual task paradigm ("speech perception of logatomes" "listening effort and working memory" and "speech perception of meaningless sentences").

Statistical analysis

The findings were analyzed in a descriptive and inferential manner. In the sample characterization, a descriptive analysis (mean and standard deviation) was used. In the inferential analysis, using the IBM SPSS Statistics software (version 2.2), the Wilcoxon non-parametric test was applied to compare the performance of right and left ears regarding the variable signal-to-noise ratio, +5 dB or -5 dB, in the three parts of the instrument; and compare the performance per ear, right or left, between the two signal-to-noise ratios in the three parts of the instrument. A significance level of $\alpha \leq 0.05$ and a confidence interval of 95% was established.

RESULTS

In Table 3 are found estimated values of mean and standard deviation of participants' scores for the three parts of the dual task paradigm analyzed (perception of logatomes, listening effort and working memory and perception of meaningless sentences) as a function of the ear variables (right and left) and signal-to-noise ratio (+ 5dB and -5dB).

Table 4 demonstrated the performance comparison of right ear and left ear, in the two SNR (+ 5dB or -5dB) in the three parts of the dual task paradigm, and this comparison did not show significant difference between the ears in any part of the instrument applied.

Table 4. Performance comparison of right and left ears based on the signal-to-noise ratio variable in the three parts of the instrument

Instrument to measure listening effort	Ear	SNR	p - value
Speech perception of logatomes (Part I)	RE × LE	SNR = +5dB	0.248
	RE × LE	SNR = -5dB	0.128
Listening effort and working memory (Part II)	RE × LE	SNR = +5dB	0.833
	RE × LE	SNR = -5dB	0.108
Perception of meaningless sentences (Part III)	RE × LE	SNR = +5dB	0.345
	RE × LE	SNR = -5dB	0.779

Wilcoxon test with p-value less than 0.05 represented by*
Caption: RE = Right ear; LE = Left ear; SNR = Signal-to-Noise Ratio; dB = Decibel

Table 5. Performance comparison per ear, right or left, between the two the signal-to-noise ratios in the three parts of the instrument

Instrument to measure listening effort	Ear	SNR	p - value
Speech perception of logatomes (Part I)	RE	+5dB × -5dB	0.043*
	LE	+5dB × -5dB	0.029*
Listening effort and working memory (Part II)	RE	+5dB × -5dB	0.017*
	LE	+5dB × -5dB	0.011*
Perception of meaningless sentences (Part III)	RE	+5dB × -5dB	0.043*
	LE	+5dB × -5dB	0.051

Wilcoxon test with p-value less than 0.05 represented by *
Caption: RE = Right ear; LE = Left ear; SNR = Signal-to-Noise Ratio; dB = Decibel

Table 5 presents the data regarding the comparison of performance per ear, right or left, between the two SNR used in this study.

When comparing the performance per ear, right or left, between the two signal-to-noise ratios, a significant difference was observed for both part I and part II of the instrument, in both ears. However, in Part III of the instrument, a significant difference was found only for comparison of the performance of right ear in the two listening relations.

DISCUSSION

Estimating the listening effort needed for understanding of spoken language is important for the identification of aspects that make difficult the auditory perception in a naturally, that is, without effort. From this identification, new therapeutic strategies and design of new algorithms for noise reduction and frequency compression of the electronic hearing devices can be developed in order to provide a better quality of life and hearing performance for patients with hearing loss.

However, for this identification process to occur, it is crucial that the measurement of listening effort is performed. Thus, it is of great scientific and clinical relevance that the method used is sensitive and provides reliable results, so that over time, a "gold standard" evaluation method is determined.

This study aimed to measure listening effort with the use of a dual task paradigm of working memory and to analyze the clinical significance of the normal hearing individuals' performance.

When listening to degraded speech signals, normal hearing and hearing impaired individuals face an increased difficulty in processing and memorizing speech signals. Moreover, these are less accurate in terms of speech perception, since even when speech is understood, words or syllables that are acoustically degraded are more difficult to remember[11,19]. The overall acoustic challenge experienced by any listener is a combination of individual auditory capacity and the external characteristics of the acoustic signal including speech quality, background noise, and unfamiliar speakers[20].

The literature states that listening effort seems to depend on cognitive processes related to the input of auditory stimulus, such as listening in noise in comparison to listening in quiet, as well as to individuals' own cognitive functions and internal factors[21]. A valid example, described in the literature, is that acoustically degraded speech requires that listeners rely more on the cognitive resource called verbal working memory[22]. Thus, one of the reasons that explains the significance found in the comparison of performance of the same ear, whether this right or left, for the different SNRs, can be explained by the increase of the cognitive demand required to perform the task with more intense background noise.

Some authors[16] used a dual task paradigm, with the repetition of final words from sets of spoken sentences and the codification of final words in memory for later recall[23]. The authors demonstrated that noise impaired word evocation in a context of competitive speech for young persons with normal hearing, particularly for sentences at the beginning of the lists, but this noise effect was weakened when a noise reduction algorithm was applied. Thus, the results of this study[16] suggested that the presence of noise could impair the transfer of information contained in the speech to the long-term storage.

The literature has shown that degradation of the auditory message can deplete information processing resources during listening tasks, as observed by performance decreases in a secondary task (i.e., working memory)[24]. Evidence in the literature supports the hypothesis[25,26] that the presence of any degree of hearing loss is commonly accompanied by increased listening effort and fatigue[27]. Therefore, the absence of statistical significance in the comparison between the ears, right and left, of the study participants can be explained by the sample evaluated, since they were young individuals with normal hearing.

Relevant aspects for future research include determining the specific cognitive processes that are involved in the listening effort measurement with the use of behavioral measures as well as the effects that the different types of noise can cause on the performance of the primary and secondary task in a dual task paradigm.

Moreover, auditory rehabilitation programs need to develop therapeutic strategies that allow the reduction of the amount of listening effort used in the comprehension of speech in several listening situations and, consequently, reduce the effects of cognitive challenge.

As limitations of this study, it is emphasized the impossibility of measuring listening effort with the use of noise with several interlocutors, such as babble noise, despite the existence of this type of noise developed by Brazilian researchers[28].

The development of a new study with the use of this noise may be relevant, cause other changes in the performance of individuals and provide diverse effects in the responses of the dual task paradigm.

Other limiting factor that should be considered for design future researches with the theme listening effort and the use of this dual task paradigm of the Brazilian Portuguese is the recording of speech stimuli aiming the reproducibility of this instrument and avoiding possible biases related to the quality of evaluator's emission. Moreover, regarding that the proposed instrument refers to a behavioral measurement that measures listening effort through the performance of a cognitive function, in this case working memory, it is suggested the prior application of a cognitive evaluation instrument in the participants.

CONCLUSION

Findings of this study showed that it was possible to estimate listening effort using the proposed dual task paradigm of working memory. This instrument showed to be sensitive for the quantification of this auditory parameter, evidencing that, for listening situations in which noise levels were more intense, the participants required more effort.

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Author contributions

LMG responsible for the study design, writing of manuscript, data collection, presentation and documentation of the article, submission and paperwork of the article; MBH responsible for the data collection; ACVC responsible for the correction of writing, submission and paperwork of the article and approval of final version of the article.