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Listening effort and recording of parasympathetic heart control during sentence recognition: Pilot study

Esforço auditivo e registro do controle parassimpático do coração durante o reconhecimento de sentenças: estudo piloto

Esfuerzo auditivo y registro del control parasimpático del corazón durante el reconocimiento de sentencias: Estudio piloto

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Abstract

Introduction: Psychophysiological measures of the autonomic nervous system in response to auditory tasks may provide a means of quantifying the effects of listening effort. **Objective**: To compare parasympathetic modulation of the heart rate in different listening situations and to determine if the heart rate variability is a sensitive psychophysiological index to measure listening effort. **Methods**: Pilot, observational, transversal and prospective study. 14 normal healthy young adults, both genders and between 18 and 30 years of age, participated in this study. They answered the anamnesis and performed pure tone audiometry to verify hearing thresholds. In order to record HRV, it was placed the cardiofrequency transducer tape in the xiphoid process region and this record was collected for 10 minutes for the "rest", "post-recovery of sentence recognition in quiet" and "post-recovery of sentence recognition in noise". Recognition task was performed using two lists of sentences presented in a randomized way, binaural,

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LMG, responsible for writing the manuscript, bibliographic review, data collection, presentation of article documentation and submission of paperwork for the article; VBG, responsible for collecting/analyzing data and writing the article, MBH, responsible for designing the study and correcting the article; VEV, responsible for data analysis of the article and writing of the manuscript; ACVC, responsible for the study design, correction of the article, and approval of the final version of article.

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in the quiet listening condition and in a signal-to-noise ratio of -5 dB, and HRV was also recorded for a period of two minutes. ANOVA repeated measures test was applied followed by the Bonferroni post-test to compare the RMSSD index in the different HRV recording moments. **Results**: Statistical analysis showed that there was no significant difference in HRV recording at different moments, including the sentence recognition task in noise, considered the most arduous task. **Conclusion**: For this sample, the HRV recording was not considered a sensitive index for auditory effort measurement.

Keywords: Hearing; Heart Rate; Auditory Perception; Cognition.

Resumo

Introdução: Medidas psicofisiológicas do sistema nervoso autônomo em resposta a tarefas auditivas podem fornecer um meio de quantificar os efeitos do esforço auditivo. **Objetivo**: Comparar a modulação parassimpática da frequência cardíaca em situações de escuta distintas e determinar se a variabilidade da frequência cardíaca (VFC) é um índice psicofisiológico sensível para mensurar o esforço auditivo. **Método**: Estudo piloto, observacional, transversal e prospectivo. Participaram 14 adultos normo-ouvintes, de ambos os sexos e com idade entre 18 e 30 anos. Estes responderam a anamnese e realizaram audiometria tonal limiar para verificação de limiares auditivos. Para o registro da VFC, colocou-se a cinta do cardiofrequencímetro na região do processo xifoide e este registro foi coletado por 10 minutos para três situações distintas: "repouso", "recuperação pós-reconhecimento de sentenças no silêncio" e "recuperação pós-reconhecimento de sentenças no ruído". O reconhecimento de sentenças foi realizado utilizando-se duas listas de sentenças, de forma randomizada, binaural, nas situações de escuta silêncio e na relação sinal/ruído de -5 dB e, também foi registrada VFC por um período de dois minutos. Aplicou-se o teste de ANOVA de medidas repetidas seguido pelo pós-teste de Bonferroni para comparar o índice de RMSSD nos diferentes momentos de registro da VFC. **Resultados**: A análise estatística demonstrou que não houve diferença significante do registro da VFC nos diferentes momentos, inclusive durante a tarefa de reconhecimento de sentenças no ruído, considerada a tarefa mais árdua. **Conclusão**: Para esta amostra, o registro da VFC não foi considerado um índice sensível para a mensuração do esforço auditivo.

Palavras-chave: Audição; Frequência cardíaca; Percepção auditiva; Cognição.

Resumen

Introducción: Las medidas psicofisiológicas del sistema nervioso autónomo en respuesta a las tareas auditivas pueden proporcionar un medio para cuantificar los efectos del esfuerzo auditivo. **Objetivo**: Comparar la modulación parasimpática de la frecuencia cardíaca en situaciones de escucha distintas y determinar si la variabilidad de la frecuencia cardíaca (VFC) es un índice psicofisiológico sensible para medir el esfuerzo auditivo. **Método**: Estudio piloto, observacional, transversal y prospectivo. Participaron 14 adultos normo-oyentes, de ambos sexos y con edad entre 18 y 30 años. Estos respondieron la anamnesis y realizaron audiometría tonal umbral para verificación de umbrales auditivos. Para el registro de la VFC, se colocó la cinta del cardiofrecuencímetro en la región del proceso xifoide y este registro fue recolectado por 10 minutos para tres situaciones distintas "reposo", "recuperación post-reconocimiento de sentencias en el silencio" y "recuperación post-reconocimiento de las sentencias en el ruido ". El reconocimiento de sentencias se realizó utilizando dos listas de sentencias, de forma aleatorizada, binaural, en las situaciones de escucha silenciosa y en la relación señal / ruido de -5dB y, también se registró VFC por un período de dos minutos. Se aplicó la prueba de ANOVA de medidas repetidas seguida por el post-test de Bonferroni para comparar el índice de RMSSD en los diferentes momentos de registro de la VFC. **Resultados**: El análisis estadístico demostró que no hubo diferencia significante del registro de la VFC en los diferentes momentos, incluso durante la tarea de reconocimiento de sentencias en el ruido, considerada la tarea más ardua. **Conclusión**: Para esta muestra, el registro de la VFC no fue considerado un índice sensible para la medición del esfuerzo auditivo.

Palabras clave: Audición; Frecuencia cardiaca; Percepción auditiva; Cognición.

Introduction

Listening effort refers to the amount of cognitive resources needed for the recognition of acoustic signals, such as speech[1]. With regard to the last decades, studies[2] have demonstrated that the interest about auditory-cognitive interactions is relevant for hearing in general and for speech comprehension, especially in challenging listening situations[3].

"Mental effort" refers to "a deliberate allocation of mental resources to overcome obstacles in the pursuit of goals to accomplish a task"; in contrast, "listening effort" refers to "a specific category of mental effort that occurs when a task involves listening"[4].

Understanding speech in noisy acoustic environments is a complex task and requires greater effort[5]. Listening effort activates several cognitive resources responsible for processing and interpretation of auditory information, higher levels of attention and memory, and a dynamic interaction between processing through the top-down and bottom-up ways [6,7,8].

In view of the findings demonstrated by studies in the field of audiology about the arduous process of speech understanding in noise, especially for hearing-impaired individuals, there is currently an increasing interest about listening effort and the use of cognitive resources to improve speech understanding [3,9].

Studies conducted on this topic have applied different methods to quantify this auditory parameter, using subjective measurements such as: questionnaires[10], rating scales[11] and/or self-report methods[12]. Although these methods are quickly applicable, the application of an objective method to quantify this effort in clinical contexts can be crucial to obtain more accurate and reliable results.

Behavioral methods also knowing as dualtask paradigms and psychophysiological methods have been used to estimate listening effort as they are complementary to self-report instruments and reflect changes in neural processing due to the increased demand for tasks[9]. Researchers in the field of audiology who survey listening effort have used psychophysiological methods to determine the occurrence of possible changes in the performance of speech perception tasks due to the increased demand for this task. One of the psychophysiological methods that can be used is the measurement of heart rate variability (HRV), which analyzes the influence of the autonomic nervous system on heart rate.

The HRV is a financially viable, non-invasive measurement validated by the literature[13] that can be used to characterize events related to the autonomic nervous system, since sympathetic and parasympathetic branches interact to preserve a hemodynamic balance within the body, adjusting body functions to respond to internal and external stimuli[14].

Psychophysiological measurements of the autonomic nervous system in response to auditory tasks can provide a method of estimating the effects of listening effort[15]. According to some authors[16], when there is an increase in the difficulty of a task, it often results in a decrease in HRV measured using parasympathetic components.

Previous studies[17,18,19] reported that changes in cardiac measurements and skin conductance are commonly observed when mental demands of the tasks are increased.

A study measured the effects of hearing loss and noise on HRV, skin conductance and subjective load/stress indices according to the task demand. For this, 18 hearing-impaired adults and 15 adults with normal hearing status, aged 22 to 79 years, were submitted to a speech perception task of sentence recognition consisted from three to 14 words. The speech perception task was performed in silence and with signal-to-noise ratios at −6, −3, 0 and +3 dB, with babble noise from five speakers. The findings of this study demonstrated that HRV measurements were sensitive to the effects of noise and hearing loss, as participants with hearing loss had greater parasympathetic suppression (evidenced by the decrease in HRV) during speech recognition in noise than the participants with normal hearing[16]. Therefore, HRV can be used to estimate listening effort in speech perception tasks with manipulation of signal-to-noise ratios.

Therefore, this study was conducted to answer the question: Is the parasympathetic control of heart rate reduced with increased demand in a sentence recognition task? The main interest of this research was to document the physiological milestones during the recording of HRV in different listening situations and also to verify whether the protocol used was sensitive for the listening effort measurement with HRV.

Therefore, the objectives of this study were to compare the parasympathetic modulation of heart rate in different listening situations and to determine whether heart rate variability is a sensitive psychophysiological index to detect changes induced by listening effort.

Based on evidence from previous studies, the hypotheses are defined as follows:

- Heart rate variability is a sensitive psychophysiological index for detecting changes induced by listening effort, especially for more difficult listening situations, regarding the effects of noise intensity;
- The use of White Noise will influence the HRV results during listening effort measurement in normal hearing persons.

Method

This study was approved by the Research Ethics Committee of the Faculty of Philosophy and Sciences of the São Paulo State University "Júlio de Mesquita Filho" (UNESP) - Marilia, under protocol nº 0385/2011 and data collection was carried out at the Study Center of Education and Health - CER II, Faculty of Philosophy and Sciences, São Paulo State University "Júlio de Mesquita Filho" (UNESP) - Marilia, São Paulo - Brazil.

The study design was pilot, observational, cross-sectional and prospective. All participants included in this study signed the Informed Consent Form (ICF), with an explanation of the procedures that were performed previously the beginning of data collection.

Participants were 14 normal-hearing adults, aged 18 to 30 years, six male and eight female participants. The number of participants was based on a study previously published, which indicated a minimum number of 14 participants [16].

Exclusion criteria for the study were: individuals with hearing loss or neurological, cardiorespiratory or psychiatric disorders; age under 18 and over 30; obstruction or foreign body in the external auditory canal that impeded the performance of the procedures; women who were on the 11th and 15th or 21st to the 25th day after the beginning of the menstrual period due to hormonal changes, as they alter the heart rate[20]; use of drugs that influence cardiac autonomic regulation, such as vasodilator drugs[21].

Audiological assessment

To assess the participants' hearing, the following procedures were performed: audiological anamnesis, meatoscopy and pure tone audiometry.

Initially, the audiological anamnesis was applied, consisting of questions about current history and audiological behavior, as well as associated signs and symptoms. Subsequently, meatoscopy was performed to check the presence of any alterations that could prevent other procedures.

Pure tone audiometry was conducted in an acoustic booth, using the Grasson-Stadler audiometer, model GSI-61 with TDH-50 headphones. Hearing thresholds were investigated by air conduction at sound frequencies from 250 Hz to 8000 Hz. Audiograms were classified based on the proposal of the World Health Organization[22], which considers the calculation of the quadritonal mean of the thresholds of 500, 1000, 2000 and 4000 Hz. A quadritonal mean of 25 dB or less in both ears was considered normal hearing.

Table 1 shows characterization of the participants in this study according to gender, age and audiological profile.

Table 1. Characterization of study participants

Nº	Gender	Age (years)	Quadritonal mean of RE (500, 1000, 2000, 4000HZ)	Quadritonal mean of LE (500, 1000, 2000, 4000HZ)
1	M	20	8.75	7.50
2	M	27	3.75	6.25
3	F	19	11.25	10.00
4	F	26	0.00	6.25
5	F	23	1.25	1.25
6	F	27	6.25	7.50
7	F	26	2.50	5.00
8	M	23	12.50	5.00
9	F	24	7.50	5.00
10	M	25	8.75	10.00
11	M	26	5.00	2.50
12	M	21	13.75	11.25
13	F	27	7.50	7.50
14	F	20	2.50	2.50
Mean	-	23.85	6.51	6.25
SD	-	2.77	4.09	2.87

Caption: SD = Standard deviation, RE = Right ear, LE = Left ear, Hz = Hertz, F = Female, M = Male.

Speech recognition task

For the sentence recognition task, "Lists of Sentences of the Portuguese Language" [23] were used. Lists 1 and 2 were applied and reproduced randomly to avoid changes in the effort due to learning effects. Each list consists of 10 sentences in Portuguese language whose score on the speech recognition test is based on the number of words that an individual perceives audibly and repeats correctly. However, as the objective of this study was to measure listening effort through HRV during a sentence recognition task, data referring to the speech perception analysis was not considered, that is, this procedure was used only as speech material.

The sentence recognition task was performed in an acoustic booth and the lists were reproduced by a female Portuguese speaker, at 50 dBSL, using the Grasson-Stadler audiometer, model GSI-61 with TDH-50 headphones.

The sentence recognition task of low demand consisted of the sentence repetition in silence and the task of high demand the repetition in noise. In the sentence recognition task in difficult listening situations, white noise was used at a signal-to-noise ratio of -5 dB. Speech stimuli and noise were presented binaurally.

The SNR = -5 dB was chosen because it refers to a listening situation whose speech perception is arduous due to the noise level is more intense than the speech signals. Thus, it was hypothesized that the SNR = -5 dB could cause a greater activity in the sympathetic autonomic nervous system and consequently a greater overload of cardiac activity.

In both listening situations, silence and noise, speech stimuli were presented to the loudspeaker at 50 dBSL and the white noise was presented at 55 dBSL, that is SNR = -5 dB. In order to avoid biases regarding the distinct characteristics of speech emission, stimuli were reproduced by the same evaluator and the participants were instructed to repeat each sentence after evaluator's emission, for both listening situations.

Recording of Heart Rate Variability (HRV)

For HRV recording, a RS800CX Polar cardiofrequencimeter (Polar Electro, Finland) and a receiver clock were used. The cardiofrequencimeter consists of a capture belt with electrodes, and when positioned on the participant's thorax, it captures heart electrical impulses and transmits them through an electromagnetic field to the monitor.

The capture belt was placed on the participants' thorax, in the distal third region of the sternum, and the heart rate receiver clock was placed on the wrist, which was previously validated for the capture of the heart rate beat by beat and the use of its data for analysis.

The HRV recording occurred at five different moments: 10 minutes at rest, two minutes recording during the recognition of Brazilian Portuguese sentences in silence,10 minutes recording of retrieval after sentence recognition in silence, then two minutes recording of recognition of Brazilian Portuguese sentences at -5 dB signal-to-noise ratio and, finally 10 minutes recording of post sentence recognition task in noise. The protocol used for recording of the collection is shown in Figure 1.

Chart 1. Protocol for heart rate variability (HRV) recording

Number of participants	Rest	Sentence recognition in silence	List of sentences for the listening situation "silence"	Retrieval post sentence recognition in silence	Sentence recognition in noise (-5dB)	List of sentences for the listening situation "SNR -5dB"	Retrieval post sentence recognition in noise	Polar number used for collection
1.	Beginning:	Beginning:	List 1 ( )	Beginning:	Beginning:	List 1 ( )	Beginning:	Polar 13 ( )
	End:	End:	List 2 ( )	End:	End:	List 2 ( )	End:	Polar 15 ( )
2.	Beginning:	Beginning:	List 1 ( )	Beginning:	Beginning:	List 1 ( )	Beginning:	Polar 13 ( )
	End:	End:	List 2 ( )	End:	End:	List 2 ( )	End:	Polar 15 ( )
3.	Beginning:	Beginning:	List 1 ( )	Beginning:	Beginning:	List 1 ( )	Beginning:	Polar 13 ( )
	End:	End:	List 2 ( )	End:	End:	List 2 ( )	End:	Polar 15 ( )
4.	Beginning:	Beginning:	List 1 ( )	Beginning:	Beginning:	List 1 ( )	Beginning:	Polar 13 ( )
	End:	End:	List 2 ( )	End:	End:	List 2 ( )	End:	Polar 15 ( )
5.	Beginning:	Beginning:	List 1 ( )	Beginning:	Beginning:	List 1 ( )	Beginning:	Polar 13 ( )
	End:	End:	List 2 ( )	End:	End:	List 2 ( )	End:	Polar 15 ( )
6	Beginning:	Beginning:	List 1 ( )	Beginning:	Beginning:	List 1 ( )	Beginning:	Polar 13 ( )
	End:	End:	List 2 ( )	End:	End:	List 2 ( )	End:	Polar 15 ( )
7.	Beginning:	Beginning:	List 1 ( )	Beginning:	Beginning:	List 1 ( )	Beginning:	Polar 13 ( )
	End:	End:	List 2 ( )	End:	End:	List 2 ( )	End:	Polar 15 ( )
8.	Beginning:	Beginning:	List 1 ( )	Beginning:	Beginning:	List 1 ( )	Beginning:	Polar 13 ( )
	End:	End:	List 2 ( )	End:	End:	List 2 ( )	End:	Polar 15 ( )
9.	Beginning:	Beginning:	List 1 ( )	Beginning:	Beginning:	List 1 ( )	Beginning:	Polar 13 ( )
	End:	End:	List 2 ( )	End:	End:	List 2 ( )	End:	Polar 15 ( )
10.	Beginning:	Beginning:	List 1 ( )	Beginning:	Beginning:	List 1 ( )	Beginning:	Polar 13 ( )
	End:	End:	List 2 ( )	End:	End:	List 2 ( )	End:	Polar 15 ( )
11.	Beginning:	Beginning:	List 1 ( )	Beginning:	Beginning:	List 1 ( )	Beginning:	Polar 13 ( )
	End:	End:	List 2 ( )	End:	End:	List 2 ( )	End:	Polar 15 ( )
12.	Beginning:	Beginning:	List 1 ( )	Beginning:	Beginning:	List 1 ( )	Beginning:	Polar 13 ( )
	End:	End:	List 2 ( )	End:	End:	List 2 ( )	End:	Polar 15 ( )
13	Beginning:	Beginning:	List 1 ( )	Beginning:	Beginning:	List 1 ( )	Beginning:	Polar 13 ( )
	End:	End:	List 2 ( )	End:	End:	List 2 ( )	End:	Polar 15 ( )
14	Beginning:	Beginning:	List 1 ( )	Beginning:	Beginning:	List 1 ( )	Beginning:	Polar 13 ( )
	End:	End:	List 2 ( )	End:	End:	List 2 ( )	End:	Polar 15 ( )

To standardize the effects of circadian rhythms, collections were performed between 8:00 am and 2:00 pm, in a climate-controlled environment, with a temperature from 20º C to 23º C. After 10 minutes of heart rate capturing at rest, the sentences recognition task and their respective retrieval periods began. These moments of HRV recording were performed with the participants sitting comfortably throughout the collection.

Analysis of Heart Rate Variability (HRV)

For analysis of HRV indexes, heart rate was recorded beat by beat throughout the experimental protocol with a sampling rate of 1000 Hz. Stable series with 256 RR intervals[24] were selected. In these series, digital and manual filtering were made, to eliminate premature ectopic beats and artifacts, and only those with more than 95% sinus beats were included in the study[25].

Most measurements in the time domain reflect a combination of sympathetic and parasympathetic activity; however, it is believed that the root mean of successive squared differences (RMSSD - calculated by the root ‘square of the square mean of the differences between adjacent normal RR intervals) mainly reflects parasympathetic activity[26]. RMSSD is highly correlated with the spectral measurement of parasympathetic activity. For this reason, time domain analysis was conducted using the RMSSD index (root square of the square mean of differences between adjacent normal RR intervals). This index corresponds to the parasympathetic component of autonomic heart rate control[24,25].

To verify normality of the distributions, Shapiro-Wilk test was applied. Regarding that distributions were parametric, repeated measures ANOVA test followed by Bonferroni post-test were used to compare the RMSSD index in different listening situations. Friedman test was applied followed by the Dunn’s post-test for non-parametric distributions. A significance level of 0.05 was adopted. To measure magnitude of the significant differences, the effect size was calculated using Cohen’s d. Values above 0.9 were considered large effect size, values between 0.50 and 0.90 as medium effect size and values between 0.25 and 0.50 were considered small effect size.

Results

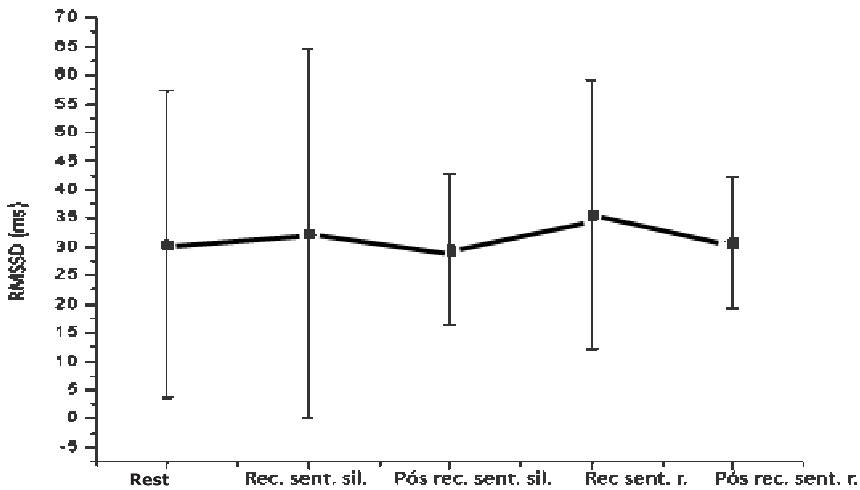
Table 2 shows the descriptive analysis of the listening effort measurement using the RMSSD index obtained during the HRV recording at five different moments. Although there was no statistical difference in the RMSSD index for the five recorded moments, the lowest mean value obtained was at the moment of retrieval post recognition of sentences in silence. It should be emphasized that the lower the value recorded, the greater the cardiac overload.

Table 2. Descriptive analysis of listening effort measurement using the RMSSD index obtained during HRV recording at five different moments

HRV recording moments	Mean	Median	Minimum	Maximum	SD	P
Rest	30.5	23.9	7.6	113.8	26.7	<0.05
Sent. Rec. Sil.	32.4	28.7	13.2	67.0	15.7	<0.05
Post Sent. Rec. Sil.	29.5	23.4	18.33	50.0	13.1	<0.05
Sent. Rec. N.	35.6	23.5	16.4	88.7	23.5	<0.05
Post Sent. Rec. N.	30.7	26.5	13.58	51.6	11.4	<0.05

Caption: Sent. Rec. Sil. = Sentence recognition in silence, Post Sent. Rec. Sil. = Post sentence recognition in silence, Sent. Rec. N. = Sentence recognition in noise, Post Sent. Rec. N. = Post sentence recognition in noise, HRV = Heart rate variability, SD = Standard Deviation.

Figure 2 shows the analysis of the performance of normal hearing individuals under different listening situations, regarding the RMSSD index, during noise exposure. It was noted that there was no significant difference among the moments.



Caption: Sent. Rec. Sil. = Sentence recognition in silence, Post Sent. Rec. Sil. = Post sentence recognition in silence, Sent. Rec. N. = Sentence recognition in noise, Post Sent. Rec. N. = Post sentence recognition in noise

Figure 2. Performance of normal hearing individuals under different listening situations, regarding the RMSSD index

Discussion

This study aimed to compare the parasympathetic modulation of heart rate under different listening situations and to determine whether heart rate variability is a sensitive psychophysiological index to detect changes induced by listening effort.

The analysis of results showed that for the studied population there was no difference between the parasympathetic control recordings under different listening situations, even for the sentence recognition task in the signal-to-noise ratio at -5 dB, which was the listening condition that demanded greater cognitive demand and it was expected that there would be a predominance of the sympathetic autonomic nervous system for this listening condition.

A study[15] conducted with 15 normal-hearing adults to determine whether the psychophysiological indices of listening effort were more sensitive than the performance measurements (correct percentage) obtained near the ceiling level during a concurrent speech task, proved a monotonous increase in mean electromyographic activity, skin conductance and heart rate with the increased demand for tasks, being the biggest changes for electromyographic activity and heart rate when the demand for tasks was changed from medium to high. For this reason, in this study, the application of the -5 dB SNR was opted because it is an arduous listening condition and, thus, being able to enable more accurate results regarding the HRV changes in normal hearing persons compared to the speech perception task in silence, as it was hypothesized that the effects of noise intensity could modify HRV in the listening effort measurement. However, regarding the population studied and the method adopted, it can be stated that the hypothesis was not confirmed.

Moreover, one of the facts that can justify the absence of difference between the parasympathetic control recording under different listening situations, even for the listening condition with the most intense and adverse noise level, would be the type of noise (White noise) used for the sentence recognition task during HRV recording. This noise may not have been as effective to demonstrate significant changes in balancing the sympathetic and parasympathetic nervous systems. Thus, it is suggested that for future studies that address the listening effort topic and its measurement through HRV, one of the aspects that must be considered is the type of competitive noise used.

A study[16] conducted with 18 hearing-impaired adults and 15 adults with normal hearing, aged 22 to 79 years, aimed to measure the effects of hearing loss and noise on HRV according to the demand for a sentence perception task in different SNR ratios, with babble noise, unilaterally. The findings of this study showed that for the participants tested, the HRV decreased in the most difficult SNRs for participants with hearing loss, but the decrease in HRV did not occur for participants with normal hearing. Authors of this study emphasized the need for further studies addressing the listening effort measurement through the HRV recording, mainly with the use of different noise types to verify the effects of this variable in changing the heart parasympathetic control. Thus, this study is justified regarding the application of white noise, since there is no other type of noise available for speech perception tasks at national level, but it is highlighted that the second hypothesis established for this study also was not confirmed.

Other aspects that may have influenced the analysis of parasympathetic activity were the duration of the sentence recognition task, which may have been long enough for the HRV recording to show some alteration in its traces and also the type of equipment used to record HRV because internationally this measurement is recorded using an electrocardiogram [27].

International studies state that HRV can be one of the indexes used to measure listening effort objectively, since research conducted on this topic that used HRV demonstrated significance. One of the inferences that can be made is that in these studies, researchers used another type of noise, the babble noise whose concurrent signal involves sounds with meaning, even unintelligible[28]. Therefore, the sentence recognition task with this type of noise requires a sharper auditory perception and, consequently there is a need for greater listening effort, which demonstrates a predominance of the sympathetic autonomic nervous system.

Recent studies conduceted with participants without hearing loss, who performed speech perception tests under different signal-to-noise ratios, showed a reduction in the precision scores for sentence repetition, resulting from listening to more negative signal-to-noise ratios, followed by a decrease in the HRV measurement over time that reflects the sympathetic and parasympathetic nervous system activity [29,30].

Moreover, the aspects mentioned, it would be interesting to continue this study with a larger number of participants and with different signal-to-noise ratios, as the noise intensity can also have some influence on the sympathetic and parasympathetic activity.

Consequently, development of studies is needed to investigate how the psychophysiological responses recorded during listening tasks are influenced by the acoustic characteristics of the stimuli, the demand for tasks, motivation and the individual's emotional characteristics and responses.

Conclusion

The comparison of parasympathetic modulation of the heart rate in normal hearing individuals demonstrated that for this population, regarding bilateral testing of the SNR -5 dB using White Noise, there was no difference between the recordings of parasympathetic control in different listening situations, being necessary the development of research with new designs to prove the use of HRV as a psychophysiological index for the listening effort measurement.

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