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Electrophysiological indices of stress: non-auditory effects of noise - preliminary data

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ABSTRACT

Noise is an environmental problem, especially in urban areas. The aim of this study was to investigate the non-auditory effects of noise using electrophysiological stress indices. Methods: Adults with normal hearing made the following measurements: electrodermal activity (EDA); heart rate variability (RR interval, RMSSD, HF-HRV power); and respiratory rate during five situations (relaxation in silence, relaxation with noise at 65 dBA and 75 dBA, visual memory task with noise at 75 dBA and speech recognition with noise at 75 dBA). Between each collection, there was a rest period of ten minutes. Subjective measures of noise annoyance were applied. Percentual variation between baseline and each situation was calculated, to normalize the data. Coefficient of Pearson was calculated and the Anova test (and Tukey post-hoc) was used, with a significance level of 5%. Results: We verified the greater the annoyance to noise, the more heart beats per minute and the higher level of skin conductance were observed, with strong correlations. Regarding the respiratory rate, which also increased according to noise annoyance, the correlation was moderate, while the RR interval decreased with moderate correlation. Annoyance to noise was significantly higher in situations with higher noise. In the analysis of the EDA phasic response, amplitude peaks of 0.26 to 0.44 were observed after the onset of noise. In relation to the baseline, the HF-HRV power decreased (from 1465.2 ms^2 in silence for 865 – 942 ms^2 in situations with noise) and the respiratory rate increased (from 15.47 CPM in silence for 17.80 – 19.90 CPM in situations with noise). Conclusion: Our preliminary findings suggest that moderate noise levels caused changes in measurements of electrodermal activity, heart rate variability and respiratory rate.

Keywords: Noise, Stress, Non-auditory, Electrophysiology indices

INTRODUCTION

Noise, an unwanted sound, is a psychosocial stressor in the environment. When perceived as dangerous or unwanted, it activates physiological effects induced by two different systems: the Sympathetic-Adrenal-Medullary (SAM) axis and the Hypothalamic-Pituitary-Adrenal (HPA) axis, compounding the autonomic nervous system (1-6).

The SAM axis is responsible for the adrenaline and noradrenaline secretion – the "fight or flight" – this is: preparation of muscles, heart and brain, and reduction of blood flow to internal organs (the Sympathetic system) (1-6).

The HPA axis is responsible for the cortisol production that prepares the body for "rest/recovery". Hyperactivity of the HPA axis, commonly observed in situations of chronic stress, is accompanied by feelings of anguish, anxiety and depression (the Parasympathetic system) (1-6).

The specific changes in the autonomic nervous system caused by physical or psychological threats, like noise, can be assessed measuring the heart rate variability (HRV) and the electrodermal activity (EDA) that can be used to monitor and evaluate physiological responses to stressors in real-time. Heart rate measurements give a picture of sympathetic and parasympathetic activity, whereas electrodermal activity measurements provide a more direct representation of sympathetic activation. Moreover, the changes in electrodermal activity can be easily correlated to a specific stimulus, while the variability of heart rate must be analyzed together with the respiratory rate (7-9).

The aim of this study was to investigate the non-auditory effects of noise using electrophysiological stress indices.

MATERIALS AND METHODS

Sample

The sample consisted of 15 adults with normal hearing thresholds, 10 females and 5 males (mean 25.6 years; SD: 6.21). The individuals had to fulfill some preconditions: good state of health, good hearing, no intake of medical drugs, alcohol or caffeine on the day of the experiment, and no lack of sleep. The ambient temperature was controlled, not exceeding 25°C.

The following procedures were performed (PowerLab, Labchart, ADInstruments) (Figure 1):

- Electrodermal activity (EDA) (measuring skin conductance (SC) level) (μS);
- Heart rate variability (HRV) (measuring absolute power of the high-frequency band - HF (ms^2); RR interval (ms); Heart beats per minute; Root mean square of successive RR interval differences RMSSD (ms));
- Respiratory rate (CPM - cycles per minute);
- Subjective measures of noise annoyance (10) based on the ICBEN scale, applied after each collection with noise.

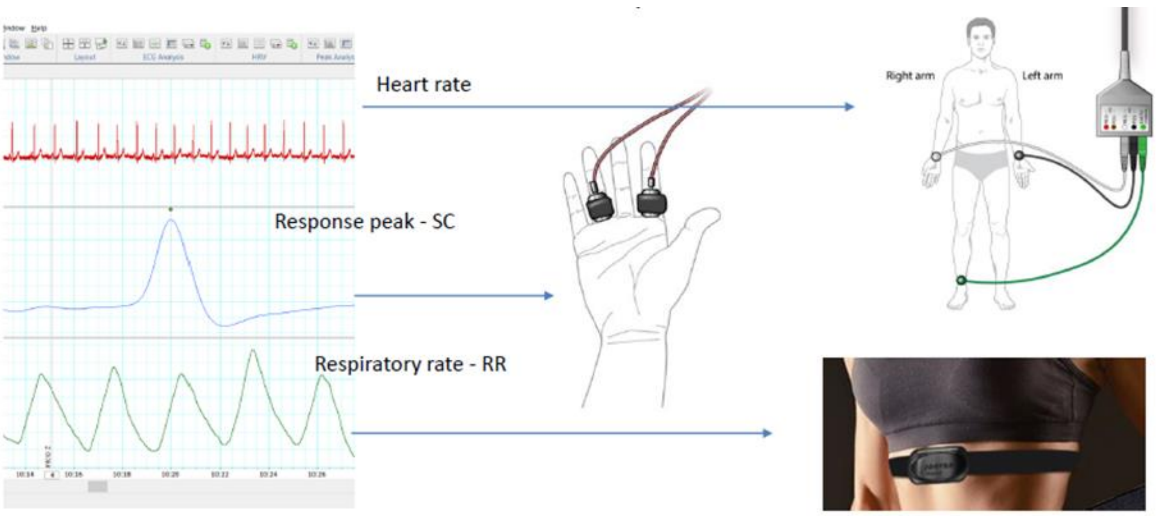

Figure 1: Examples of procedures

All these parameters reflect changes of the physiological state of the body in a dimension of activation of the vegetative system elicited by external stimuli as well as by physical tension or emotional arousal. These measurements were collected in following situations in an acoustic booth:
1) Baseline - Relaxation (subject sitting comfortably in the chair) in silence (five minutes);
2) Relaxation with pink noise at 65 dBA (TDH headphones) (five minutes);
3) Relaxation with pink noise at 75 dBA (TDH headphones) (five minutes);
4) Visual memory task (i.e., Genius game with visual stimuli only) with pink noise at 75 dBA (TDH headphones) (five minutes);
5) Speech recognition task (the correct word answer should be given through a tablet through forced choice between three monosyllables) with pink noise at 75 dBA (TDH headphones) (five minutes).

Between each collection (between situations), there was a rest period of ten minutes in silence condition.

The equipment was calibrated prior to collections to provide reliable results. After data acquisition, a low frequency filter was used to decrease the physiological/environmental noise and improve the collected samples. Some excerpts from two individuals who presented tracings containing many artifacts were discarded from the analysis as outliers.

For analysis, means for each situation, variable and subject were calculated and after that, the percentual variation between baseline and each situation was calculated (situation - baseline / baseline), to normalize the data. Also, coefficient of Pearson was calculated and the Anova test (and Tukey post-hoc) was used, with a significance level of 5%.

RESULTS

We verified the greater the annoyance to noise, the more heart beats per minute and the higher level of skin conductance were observed by Pearson's coefficient, with strong correlations. Regarding the respiratory rate, which also increased according to noise annoyance, the correlation was moderate, while the RR interval decreased with moderate correlation (Table 1).

Table1: Percentual variation comparing each situation with baseline and Pearson coefficient (correlating with annoyance to noise)

Percentual variation	**Relaxation - Situation With noise (65 dBA) versus Baseline (silence)**	**Relaxation - Situation With noise (75 dBA) versus Baseline (silence)**	**Visual memory task with noise (75 dBA) versus Baseline (silence)**	**Speech recognition task with noise (75 dBA) versus Baseline (silence)**	**Pearson Coefficient**
Annoyance to noise (mean)	5.82 (2.25)	7.64 (2.27)	7.71 (1.63)	8.00 (1.46)	
RR interval (%)	-2.04 (4.25)	-2.28 (4.61)	-4.31 (7.76)	-3.61 (6.50)	-0.663
Heartbeats per minute (%)	1.95 (4.17)	2.48 (4.52)	4.89 (7.80)	3.97 (6.48)	0.705
Root mean square of successive RR interval Differences (RMSSD) (%)	-9.63 (35.66)	-15.84 (38.66)	-11.92 (35.81)	-10.88 (26.66)	-0.500
Absolute power of the high-frequency band (%)	-37.77 (28.87)	-23.48 (53.63)	-38.59 (31.56)	-35.92 (32.08)	-0.281
Respiration rate (%)	21.11 (30.12)	21.61 (31.52)	36.77 (44.72)	35.79 (32.79)	0.664
Skin conductance level (%)	31.53 (47.55)	41.35 (54.92)	44.29 (56.05)	40.06 (60.39)	0.904

We verified that annoyance to noise was significantly higher in situations with higher noise (75 dBA), when compared with the situation with less intense noise (65 dBA). In the analysis of the EDA phasic response, amplitude peaks of 0.26 to 0.44 were observed after the onset of noise, but without statistical significance between situations. In relation to the baseline, the HF-HRV power decreased (from 1465.2 ms^2 in silence for 865 – 942 ms^2 in situations with noise), without statistical significance and the respiratory rate increased (from 15.47 CPM in silence for 17.80 – 19.90 CPM in situations with noise), with statistical significance.

Table 2: Means (SD) of skin conductance, high frequency of HRV and respiratory rate in all situations

	Baseline Relaxation - Silence	Relaxation - Situation With noise (65 dBA)	Relaxation - Situation With noise (75 dBA)	Visual memory task with noise (75 dBA)	Speech recognition task with noise (75 dBA)	p-value
Annoyance to noise	-	5.82 ^{A} (2.25)	7.64 ^{B} (2.27)	7.71 ^{B} (1.63)	8.00 ^{B} (1.46)	0.012* (between A and B)
EDA (µS)	-	0.31 (0.47)	0.41 (0.54)	0.44 (0.56)	0.26 (0.28)	0.703
HF-HRV (ms^2)	1465.2 (1666.65)	896.37 (604.26)	942.14 (584.22)	865.53 (480.26)	932.08 (552.08)	0.332
Respiratory rate (CPM)	15.47 ^{A} (4.09)	17.96 ^{B} (3.53)	17.80 ^{B} (2.47)	19.90 ^{B} (3.46)	19.82 ^{B} (2.46)	0.002* (between A and B)

Legend: * p<0.005

DISCUSSION

Our findings showed greater annoyance to noise for situations with higher SPL. When comparing situations with the same NPS but different cognitive demands, there were no statistically significant differences. Previous studies have shown a trend of greater annoyance to noise for situations with higher noise levels. However, other variables interfere in this issue, such as noise sensitivity (11).

Individual responses to noises depends on non-acoustical factors such as individual personalities, attitudes toward noises, previous experiences, and exposure to the noise environment, and acoustical factors such as noise levels and frequency characteristics. Therefore, to explain noise sensitivity, it is necessary to consider the characteristics of the noise itself and the various non-acoustical factors that affect individual responses (12).

Regarding the absence of difference in terms of annoyance related to cognitive demand, similar findings were observed by Sandrock et al. (13), who suggested that other cognitive tasks should be used to verify this specific issue of increased annoyance related to tasks in presence of noise.

Analyzing the increase at the noise pressure level (and the increase at the noise annoyance) and comparing it with the electrophysiological measures, we found that the greater the annoyance, the more heart beats per minute were observed, in addition to the increase in respiratory rate and decrease in the RR interval. Also, we verified higher level of skin conductance. All these measures are correlated, since they are regulated by the autonomic nervous system and, specifically these HRV measurements, primarily reflect sympathetic stimulation, which promotes increased heart and respiratory rate, and increased EDA, in more stressful situations (9,14).

Previous studies have observed different results in relation to electrophysiological findings related to non-auditory effects of noise. Masullo et al. (9) found changes in the EDA but not in the RR interval, depending on the noise levels evaluated. Lee et al (15) did not observe changes in heart rate but found different responses in the LF / HF ratio for different noise intensities. It is important to mention that the methodologies used in each of these studies are different and this must be taken into account, in addition to the variability of measurements between individuals. Therefore, methods for data normalization are important and should be used whenever possible.

A limitation of this type of analysis of electrophysiological measures of stress, where the intersubject responses are very variable, is that checking the raw signal, although important to identify possible artifacts that may interfere with the results, is subjective and, therefore, must be careful and, preferably, carried out by independent judges, to give greater data reliability.

CONCLUSION

Our findings suggest that moderate noise levels caused changes in skin conductance, heart rate variability and respiratory rate measurements, but they must be analyzed with caution, as the sample is small and the data are preliminary.

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