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A Study of Strong Noise on Human Heart Rate Changes

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ABSTRACT

Under stressful conditions, the body produces a series of biological responses, such as significant changes in heart rate, blood pressure, respiration, and glandular activity, etc. Strong noise also has an effect on physiology. In the following research, Heart rate was selected as the psychophysiological index reflecting the psychological changes of the subjects, and the psycho-emotional changes of the subjects under the stimulation of strong noise samples were analyzed laterally by measuring the results of the physiological indexes before and after the subjects' experiments. Results showed that Subjects' heart rate variability changed significantly and with similar trends under noise stimulation, and changed more as the noise loudness level increased.

KEYWORDS

Strong noise; HRV

1. INTRODUCTION

Different emotions have different physiological response patterns, e.g., the human heartbeat rhythm is generally normal when satisfied and happy; when distressed, the vascular volume is reduced; and when fear or anger emotions occur, the heartbeat is usually accelerated, blood pressure is elevated, and breathing is accelerated [1]. Potential mechanisms of noise-induced mental stress focus on increases in stress hormone levels, blood pressure, and heart rate [2]. Many scholars have used psychological experiments based on physiological signals in an attempt to reflect psychological changes through objectively recorded physiological changes such as heart rate, ECG, EMG, blood pressure, and EEG. Fay Zhou [3] collected physiological data from coal mine general mining workface workers and established a regression model between environmental factors such as noise and various physiological and psychological indicators (blood pressure, heart rate, respiration rate, body temperature, fatigue, etc.). Hu Junxiang [4] measured the blood pressure of subjects under noise stimulation of 80dB and 100dB, and analyzed heart rate variability by ECG, and experimentally proved that noise stress had a significant effect on the cardiovascular system, with increased blood pressure and accelerated heart rate in noise-stimulated subjects; the R-R interval of heart rate variability decreased when the high-frequency and low-frequency components of noise increased; the effect of noise at higher sound levels was stronger. Jing Guoxun et al [5] collected heart rate variability and skin conductance data from subjects as physiological signal indicators to study the effects of different sound levels and exposure times on subjects. The experimental results showed that the HRV of the control and experimental groups differed significantly. The changes in physiological indexes were dramatic in subjects just exposed to noise, and then leveled off, and then increased significantly after the stimulation duration was gradually lengthened (35 min), and then leveled off again. Mo Qiuyun [6] experimentally found that the main response of subjects under noise stress was accelerated heart rate, and heart rate and heart rate variability were used as human load evaluation indicators to measure noise effects from psychological and physiological perspectives.

Changes in physiological signals and behavioral responses occur in the human body when significant psychological changes occur. The objective evaluation is mainly through the experimental observation and recording of the subjects' physiological and psychological indicators and behavioral response changes, and the side analysis measures the psychological changes, which has the advantage of being objective and not easy to be faked.

2. EXPERIMENTAL PROCEDURES

Before the experiment, subjects sat at the designated position for 5 minutes to get familiar with the experimental environment, and their calm state heart rate values were measured and recorded. Each time the subjects completed the subjective evaluation of one sound sample, their heart rate data were immediately collected, and the subjects' psychological changes under strong sound stimulation were analyzed by the physiological responses triggered by emotions.

3. DATA PROCESSING AND ANALYSIS

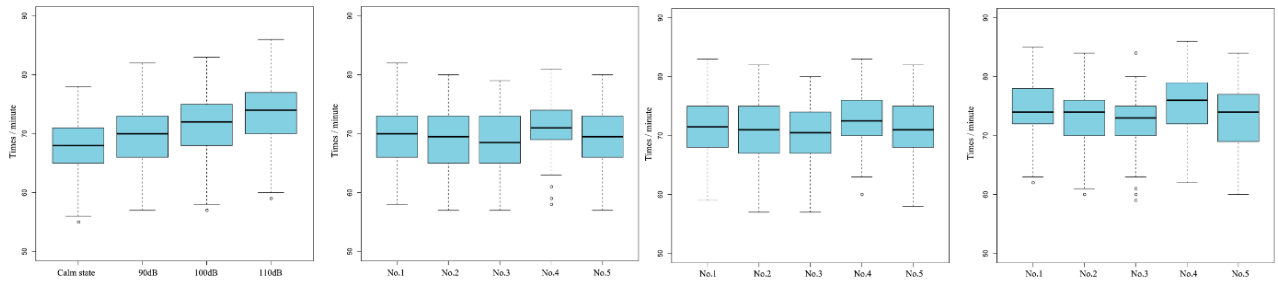
Subjects' heart rate measurements were counted and the statistics were divided into three groups by sound pressure level: 90dB, 100dB, and 110dB, with five noisy samples of experimental data within each group.

Blood pressure and heart rate are important physiological indicators to describe the mental changes of the subjects, and three groups of sound pressure levels, 90dB, 100dB, and 110dB, were distinguished to statistically describe the subjects' heart rate data, as shown in Table 1.

Table 1. Statistical description of heart rate results

groups	within a group	mean value	standard deviation	standard error
quiescence		66.90	5.530	1.010
90dB	Noise sample No.1	69.47	5.655	1.032
	Noise sample No.2	68.70	5.694	1.040
	Noise sample No.3	68.40	5.506	1.005
	Noise sample No.4	70.47	5.563	1.016
	Noise sample No.5	68.77	5.557	1.014
100dB	Noise sample No.1	71.13	5.871	1.072
	Noise sample No.2	70.47	5.859	1.070
	Noise sample No.3	69.67	5.585	1.020
	Noise sample No.4	72.47	5.673	1.036
	Noise sample No.5	70.67	5.756	1.051
110dB	Noise sample No.1	73.73	5.595	1.022
	Noise sample No.2	72.63	5.774	1.054
	Noise sample No.3	71.83	5.754	1.051
	Noise sample No.4	75.10	5.780	1.055
	Noise sample No.5	72.90	5.938	1.084

The distribution of subjects' heart rate data was analyzed using R language to plot box plots of subjects' heart rate distribution under three sound pressure levels and to distinguish between different sound pressure levels to plot box plots of subjects' heart rate distribution under different noise sample stimuli, see Figure 1.



a) Different sound pressure levels; b) 90dB sound pressure level; c) 100dB sound pressure level; d) 110dB sound pressure level

Figure 1. Box plot of heart rate distribution

From Table 1 and Figure 1, it can be seen that: the mean heart rate of subjects at different sound pressure levels differed, and the heart rate increased simultaneously as the sound pressure level increased; at the same sound pressure level, the subject's heart rate was highest for noise sample No.4, followed by noise sample No.1, and the subject's heart rate under the stimulus of noise sample No.1 was higher than that of noise samples No.2 and No.3.

Data on psychophysiological indicators of the subjects were statistically inferred to determine whether there was a correlation between the variables and ANOVA was performed, and the results of the analysis are shown in Table 2.

Table 2. Heart rate and sound pressure level ANOVA results

		Sum of squares	Mean Square	F value	P value
90dB	intergroup	39.533	9.883	.227	.923
	Within Group	6326.467	43.631		
100dB	intergroup	76.973	19.243	.446	.775
	Within Group	6261.700	43.184		
110dB	intergroup	120.093	30.023	.688	.602
	Within Group	6331.967	43.669		

As can be seen from Table 2, there was no difference between groups in heart rate at different levels of sound pressure levels, with p-values greater than 0.05. Combined with the analysis in Figures 4-8, the subjects' heart rate gradually increased at 90dB, 100dB, and 110dB sound pressure levels, but the increase was not significant. The differences in heart rate were equally significant, where all noise samples had p-values less than 0.05 and all had statistically significant differences. The difference was likewise most significant for noise sample No.4, with noise samples No.1, No.2, and No.3 showing the greatest change among noise samples No.1.

4. EXPERIMENTAL RESULTS

(1) Psychophysiological indicators of strong noise stimulation were positively correlated with sound pressure level. The heart rate of subjects increased with the increase of sound pressure level in the same noise sample.

(2) High-frequency noise is more likely to stimulate psychological changes in subjects than medium- and low-frequency noise. Mainly in the same sound pressure level, high-frequency noise caused higher heart rate compared with medium and low frequency noise.

(3) The most obvious changes in the psychophysiological indexes of the subjects under the stimulation of noise sample No.4. The increase in the heart rate of the subjects was most obvious at the same sound pressure level caused by noise sample No.4. Noise sample No.4 was the noise sample

produced with drastic changes in timbre and frequency; therefore, the drastic changes in noise had a greater effect on the psychophysiological indicators of the subjects.

5. CONCLUSION

(1) Strong noise stimulation by acoustic dispersers produces strong emotional changes in subjects

Under the strong noise stimulation of 90dB or more, the subjects reported feeling significantly uncomfortable, irritable and frightened during the experiment, accompanied by palpitations, tinnitus, and rapid heartbeat. The results of the psychophysiological indicators of the subjects also confirmed this pattern, and the subjects' heart rate increased significantly under the strong sound stimulation compared with the calm state.

(2) The higher the sound pressure level of a strong acoustic stimulus is, the more intense the subject's agitation is

Subjective agitation of subjects was positively correlated with sound pressure level by subjective evaluation experiment. In the results of the psychophysiological index measurements, the change in the subjects' psychophysiological indexes increased with the increase in the sound pressure level of the noise samples. The subjects also all reported that the higher the sound pressure level, the more psychophysiological discomfort they felt. Thus, strong SPL noise stimuli induce more intense physiological changes.

(3) Subjects were more agitated by high frequency noise stimuli than by medium and low frequency noise

The pattern of psychophysiological indicator measurements is consistent with the results of subjective evaluations. Some noise samples of particular timbre may cause great subjective emotional discomfort in subjects even if they cause little change in psychophysiological indicators; therefore, improving acoustic disperser noise samples has implications for improving the operational effectiveness of acoustic dispersers.

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