

## EFFECTS OF VARIOUS FREQUENCY NOISE EXPOSURE ON AMBULATORY BLOOD PRESSURE IN CONTROL ROOM OPERATORS

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### ABSTRACT

**Purpose:** Noise is a potential source of stress for people and can cause non-auditory effects. The aim of this study is to find the effect of the quality, independent of quantity, of any type of noise on blood pressure and to investigate some of its non-auditory effects.

**Settings and Design:** This experimental study was carried out on 60 staff of petrochemical control rooms. Each subject, filled a GHQ screening questionnaire. The experiment was carried out in a measuring room that conformity by OSHA 1910.95 App D. Eight types of noises were used: white, blue, pink noise and noise in 125, 500, 1000, 2000, 4000 Hz frequency with flat-frequency character.

**Methods and Materials:** The level of sound pressure in A-weighted of both noises was below 75 dB. Subjects completed noise sensitivity questionnaire. Blood pressure was measured by a digital blood pressure-meter before and after noise exposure.

**Statistical analysis used:** Then the statistical analyses were performed using the SPSS software.

**Results:** Result showed that there was a significant difference in systolic blood pressure by the exposure to base noise and all of 8 noise types ( $p < 0.005$ ), except for white noise. Noise exposure had the most noticeable effect on systolic and diastolic blood pressures by SPL 65-75 dB(A) in leader frequency 1,2 kHz. Noise annoyance in 1, 2 kHz was more than other types of noise exposures.

**Conclusion:** These results imply that blood pressure and noise annoyance are more sensitive to some types of noises, as noise exposure by SPL 65-75 dB(A) in leader frequency 1,2 kHz.

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### Introduction

Sound as noise is a source of stress for people by causing some non-auditory interference [1]. Research is being continually carried out on the non-auditory effects of noise [2]. Nevertheless, there is uncertainty about the non-auditory effects of the quality and quantity of noise on human health [3]. It has been found that there are many factors that cause these effects, such as length of exposure, exposure in another workplace and the perceived control over noise exposure [4].

Unexpected impulsive or time changed noise will cause psychological responses in human health. These responses affect physiological health [5]. Responses may include changes in breathing volume, cardiovascular blood pressure, pulse rate, gastrointestinal motility, endocrine gland excretions, and other neural and human activities. These responses are sometimes designated as "arousal" and sometimes as "stress" responses. The cause of these responses are difficult to individualize from emotional states such as fear or anger [6]. So far, the effects of noise have been determined on blood pressure and biological parameters, such as cholesterol and triglycerides [7], blood viscosity, number of platelet and level of glucose [8]. Community studies have shown some evidence that low levels of noise influence blood pressure and it has been found that this noise may be a minor risk factor for the cardiovascular system (Relative Risk 1.1–1.5) [9-11].

A longitudinal study carried out on industrial noise determined that levels of noise increase blood pressure when workers do complex jobs, but such variations do not exist when they are doing simple jobs [12]. Some studies that have proved that environmental noise and blood pressure are related [2]. Also, occupational noise, caused by workers' exposure, has some relation with hypertension. Dose response relationships beside annoyance, noise exposure can affect blood pressure [3]. Exposure to noise can cause an increase in heart rate so that in workplace it increases up to +3.7bpm; where there is low level of noise exposure, such as at home, the heart rate is 2.8bpm [2]. Occupational noise exposure studies have shown that blood pressure of workers who are chronically exposed to continuous noise, even less than 85 dB, is different from those workers who are not exposed to noise [13, 14]. It seems that exposure to occupational noise elevates blood pressure; also, there is a relationship between noise and mortality. Long term occupational studies should demonstrate main causes of blood pressure changes in these settings [2]. A meta-analysis of 43 epidemiological studies, about blood pressure and occupational and environmental exposure to noise, revealed that the effect of noise exposure on changes in blood pressure is inconsiderable [2]. Some studies have provided evidences for the effect of exposure to noise on the coronary heart disease, resulting from blood pressure in occupational noise exposure [15].

Low level of noise exposure increases blood pressure in complex jobs more than in simple ones. On the contrary, high levels of noise exposure, raises blood pressure [16].

However, in high pressure level noisy conditions in complex jobs rise in blood pressure is more than simple jobs up to three times. This interaction between task complexities, noise exposure and physiological effects may have wide implications for human health aspects [2].

Carter et al. studied 476 workers by normal blood pressure and aged 20 to 50 years. Their mean systolic blood pressure was 6mm and diastolic blood pressure was 3mm higher during noise exposure, compared with non-noise exposed subjects, this continued for 2-3 hours after noise exposure. As an added control measure, ambulatory blood pressure was also measured at home, which did not differ between noise exposed and non-exposed group [17].

In two further studies, it has been found that there is a relationship between industrial cumulative noise exposure and diastolic blood pressure, adjusting for various confounding factors [18]. Considering previous studies, dynamic change in blood pressure on these additional studies add biological plausibility to the noise exposure effects on blood pressure. Homeostatic mechanisms return blood pressure to normal condition after acute noise exposure. The aim of these longitudinal studies, regarding noise exposure and blood pressure, is to investigate whether long-term noise exposure makes permanent raises in blood pressure, and subsequently increases the risk of hypertension or not [2]. Long-term hypertension studies adjust confounding workplace factors, such as the quality of noise that may be a problem [19]. A noise study in an industrial setting determined that noise exposure can change systolic and diastolic pressure in jobs based on their complexity [20].

This study is conducted to satisfy the need for a better characterization of noise exposure, to investigate any type of frequency spectrum of noise, by focusing on vulnerable selected groups and controlling mediating and confounding factors. It uses multiple outcome measures in laboratory studies and further considers the after effects of noise. The aim of this research is to find the effect of diverse types of noise quality, independent of quantity, on blood pressure and to investigate its non-auditory effects with the purpose of the refinement of the general health outcomes.

### **Subjects and methods:**

#### *Subjects:*

Sixty male subjects who were the staff of petrochemical control rooms participated in this study. All the subjects were process controller who monitored with computer systems, and had an average age of 33.8 years (SD=3). Each subject with normal hearing filled a GHQ screening questioner, and only those with normal mental health score of 22 were included in the study. The subjects signed informed consent for their participation.

#### *Acoustic test room:*

The experiment was carried out in a room with a surface of 10 m<sup>2</sup>. This room was used to control other disturbing factors such as temperature, light and surrounding noise. The room conformity by OSHA 1910.95 App D. Air temperature was 20-21 °C, humidity 45-55% and illumination was 300 lux in 6500 k. The noise was emitted from 6 loudspeakers, placed in the room, including 4 main loudspeakers, 1 subwoofer and 1 tweeter which could reproduce different frequencies. Normally, one subject performed the test session at any time.

#### *Noise exposure*

Eight types of noises were used: white, blue, pink noise and noise in 125,500,1000,2000,4000 Hz frequencies with flat-frequency character. The A-weighted sound pressure level of both noises was below 75 dB; the corresponding C-weighted sound pressure levels were below 75 dB for the reference noise and 65 dB for the other frequency noise.

A recording of a petrochemical control room noise, with rather flat frequency characteristics (measured in octave band), was used to create the base exposure noise. The specified noise characteristic was incorporated in the acoustic room to avoid other disturbing sounds from the surrounding. All types of noises were added by a noise generator and filtered by a resonance filter with a frequency regulator. A sinusoidal tone at any noise type was emitted. This was done to provide the specified noise frequency in exposure room. The processing of the sound was done using software and a digital sound processor system (Pioneer speaker SP-PK52FS). The equivalent octave band noise pressure levels of the emitted noises were measured at ear level at the position of a seated subject by a TES 1358 sound analyzer. The sound pressure level variation in the A-weighted at the 8type in the room was 70.3 dB

Experimental design and procedure

In the first stage, all subjects completed noise sensitivity questionnaire to understand personal sensitivity of subjects to noise. Systolic and diastolic blood pressures were measured by a digital blood pressure measuring device (Medisana HGF). Before the start of exposure, blood pressure of each subject was measured and then due to the defined procedure, subjects were exposed to a certain type of noise. After 15 minutes of exposure, the blood pressure was measured again. At the same time, noise sensitivity was determined by pressure measuring annoyance by. The experimental design is shown in the table 1.

**Table1.** Experimental design with time schedule

Time (min)	Moment
5	Rest in a relaxing room
5	GHQ questioner (if the score is above 22, next stage; otherwise, the next person)
3	Demographic information entry
2	Blood pressure measurement
5	Personal noise sensitivity
1	Noise sensitivity scale
10	Exposure to a specified noise
2	Blood pressure measurement
	Rest in a relaxing room
*	Repeat noise exposure by the next specified noise

Analysis and statistical methods:

The experiment had 8 noise-type exposures for 60 subjects. Their systolic and diastolic blood pressure, noise sensitivity and impressionable personality against noise were investigated. Repeated measures in linier model were performed to evaluate the influence of any type of noise conditions on the systolic and diastolic blood pressure. Sphericity assumed analyses were used to identify relationships between noise annoyance results, subjective reports and subjective sensitivity. All analyses were repeated, and a p-value below 0.05 was considered statistically significant, while a p-value up to 0.10 is reported as a tendency. The statistical analyses were carried out using the SPSS software (SPSS base 15.0 for Windows).

The tests of the noise type effects on blood pressure in laboratory conditions were conducted concurrently (Figure 1).

Laboratory Exposure											Result	Analysis
Selected group	Various noise type										Systolic, diastolic blood pressure	Repeated measure Sphericity assumed descriptive
	Base	White	pink	blue	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz		
	≤ 55 dB	= 75 dB	65-75 dB	75-65 dB	75 dB	75 dB	75 dB	75 dB	75 dB	75 dB	Demographic data	
	Blood pressure measurement Noise annoyance measurement										Noise sensitivity	

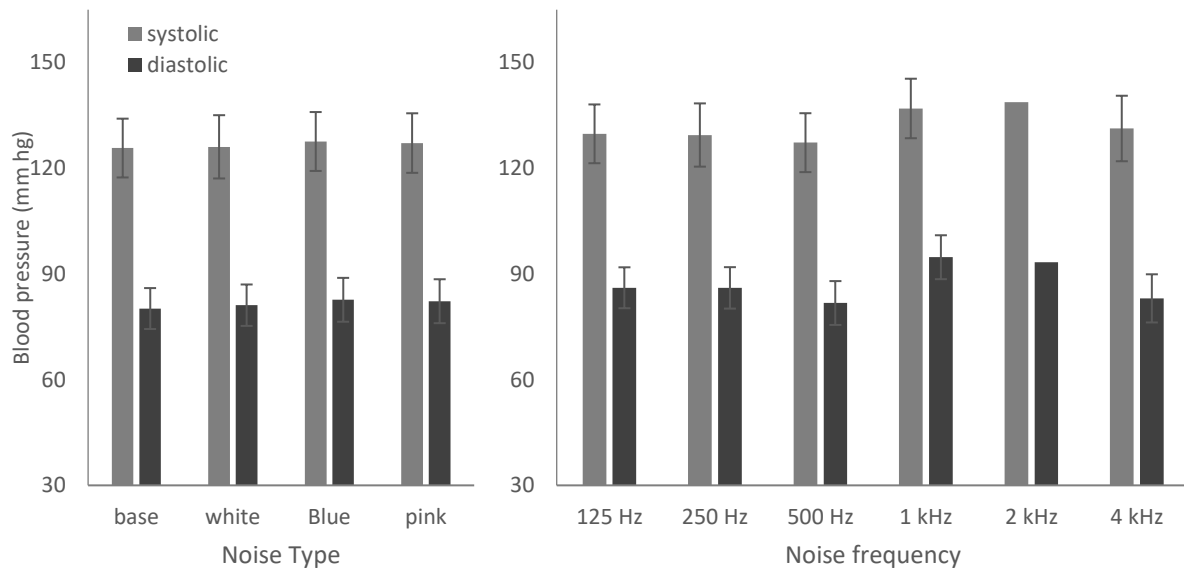
**Figure1** general diagram of the study of noise type effect on blood pressure

**Result:**

Participants' age ranged from 22 to 40. Range of noise exposure in work place was 1-15 years. General health condition in participant was 3-16 of GHQ questionnaire and noise sensitivity in participant was 36-110 by Weinstein's noise sensitivity scale. Table 2 shows the summery information about participants before the test start. Figure 2 presents crude blood pressure in 9 noise frequency groups.

**Table 2** participant demographic data

	Mean	Max	Min	SD
Age	33.9	40	22	3.4
Experience	6.4	15	1	3.9
General Health	9.3	16	3	3.5
Noise sensitivity	75	110	36	22.9



**Figure2-** crude blood pressure in 8 noise frequency groups

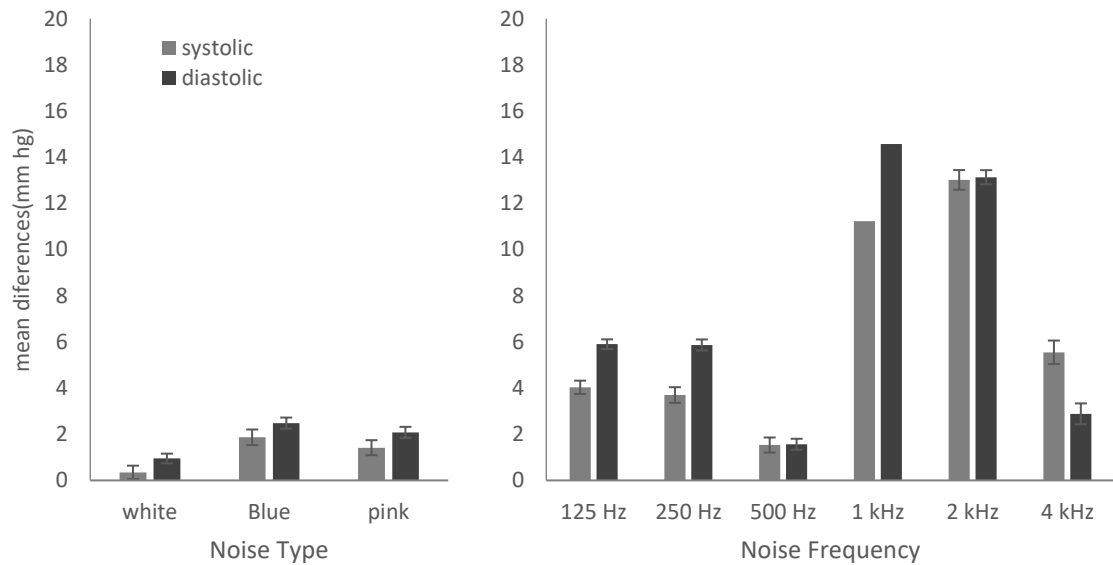
Blood pressure increases noticeably at some frequency exposures. To explore this increased blood pressure in greater detail a repeated measure was carried out, adjusted for age, experience, annoyance and noise sensitivity (table 3). Repeated measure was used because of the high proportion of the blood pressure current on any type of noise exposure.

**Table 3** repeated measure analysis in systolic and diastolic blood pressure (adjusted by age, experience, annoyance and noise sensitivity)

	Mean Difference		Sig.(a)		95% Confidence Interval for Difference(a)			
					Lower Bound		Upper Bound	
	Systolic	Diastolic	Systolic	Diastolic	Systolic	Diastolic	Systolic	Diastolic
White	-.350	-.950	.231	.000	-.929	-1.373	.229	-.527
Pink	-1.867	-2.483	.000	.000	-2.546	-2.965	-1.187	-2.002
Blue	-1.417	-2.083	.000	.000	-2.071	-2.561	-.762	-1.606
125 Hz	-4.033	-5.900	.000	.000	-4.887	-6.511	-3.180	-5.289
250 Hz	-3.700	-5.867	.000	.000	-4.717	-6.774	-2.683	-4.959

500 Hz	-1.533	-1.567	.006	.003	-2.616	-2.593	-.450	-.540
1 kHz	-11.233	-14.567	.000	.000	-12.958	-17.827	-9.508	-11.306
2 kHz	-13.017	-13.133	.000	.000	-15.235	-15.041	-10.798	-11.225
4 kHz	-5.550	-2.883	.000	.240	-8.063	-5.369	-3.037	-.397

Results show there were increases in both systolic and diastolic blood pressures. There is a significant difference in systolic blood pressure by the exposure to base noise and all of 8 noise types ( $p < 0.005$ ), except for white noise. This means that, white noise exposure cannot affect systolic blood pressure. Regarding diastolic blood pressure, there is a significant difference between systolic blood pressure in exposure to base noise and all of 8 noise types ( $p < 0.005$ ), except for the 4 kHz noise. The most noticeable effects on systolic and diastolic blood pressure were in 1, 2 kHz noise exposure, compared with base noise condition. Figure 3 shows blood pressure mean difference between diverse types of noise and the base noise condition.



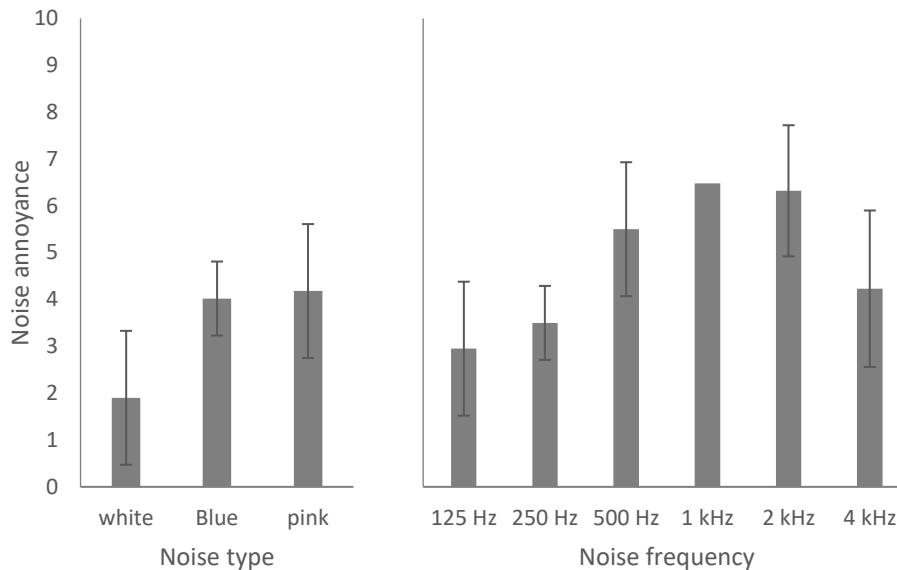
**Figure 3** mean difference of blood pressure in the base noise and other types of noise exposure

Noise annoyance in participants is different, based on the type of noise being exposed to, but differences in noise conditions ( $p < 0.05$ ) cause significant differences. Table 4 shows differences between all types of the noise exposure. By Sphericity assumed statistical test, it was found that confounding factors such as age, experience are confounding effect and noise sensitivity there are not effect on noise annoyance.

**Table 4** noise annoyance differences in noise exposure

	White	Pink	Blue	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
White	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pink	0.000	-	0.419	0.000	0.41	0.000	0.000	0.000	0.59
Blue	0.000	0.419	-	0.000	0.20	0.000	0.000	0.000	0.809
125 Hz	0.000	0.000	0.000	-	0.077	0.000	0.000	0.000	0.000
250 Hz	0.000	0.041	0.20	0.77	-	0.000	0.000	0.000	0.05
500 Hz	0.000	0.000	0.000	0.000	0.000	-	0.000	0.06	0.000
1 kHz	0.000	0.000	0.000	0.000	0.000	0.000	-	0.501	0.000
2 kHz	0.000	0.000	0.000	0.000	0.000	0.000	0.501	-	0.000

Results revealed that noise annoyance in 1, 2 kHz is more than other noise exposures. Figure 4 demonstrates noise annoyance mean in different noise exposure.



**Figure 4** noise annoyance mean in different noise exposure

#### Discussion:

Based on the analysis of the blood pressure and annoyance produced by exposure to all noise types, it can be concluded that:

- 1- Noise exposure by SPL 65-75 dB(A) in leader frequency 1,2 kHz can raise systolic and diastolic blood pressure;
- 2- 500-2000 Hz noise in 75 dB(A) can annoy people independent of age, noise sensitivity and rate of exposure;
- 3- There are no significant relationships between age, experience and noise sensitivity and noise annoyance, and hypertension;
- 4- Two meaningful noise was found to be more blood pressure and annoying than a meaningless noise.

Therefore, it can be concluded that serious steps should be taken in order to control noise. The qualitative aspect obtained for this study are experienced, quantitative discussion of these results gives an anxiety about effect of low level noise pressure.

One possible reason for the increase in blood pressure by noise exposure can be an intermediate response, such as noise annoyance [14], although this probable reason has not been clearly proved [21]. Fyhri, Aand colleagues showed that hypertension in traffic noise found that relation in 50 dB(A) noise level the odds ratio for hypertension was 1.4 (95%CI 0.6-3.2) in men and 1.8 (95%CI 0.8-4.1) in women [22]. Some risk factors can confound blood pressure; when the impact of these risk factors is removed, substantive relationship between noise and blood pressure may arise [1]. Results of a Swedish study showed that increase in blood pressure was higher in people exposed to at least 55 dBA as time weighted averaged noise levels or noise levels above 72 dBA around airport [9]. In the study of Cohen et al. (1980), results showed that chronic exposure to aircraft noise was associated with changes in systolic and diastolic blood pressure but these changes were within the normal limits [23].

In low level noise exposure conditions, those with simple jobs had greater increases in blood pressure, while those with complex jobs were relatively protected. However, under noisy conditions, those with complex jobs had a threefold raise in blood pressure, compared with those doing simple tasks. This interaction between task complexity, noise exposure and physiological effects may have wide implications for other health outcomes [3]. Air pollution may be a confounding factor or a moderator of noise effects on cardiovascular outcomes [24].

As mentioned in some studies and ours, there are relationships between amounts of blood pressure and noise characteristics. Increase in some of these characteristics, such as level of pressure at 1, 2 kHz, affects blood pressure. The response of nervous system to noise exposure is hormones secretion and blood pressure augmentation [7-10, 14].

Some of noise related studies have shown annoyance as a possible mediating factor for cardiovascular outcomes [25]. Adjusting for age, body mass index (BMI) and smoking, among the 3622 residents of Pancevo, Serbia, very much or extremely annoyed men had an increased risk of reporting hypertension (OR= 1.895% CI 1.0-2.4) and myocardial infarction (OR= 1.7 95% CI 1.0-2.9) than those who are not at all annoyed [26].

Our study reports that if the annoyance is higher, exposure to noise frequency leads to higher blood pressure. These results can be indicative of the fact that noise annoyance in people causes mental effects and these effects raise blood pressure.

#### Conclusion

The primary purpose of this study was to verify if there was any relationship between office noise by different leader frequency, blood pressure and noise annoyance. This study has been successful in demonstrating that low level noise affects the blood pressure in the selected group of people that may be attributed to noise exposure. It is further suggested to do a longitudinal

industrial noise study, for determine rate of hypertension from different types of noise. It is also proposed to control noises in frequency 500-2000 kHz at below the 65-75 dB.

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