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ARTICLE

Analysis of the Relationships between Noise Exposure and Stress/Arousal Mood at Different Levels of Workload

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ABSTRACT

Noise is one of the environmental factors with mental and physical effects. The workload is also the multiple mental and physical demands of the task. Therefore, his study investigated the relationship between noise exposure and mood states at different levels of workload. The study recruited 50 workers from the manufacturing sector (blue-collar workers) as the exposed group and 50 workers from the office sector (white-collar workers) as the control group. Their occupational noise exposure was measured by dosimetry. The Stress-Arousal Checklist (SACL) and the NASA Task Load Index (NASA-TLX) were used to measure mood and workload, respectively. The equivalent noise exposure level of the exposed group at high and very high workload levels was 85 and 87 dBA, respectively. The mean mood score of the exposed group was 76 at very high workload. The correlation coefficient between noise exposure level and mood state based on workload levels ranged from 0.3 at medium workload to 0.57 at very high workload. Noise exposure at high workload levels can increase its adverse effects, so controlling and optimizing the multiple demands of the task in the workplace can be used as a privative measure to reduce the adverse effects of noise.

KEYWORDS

Noise stress; workload; noise sensitivity; mood; NASA-TLX; stress-arousal checklist (SACL)

1 Introduction

Noise is known as one of the main sources of mental stress [1]. Exposure to ambient noise can activate the central nervous system (CNS) and increase the response to environmental stressors [2]. In summary, it has been observed that noise exposure can cause hormonal changes in the body, including elevated levels of adrenaline, noradrenaline, and cortisol, which can lead to mood disorders and discomfort. Noise exposure also causes loss of concentration, loss of professional skills, and stress [3,4].

Stress-related mental disorders have become a prevalent health concern in recent years. It has been estimated that around 30% of the global population may experience mental illness at some stage in their lives [5]. This represents 32.4% of disability-related years and 13% of years lived with disability [5]. The results of studies show that chronic exposure to environmental noise leads to auditory and non-auditory health effects, which include hearing loss, cardiovascular diseases, adverse birth outcomes, sleep disorders, and cognitive dysfunction. While some studies have reported a direct correlation between noise exposure and chronic stress symptoms, others have not been able to confirm such a relationship. According to the studies, it has been found that noise annoyance plays an indirect role in the correlation between environmental noise and psychological stress [5].

Noise annoyance is a feeling of discomfort caused by an unwanted noise and its conditions that can affect people's health and because it affects a significant number of people, it can significantly increase the burden of disease caused by environmental noise exposure [6,7]. It has been suggested that noise exposure may act as a stressor, potentially leading to functional changes in an individual's cognitive and emotional behavior. Noise can trigger defensive responses that lead to the secretion of stress-related hormones in the hypothalamic-pituitary-adrenal (HPA) brain axis, which is primarily responsible for responding to non-auditory effects of noise [8,9].

Noise exposure is one of the main risk factors for brain and cognitive disorders [10–13] which can cause endocrine changes such as increased adrenaline, noradrenaline and cortisol that lead to mood disorders [14]. Mood is the emotional states of individuals that have far-reaching effects on mental health and executive functions (attention, concentration, judgment, and decision-making) [15].

It is important to note that high workload levels can lead to stress, which has been shown to have negative psychological effects. These effects include reduced ability to perceive environmental stimuli in the workplace, such as noise and lighting, as well as behavioral effects, such as increased operator error [16–18]. It has been observed that an excessive workload may have a negative impact on individuals' performance and perception of their environment. Workload optimization can also increase productivity and job satisfaction [19]. Workload affects people's perceptual capacity and concentration [20] so that people at different levels of workload react differently to environmental stimuli such as noise.

Hence, it is imperative to thoroughly examine the impact of noise on the mental well-being and emotional states of employees, taking into account the influence of noise exposure on cognitive function, as well as the demands of their workload. The objective of this study is to explore various non-auditory consequences of noise. This study seeks to examine the impact of varying degrees of noise exposure on the emotional well-being of employees in the tile industry. The study will concentrate on levels of workload.

2 Method

This study presents a descriptive-analytical investigation conducted in a tile industry. The sample size was determined, and dosimetry was used to measure noise exposure. Mood was assessed using a checklist. Furthermore, the study examined noise sensitivity, noise annoyance, and workload in both the exposure and control groups. The method for measuring each of these indicators is described below.

2.1 Participants

The sample size for the study was determined using Eq. (1), with a power of 80% and a confidence level of 95%.

$$n = \frac{Z_{\frac{\alpha}{2}}^{2}\,\delta^{2}}{d^{2}} \tag{1}$$

where $\alpha = 0.05$ (i.e., 95% confidence level) and $Z_{\frac{\alpha}{2}} = 1.96$ for two side tests; σ^2 represents the variance of continuous outcome (σ is the standard deviation (SD)) and d is marginal error.

The study recruited male volunteers under the age of 50 with at least 6 months of work experience. Also people with cardiovascular diseases, diabetes, congenital hearing impairment and any use of antidepressant drugs were excluded from the study [14], at the conclusion of the study, 50 workers were chosen for the exposed group and 50 workers were chosen for the control group (refer to Eq. (1)) [21,22]. The participants were included in the study after giving their informed consent. This study was approved by the ethics committee of Shahid Sadoughi University of Medical Sciences (code: IR.SSU.SRH.REC.1400.006).

2.2 Noise Exposure Measurement

The workplace noise was measured using a calibrated dosimeter (TES 1354; Taiwan). Individuals who were exposed to noise levels exceeding the allowable limit of 85 dBA for 8 h of work, as defined by the American Conference of Governmental Industrial Hygienists (ACGIH), were identified in various parts of the industry. According to the recommendation of ISO 9612 standard [23], the microphone of the dosimeter device was installed at a distance of 10–30 cm from the external ear canal of the people on their collars [24]. Eight-hour equivalent sound pressure level (Leq_{8h}) was calculated using the Eq. (2):

$$leq_{8h} = 10Log\left(\frac{\text{Noise Dose} \times (\text{Daily working time scale})}{100 \times \ Exposure\ time}\right) + \text{Permissible noise pressure level} \tag{2}$$

Noise dose: the measured noise (%)

Exposure time: 8 h

Daily working time scale: 8 h

Permissible noise pressure level: 85 dBA

2.3 Mood Measurement

The Stress-Arousal Checklist (SACL) was used to assess mood states, which contains 30 items to describe a person's psychological experience of stress. This checklist describes the mood originally created by Cox et al. [25]. The SACL has two subscales, stress and arousal. The stress subscale uses 18 mood-related traits and the arousal subscale consists of 12 items. The sum of negative and positive traits in the stress subscale represents a score from 0 to 18, and the arousal score is from 0 to 12. The stress subscale is related to happiness and pleasure and the arousal subscale is related to activity and alertness. Higher scores indicate higher levels of these two subscales. Respondents must choose the best answer that describes their feelings at a given time. They can rate that particular attribute between a negative one (−) and a positive two (++). So if the adjective exactly describes their feelings, they choose the ++ mode, if the adjective partly describes their feelings, they choose the + mode, and if the adjective does not describe their feelings at all, they choose the − mode. For unintelligible words or situations where they cannot decide, they choose the mode (?). In this checklist, for positive attributes (++) and (+) a score of one, (?) and (−) are considered as zero, and for negative attributes the scoring method is the opposite, i.e., for (++) and (+) a score of zero and (?) and (−) are considered as one.

2.4 Measurement of Noise Sensitivity and Noise Annoyance

The noise Sensitivity Questionnaire was used to identify situations experienced by individuals throughout the day, such as fatigue, lethargy, drowsiness, reduced concentration, dizziness, headaches, discomfort, and other issues. The questions were scored on a scale ranging from never (1 point) to always

(5 points), with rarely (2 points) and sometimes (3 points). The level of noise annoyance was evaluated through the scale outlined in ISO 15666 [23]. The validity and reliability of this scale have been confirmed by researchers, with a Cronbach's alpha value of 0.81. The scale employs a Likert scale that ranges from 0 to 10 to measure the level of noise annoyance experienced by individuals in their work environment. The highest score indicates the highest level of noise annoyance a person experiences in their work environment [26,27]. Respondents were requested to provide their rating of workplace noise annoyance over the previous 12 months using a numerical scale.

2.5 Workload Measurement

Workload assessment methods that are considered subjective are often used due to their ease of use and high sensitivity to workload variables. It is important to note that subjective evaluations should be clearly marked as such to maintain objectivity. In fact, these methods help the operator to assess the level of effort and productivity [28]. The NASA Task Load Index (NASA-TLX) is a well-established method for evaluating workload, comprising six subscales: The NASA Task Load Index (NASA-TLX) is a well-established method for evaluating workload, comprising six subscales: This index is frequently employed in both academic and industrial settings to provide an impartial assessment of workload. Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, Frustration [28,29]. This index has been developed by Hart & Staveland (1988) [30]. A comparison of the results of different workload measurement methods shows that the NASA-TLX method has the advantage of covering all dimensions of workload [31]. The NASA-TLX questionnaire produces a score between 0 and 100. According to the classification by Hart & Staveland (1988), scores between 0–25 indicate low workload, scores between 26–50 indicate medium workload, scores between 51–75 indicate high workload, and scores between 76–100 indicate very high workload [30]. The mental demand subscale assesses the level of cognitive and sensory activity necessary to carry out the work. The physical demand subscale evaluates the extent of physical activity required to fulfil the job. The temporal demand subscale gauges the time pressure arising from the pace of events in each task. The performance subscale invites the individual to assess their achievement in meeting the task objectives. The effort scale measures the amount of mental or physical effort required to achieve a desired level of performance. The frustration subscale assesses a person's feelings about themselves and their performance [30].

2.6 Statistical Analysis

The normality of the data and demographic variables matching between the two groups was assessed using the Shapiro statistical test. Mean differences of multivariate quantitative variables were evaluated using the ANOVA test, and qualitative variables were evaluated using the chi-square test. The differences between the mean parameters of noise sensitivity, noise pressure level, mood state, and workload of the exposed and control groups were compared using the *t*-test. Additionally, the correlation between quantitative variables was evaluated using a correlation test.

3 Results

The study found that the mean age of the exposed group was 34.48 (±6.73) years, while the control group had a mean age of 32.36 (±5.53) years. Additionally, the exposed group had a mean work experience of 5.58 (±4.18) years, compared to 5.76 (±2.23) years for the control group. It was also observed that 70% of the exposed group and 58% of the control group were married. Comparison of demographic variables between the two groups indicates no statistically significant differences in work experience, marital status, education level, and age ($p > 0.05$) (refer to Table 1).

Table 1: Demographic variables in exposure group and control group

Variable	Range	Exposed group		Control group		*p*-value*
		N	%	N	%	
Age (year)	21–26	8	16	13	26	0.072
	27–33	24	48	28	56	
	33–40	18	36	9	18	
Work experience (year)	1–3	9	18	13	26	0.724
	3–5	25	50	20	40	
	5–7	16	32	17	34	
Married status	Single	15	30	21	42	0.214
	Married	35	70	29	58	
Education	Illiterate/Elementary	18	36	10	20	0.064
	Pre-high school	16	32	21	42	
	Diploma	16	32	10	20	
	Bachelor	0	0	9	18	

Note: *Difference between the mean of the variables between the two groups of exposure and control.

The study shows that the eight-hour equivalent sound pressure level was 86 (4.49) dBA and 59 (3.02) dBA for the exposed and control groups, respectively. Table 2 presents the results of assessing noise sensitivity, noise annoyance, workload, and mood states (two subscales of stress and arousal). It was observed that the scores of these variables in the exposed group were significantly higher than those in the control group (p-value < 0.05).

Table 2: Mean (SD) variables in control and exposed groups

Variable		Exposed group (n = 50)	Control group (n = 50)	*p*-value
Noise sensitivity		33.98 (3.32)	27.24 (2.36)	0.001
Noise annoyance		7.64 (1.65)	2 (0.90)	0.001
Workload		57.53 (12.75)	35.17 (6.97)	0.001
Mood	Arousal	4.54 (1.69)	7.58 (1.38)	0.001
	Stress	4.14 (2.26)	7.70 (1.98)	0.001

The study found that the mean total score of NASA-TLX was 57.53 in the exposed group and 35.17 in the control group.

Table 3 presents the scores for the six dimensions of the NASA TLX in the entire study population and in the two groups of exposed and control separately. The results suggest that the workload in the exposed group is significantly higher than in the control group ($p < 0.05$) when comparing the difference between the mean of the six dimensions of workload between the two groups. The noise-exposed group experienced higher physical and mental demands, as well as temporal demands, compared to the control group.

Table 3: Workload scores mean (SD) in both exposure and control groups

Workload	Exposed group (n = 50)	Control group (n = 50)	*p*-value
Mental demand	59.50 (13.96)	36.50 (9.96)	0.001
Physical demand	58.70 (13)	34.60 (8.68)	0.001
Temporal demand	58.10 (14.63)	34.30 (7.35)	0.001
Performance	55.80 (12.38)	35.40 (8.68)	0.001
Effort	56.40 (14.25)	36 (9.36)	0.001
Frustration	55 (14.60)	35.70 (8.08)	0.001

Table 4 presents the mean variables for noise exposure level, mood, noise sensitivity, and noise annoyance in the four workload categories. It is worth noting that the low workload level was not present in the exposed group, and the high and very high workload levels were not present in the control group; therefore, they are not mentioned in Table 4. Additionally, the mean of all the mentioned variables is higher in the exposed group than in the control group ($p < 0.05$).

Table 4: Mean (SD) of variables at different levels of workload

Group	Workload levels	Noise sensitivity	Noise annoyance	Noise exposure level (dBA)	Stress	Arousal
Exposure	Low	–	–	–	–	–
	Medium	34.2 (3.18)	7.93 (1.27)	87.13 (3.70)	3.80 (2.07)	4.47 (1.50)
	High	33.51 (3.43)	7.51 (1.86)	85.86 (4.79)	4.45 (2.41)	4.69 (1.69)
	Very high	35.66 (3.01)	7.50 (1.51)	87.50 (5.12)	3.50 (2.07)	4 (2.28)
	p-value*	0.346	0.721	0.567	0.518	0.658
Control	Low	26.83 (1.94)	1.66 (0.81)	58.33 (3.20)	14.83 (1.47)	7.67 (2.42)
	Medium	27.29 (2.43)	2.04 (0.91)	59.38 (3.02)	13.55 (2)	7.57 (1.22)
	High	–	–	–	–	–
	Very high	–	–	–	–	–
	p-value**	0.569	0.341	0.430	0.137	0.872
p-value***		0.001	0.001	0.001	0.001	0.001

Note: *Mean difference of variables between different levels of workload in the exposed group. **Mean difference of variables between different levels of workload in the control group. ***Mean difference of variables between exposed and control groups.

Table 5 displays the Pearson correlation coefficient between the variables under study based on workload levels. The coefficients and significant values suggest that the relationship between the variables is stronger at high levels of workload compared to lower levels. It can be inferred that very high workloads may amplify the effect of the studied variables on each other.

Table 5: Correlation between variables according workload levels in the exposed group

Variable	Workload levels	Coefficients	Noise exposure level	Noise sensitivity	Noise annoyance	Stress	Arousal
Noise exposure level	Low	Pearson coefficient (r)	–	–	–	–	–
		p-value					
	Medium	R	–	0.349	−0.496	0.301	−0.063
		p-value		0.203	0.060	0.276	0.823
	High	R	–	−0.132	−0.368	−0.50	−0.168
		p-value		0.495	0.050	0.797	0.383
	Very high	R	–	−0.376	0.013	−0.536	0.479
		p-value		0.463	0.981	0.273	0.337
Noise sensitivity	Low	R	–	–	–	–	–
		p-value					
	Medium	R	0.349	–	−0.224	0.047	0.128
		p-value	0.203		0.422	0.867	0.650
	High	R	−0.133	–	−0.060	0.113	0.29
		p-value	0.495		0.757	0.559	0.883
	Very high	R	−0.367	–	0.569	0.384	0.524
		p-value	0.463		0.238	0.452	0.286
Noise annoyance	Low	R	–	–	–	–	–
		p-value					
	Medium	R	−0.496	−0.224	–	0.156	0.351
		p-value	0.060	0.422		0.579	0.200
	High	R	−0.368	−0.060	–	0.604	0.578
		p-value	0.050	0.757		0.204	0.229
	Very high	R	0.013	0.569	–	0.604	0.578
		p-value	0.981	0.238		0.204	0.229
Stress	Low	R	–	–	–	–	–
		p-value					
	Medium	R	0.301	−0.047	0.156	–	0.101
		p-value	0.276	0.867	0.579		0.722
	High	R	0.050	0.113	0.045	–	0.411
		p-value	0.797	0.559	0.815		0.027
	Very high	R	0.536	0.384	0.604	–	0.042
		p-value	0.273	0.452	0.204		0.229

(Continued)

Table 5 (continued)

Variable	Workload levels	Coefficients	Noise exposure level	Noise sensitivity	Noise annoyance	Stress	Arousal
Arousal	Low	R	–	–	–	–	–
		p-value					
	Medium	R	−0.063	0.128	0.351	0.101	–
		p-value	0.823	0.650	0.200	0.722	
	High	R	−0.168	0.029	0.064	0.411	–
		p-value	0.383	0.883	0.741	0.027	
	Very high	R	0.479	0.524	0.578	0.042	–
		p-value	0.337	0.286	0.229	0.937	

4 Discussion

The aim of this study was to investigate the relationship between noise exposure and mood states in workers at different levels of workload. The study suggests that there is a positive and significant correlation between workload levels and average noise exposure, indicating that as noise levels increase, workload also increases. Specifically, the mean noise exposure was 58.33 dBA in low workload, 66.44 dBA in medium workload, and 85.86 dBA in high workload. The study found a positive and significant correlation coefficient ($r = 0.664$) between noise exposure level and workload level. Previous research has demonstrated a direct relationship between noise exposure in the workplace and workload, with increased workload exacerbating the adverse cognitive effects of noise exposure [32,33].

Noise sensitivity is considered as a predictor of adverse effects of noise in individuals that is an internal state (related to physiology, psychology, or lifestyle or daily activities) that increases a person's response to noise [34]. Differences in noise sensitivity between people result in different levels of noise annoyance. Jordan et al. stated that individual differences in physiological response to noise as a function of noise sensitivity [35].

Noise sensitivity predicts the reactions of people exposed to different noise levels and is one of the factors that exacerbate the adverse health effects of noise. In fact, people who are less sensitive to noise experience less discomfort and annoyance than people with high noise sensitivity, and also have better concentration and accuracy at work [2,33]. In addition, noise sensitivity predicts adverse effects of noise exposure, such as level of annoyance, quality of life, and cognitive and mental functioning [33].

The results suggest a positive correlation (p-value < 0.05) between noise sensitivity and workload levels. In the exposed group, the mean score of noise sensitivity at medium, high, and very high workload levels were 34.2, 33.51, and 35.66, respectively. This indicates that increasing workload is associated with increased noise sensitivity, and consequently, individuals with higher workload levels may be at a greater risk of experiencing noise annoyance ($r = 0.555$). As per Sjodin review, it has been observed that high workload levels can worsen the negative cognitive effects of noise exposure. A review by Sjodin shows that more noise sensitivity intensifies its effects so that people who are more concerned about noise exposure and more sensitive are more prone to injury [36]. This is in line with the findings of a study by Crichton et al. that more noise sensitivity causes more noise annoyance [37]. Noise increases the number of error in performing tasks and can impair cognitive function [38]. The study conducted by Tseng et al. investigated the impact of various levels and types of noise exposure on operating room nurses [39].

According to the results, sound pressure level is a significant factor that affects the workload, awareness, and concentration of nurses. The study recommends keeping the noise level in the operating room below 60 decibels. They recommends that using low-pitch music in the operating room can improve occupational health and improve performance [39].

Excessive workload increases fatigue [40] and causes negative emotions such as anger and stress [41]. People's emotional states, called moods, have far-reaching effects on mental health and executive functions [15]. The assessment of mood scores involves two variables: stress and arousal. It was observed that there is a positive and significant relationship between workload and mood states, as indicated by the mean score of mood states across four levels of workload. Specifically, the mean scores of mood states were 69.17, 70.51, 79.48 and 76.83 at low, medium, high and very high levels of workload, respectively. It is worth noting that an increase in workload may lead to an increase in negative moods experienced during work. The correlation coefficient of 0.415 suggests a positive relationship between mood and workload levels.

The analysis of the relationship between the mean score of mood states and demographic variables suggests that age, marital status, education level, and work experience do not have a significant impact on moods. However, it is worth noting that there is a positive and direct correlation coefficient of 0.488 between noise sensitivity and mood at different levels of workload. The significant relationship between noise sensitivity and mood indicates that noise sensitivity acts as a predisposing factor in the occurrence of adverse mood conditions in noise exposure [33]. The study results suggest that there is a correlation between noise level and mood states, as well as between noise level and noise sensitivity at different levels of workload. It is worth noting that this relationship appears to increase with increasing workload. Psychological injuries caused by noise exposure include physiological stress responses, adverse social consequences, sleep disturbance as well as economic losses [41,42].

The analysis suggests a positive and significant relationship between the NASA workload score and noise exposure levels, regardless of the type of exposure. It is possible to use the workload score to predict the group with the highest level of exposure. The correlation test results suggest a positive and significant relationship between the NASA score and noise level (correlation coefficient = 0.629, p-value < 0.05). According to the data, there appears to be a correlation between higher levels of workload and increased noise annoyance. This suggests that noise may have an impact on individuals' ability to manage an increased workload. The stress caused by high workload is an important issue and the results of studies show that the psychological effects of workload such as the effect on the ability to perceive environmental stimuli in the workplace (noise, lighting) as well as effects like increasing the operator error [16–18,43]. The result of the study by Tseng et al. in 2023 was that music at a level of 55 to 60 dB caused less mental tension and anxiety in nurses than those exposed to a level of 75 to 80 dB [44]. Monazzam et al. found that for every decibel increase in noise exposure, there was a 0.32 increase in mental disorder and a 0.157 decrease in the work ability index [45].

Examination of the relationship between study variables at different levels of workload in the exposed group (Table 5) reveals that the level of noise exposure has the strongest correlation with mood states, specifically stress and arousal, particularly at a very high level of workload. The correlation coefficients suggest that exposure to high noise levels may have a stimulating effect on human mood, as there is a positive correlation between noise level and both stress (0.563) and arousal (0.479).

The analysis of the correlation between noise sensitivity and the studied variables at a high workload level indicates that the strongest correlation is between noise sensitivity and noise annoyance (0.569), arousal (0.534), and stress (0.384), respectively. It is observed that the effect of the variables on each other increases with an increase in workload. The correlation between noise annoyance and stress (0.604) and arousal (0.578) suggests that noise annoyance, as an adverse effect of noise exposure, is closely associated with the emotional state of those exposed. According to Jafari et al., it was found that noise exposure at a level of 95 dBA had a significant impact on the participants' mental workload and visual/auditory attention [32].

The study's limitations include the exclusion of women and the lack of consideration for other environmental factors, such as lighting. It is recommended that future studies investigate the personality types of participants, frequency of noise exposure, and include a larger sample size of both men and women.

5 Conclusions

It has been observed that prolonged noise exposure in the workplace can lead to increased stress levels, irritability, and noise annoyance, which in turn can affect the perception of environmental stimuli. The study results suggest that individuals in the exposed group tend to feel more tired, lethargic, and sleepy during their working hours. This is a matter of concern as it can pose a serious safety risk in the workplace. It is important to acknowledge the negative impact of noise on people's health and take necessary measures to address the issue. Given the significant role of industry in any country's economy and the large number of workers employed in this sector, it is important to acknowledge that exposure to workplace noise can result in worker incapacity and disability, reduced productivity and production, and ultimately, decreased service quality, customer dissatisfaction, and economic losses. Therefore, it is important to address the adverse effects of noise exposure in the workplace. Hence, it is of utmost importance to thoroughly examine and assess the impact of noise exposure on both physical and psychological well-being.

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Availability of Data and Materials: Data and Materials is made available upon reasonable request.

Ethics Approval: This study is related to Project 11163 from of Industrial Diseases Research Center, Center of Excellence for Occupational Medicine, Shahid Sadoughi University of Medical Sciences in Yazd, Iran. This study has been approved by the IR.SSU.SRH.REC.1400.006 code of ethics and has the informed consent: The participants were included in the study after giving their informed consent.

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