The rate of the occupational noise-induced mental workload at medium levels

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ABSTRACT

Occupational noise exposure is associated with several psychological adverse effects and impairs recuperation. The aim of this study was to investigate the effects of the five noise conditions: quiet condition (QC), closed offices (CO), open plan office (OPO), control rooms (CR), and industrial noise (IN)) on mental workload. The noise levels were fixed at 54±0.3 dB(A) (QC), 64±0.4 dB(A) (CO), 68±0.8 dB(A) (OPO), 73±0.3 dB(A) (CR) and 80±0.1 dB(A) (IN). A total of 31 normal hearing male subjects were recruited. They were asked to judge the noise annoyance (NA) and noise-induced mental workload (NIMWL) using NASA-TLX software at the end of each condition. The results were evaluated in the view of impact of noise and moderating factors using linear models and a dose-response relationship was found for each response. The overall average of the NA rating was 9%, 28.9%, 34.3%, 35.7%, and 40.4%, and also the NIMWL rating was 31.7%, 39.5%, 50.3%, 56.9%, and 64.4% in the QC, CO, OPO, CR, and IN, respectively. The medium levels of occupational noise, besides annoyance, can significantly affect the MWL.

Keywords: Mental workload, Medium levels, Dose–response relationship, Occupational noise

INTRODUCTION

Noise has been found as a non-specific biological stressor that dominantly influences the processing mechanisms of the brain and mental health. Excessive exposure to occupational noise at levels ≥ 85 dB(A) lead to hearing impairment, sleep disturbance, cardiovascular effects,

and other physiological responses than individuals not exposed to noise. Beside, noise is associated with several psychological adverse effects, and these effects have been addressed somewhat in laboratory and empirical studies. The annoyance, mental workload, and fatigue are most important occupational noise-induced perceptual and mental effects that people subjectively experience them. Moreover, disorder in cognitive function and memory, effects on behavior, drowsiness, depression, and reduced performance are other indirect psychological effects of noise. The mechanism of noise-induced mental effects is not known, but it has been theorized that exposure to noise activates the central nervous system.

Noise-induced annoyance is a feeling of displeasure or dissatisfaction evoked due to noise exposure. Previous studies have highlighted that noise-induced annoyance is strongly related to age and noise sensitivity. On the other hand, noise annoyance may play a role in the relationship between noise exposure and other noise-induced health effects. Mental workload (MWL) is the analysis of interactional effects between the operator's capacity and occupational demands. MWL is basically related to an individual's mental capacity. Noise-induced mental workload (NIMWL) define as the extra expenses imposed on the operator due to noise (regardless of duty's demands) to achieve a certain level of performance. Fatigue is a subjective feeling of tiredness. Noise-induced subjective fatigue is inability to maintain optimal cognitive performance and feelings of tiredness by noise exposure.

It should be noted that these effects can be seen at exposure levels below those recognized as causing hearing impairment and imposed by occupational regulations. The sound pressure level has been identified as a crucial factor affecting these effects. Type of noise and duration of exposure to noise also determine the harmful effects of noise. Moreover, many individual variables such as age, gender, health status, individual susceptibility, tobacco and alcohol use, anxiety, stress, and personality traits influence these outcomes. Since individuals differ greatly in how they perceive and react to noise, it is relevant to ask what role such individual differences play for the relationship between noise exposure and adverse health effects. Besides, by identifying the role of personality and individual traits in noise-induced psychological effects, can be correctly recruit personnel and fit the job to the human in the occupations involved cognitive functions. However, changes in any of the individual variables such as age, health, sensitivity, anxiety, and personality traits (extroversion, openness, and neuroticism) may lead to alterations in any of the reported complications. Therefore, the aim of this study was to determine the role of individual (age, general health, body mass index, anxiety, and noise sensitivity) and personality traits (extroversion, openness, and neuroticism) in occupational noise-induced perceptual and psychological effects such as annoyance, mental work load, and fatigue.

2. Methods

2.1. Participants

The participants were 31 male students by 30.19±6.6 years old (range 25-43 years old) and a body mass index (BMI) of 24.14±3.50. The eligibility criteria for the inclusion of participants were: normal hearing, nonsmoking, non-alcohol and non-drugs, enough and good quality sleep, no previous exposure to occupational noise. The hearing health of participants (mean HL with

at least 20 dB in the frequency range of 125–8 kHz) was determined using a calibrated audiometer by an audiologist. All participants had slept at least 7 h in the night before each session. They were also free from smoking, alcohol, and drugs. All subjects reported that they had not experienced an exposure to noise in the workplaces or issues with noise in their current dwelling. All participants signed a consent form. The study was approved by the Medical Ethics Board at the Hamadan University of Medical Science, Hamadan, Iran.

2.2. Assessment of Mental work load

Mental workload (MWL) perceived by the participants during tests was evaluated using the NASA-TLX software at the end of each session of noise condition [28]. It is a subjective and the retrospective judgment of the mental load they experienced during the experiment. MWL includes six subjective subscales: Mental and Temporal demands of the task, Performance, Effort, Loudness, and Annoyance under noise conditions. Each question is answered on a 21-point scale. Subscale value and rank importance are weighted and summed up to get an MWL value (Table 1).

Table 1. Rating scale of NASA TLX: Task Load Index for noise-induced mental workload

Title	Endpoints	Descriptions
Mental Demand	Low/High	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering ,looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Loudness	Low/High	How was the subjective perception of noise pressure? (slow or brisk, slack or strenuous, restful or laborious)?
Temporal Demand	Low/High	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Effort	Low/High	How hard did you have to work mentally to accomplish your level of performance?
Performance	Good/Poor	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself?(How satisfied were you with your performance in accomplishing these goals?
Annoyance	Low/High	How irritated, stressed and annoyed versus secure, relaxed and complacent did you feel during the task?

2.3. Study procedure

The study was an experimental study. The experiments were designed in five noise conditions: (1) quiet conditions (QC), (2) closed offices (CO), (3) open plan offices (OPO), (3) control rooms (CR), and (4) industrial workplaces (IW). The sessions were random in 5 consecutive days during the morning, so that each session lasted for 1h. To design noise situations with realistic working conditions, all the experimental sessions were carried out in an air-conditioned room (dimensions: 3.4 × 5.6 × 3.05 m, temperature: 22ºC, relative humidity: 50%, and light intensity: 400 lx) in the research laboratory of the Hamadan University of Medical Sciences. At first, a training session about the experiments was held to become familiar participants. The LAeq,1h were presented via a spherical loudspeaker (12 matched loudspeakers in a dodecahedral configuration) (OS003-BSWA Technology Co) located in the center of the room and behind of the listener (at a height of 1.1 and distance of 1m from the listener). Throughout exposure to noise, LAeq values were monitored using a calibrated SVAN 104 dosimeter, which was attached

to the participant's collar. At all sessions, the subjects were asked to do cognitive tests during one-hour exposure to noise was presented.

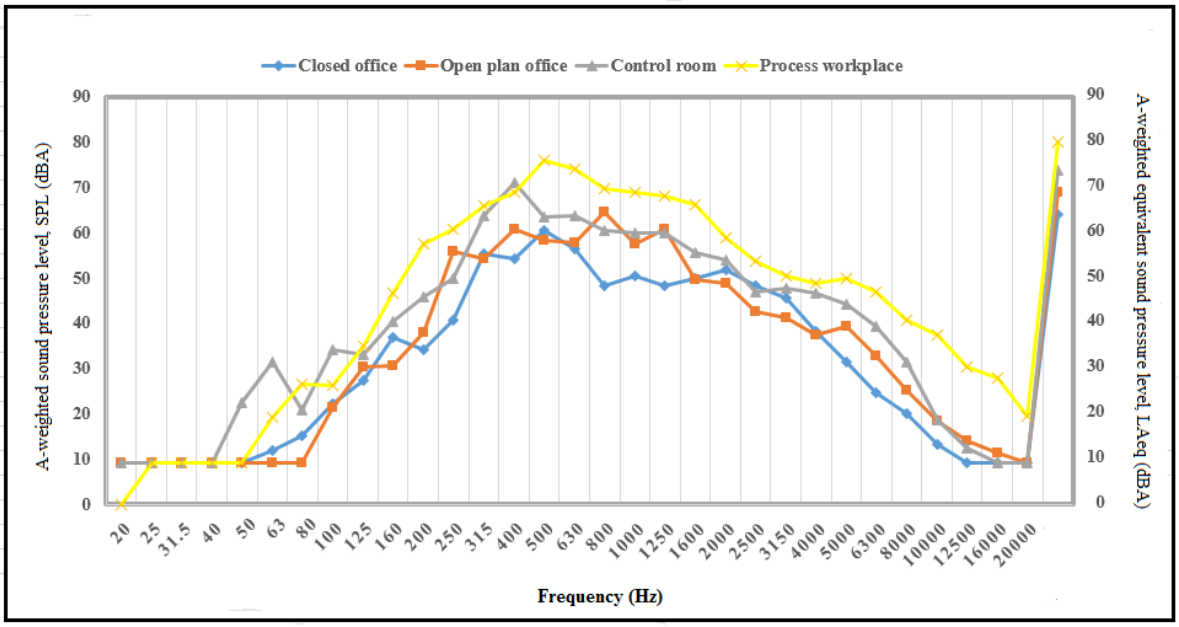
2.5. Data analysis

Descriptive analysis was performed based on mean±SD for quantitative variables. Normality was tested using the nonparametric Kolmogorov–Smirnov test. When the variables did not exhibit normal distribution, the nonparametric Friedman's test was applied to evaluate performance parameters and compare the pairwise means. A 3-level linear mixed-effects model (3-LMM) were developed to determine the role of individual (age, general health, noise sensitivity, anxiety, and body mass index) and personality traits (Neuroticism, Extraversion, and Openness) in three occupational noise-induced perceptual and psychological effects. In this study, p values less than 0.05 were considered statistically significant. Computations were performed using R version 3.4.1 [29], and SPSS 24.

3. Results

The characteristics of four conditions of occupational noise was presented in Figure 3. It shows the time (1h), the noise level, and the dominant frequency for each noise condition separately. The noise levels were ranged from 60 to 80 dB(A) with similar dominant frequency characteristics at 500-1000Hz. The mean±SD LAeq values in five noise conditions were: (1) QC: 54±0.6 dB(A), (2) CO: 64±0.4 dB(A); (3) OPO: 68±0.8dB(A) (4) CR: 73±0.3dB(A); (5) IW: 80±0.1dB(A).

Fig 3. The characteristics of four conditions of occupational noise



The average of GHQ score of subjects was 15.77±4.83. The average of NS score of subjects was 57.16±11.08. The average anxiety score of subjects was 14.71±2.33. The average of Neuroticism, Extraversion, and Openness score of subjects were 54.6±10.42, 52.87±8.53, and 47.52±9.10, respectively.

Descriptive statistics of the mental workload during exposure to five noise conditions are shown in Table 2. The results showed that the Mental and Temporal demands and also Effort were higher in the conditions OPO and CR. The performance score was lowest for OPO and CR conditions. Participants also experienced higher subjective annoyance and loudness in noise conditions with higher levels. The overall average of the six dimensions of the NASA- TLX software shows the perceived MWL required by the tasks in terms of noise exposure. The overall average of the six dimensions was higher in noise conditions with more level. There was a significant difference between MWL in five in noise conditions.

Table 2. Descriptive statistics of mental workload during exposure to five noise conditions

parameters	QC		CO		OPO		CR		IW		P value
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Mental demand	27.12	26.50	55.15	22.44	74.07	29.50	73.43	21.70	67.12	26.50	0.061
Temporal demand	21.28	27.97	36.00	19.26	49.36	17.42	43.90	22.60	35.80	24.66	0.118
Performance	50.80	24.66	44.50	20.31	30.81	17.30	36.50	27.60	44.00	22.63	0.243
Effort	52.80	25.27	62.30	23.84	75.90	20.58	78.30	20.40	72.80	25.27	0.265
Loudness	16.00	22.63	29.34	18.57	31.10	24.70	36.90	23.40	41.28	27.97	**0.032**
Annoyance	27.50	28.60	38.40	12.72	50.00	14.33	52.04	28.60	58.50	28.60	**0.002**
Overall (MWL)	31.71	10.11	39.57	10.25	50.37	14.33	56.91	16.40	64.46	15.28	**0.001**

Noise conditions: QC: Quiet conditions, CO: closed office, OPO: open-plan office, CR: control room, IW: industrial workplace, MWL: mental workload

The noise-induced mental load rating in three level of Noise Sensitivity (NS) and Neuroticism (N), Extraversion (E), and Openness (O) based on GEE model has been shown in Figure. 2.

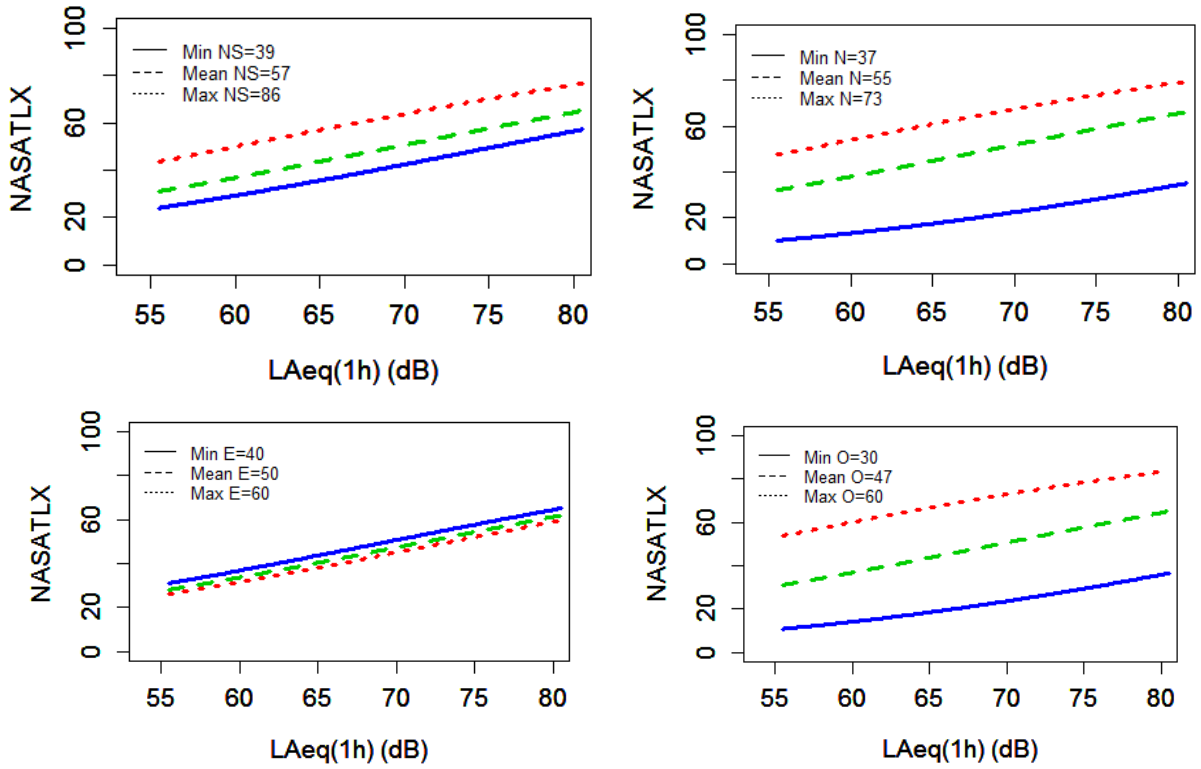


Fig. 2. Noise-induced mental load rating in three levels of min, mean, and max of Noise Sensitivity (NS) and Neuroticism (N), Extraversion (E), and Openness (O) based on GEE model

4. Discussion

The current study intended to provide new data about the role of individual and personality traits in noise-induced perceptual and psychological effects of the four types of working setting involved in cognitive function despite occupational differences. In general, the level of occupational noise-induced perceptual and psychological effects generally accelerate with the increase in the sound pressure level. However, the results of this study indicated that several individual and personality variables can be mediated or moderated the level of these effects. The results indicated that ratings of the noise-induced annoyance were highly correlated with the noise level and the age, health status, noise sensitivity, and neuroticism contributes to explaining the variance of its rating. That way, the neurotic individuals and sensitive to noise felt more noise-induced annoyance, than those who were not. Many studies have evaluated the role of noise sensitivity in noise-induced annoyance (). In a laboratory study, Park et al. reported that high noise sensitivity indicative a higher annoyance rating (). In another laboratory study on 169 students (80 females and 89 male), Beheshti et al. (2019) reported that noise-induced annoyance among neurotic individuals was more than non-neurotic ones (). Also, individuals who have poor health felt more noise-induced annoyance, than those who are in better health status. The results also showed that as age increases, the level of noise-induced annoyance increases.

The finding of the study also showed that there was a significant difference between noise-induced subjective fatigue and two traits of noise sensitivity and neuroticism. In another word, noise-induced subjective fatigue exacerbates in the individuals of neurotic and sensitivity to

noise. Moreover, there was a certain degree of MWL during exposure to five noise conditions, that is noise can be a crucial factor affecting MWL in the workplace.

The noise-induced mental workload was mainly due to three sub-scales of mental demand, annoyance, and loudness in the NASA-TLX scale. As the findings from the present study suggest, in addition to the noise level, the personality traits play a major role in causing noise-induced mental workload. Based on the results of this study, for the occupational noise to the level of less than 80 dB, at speech frequencies, neurotic individuals felt more mental load than non-neurotic ones. Moreover, they were the extrovert individuals who experienced greater mental load due to the noise stimuli. Studies that have examined the impact of personality traits on the levels of the mental load caused by noise exposure are relatively scarce. Hill et al. showed that noise sensitivity has been associated with health problems, such as anxiety and depression (). Openness and noise sensitivity traits also have a decisive role at the noise-induced mental load. This may be because of individual feelings/emotionality of sub-scale loudness and mental demand.

Prospective studies have shown that neuroticism is linked to health problems and increased noise-induced physiological responses such as cardiovascular disease. Moreover, most of the studies have indicated that noise sensitivity and neuroticism modify noise-induced health problems (). Park et al. reported that noise sensitivity significantly affects physiological responses such as heart rate, electro dermal activity, and respiratory rate ().

During this research, there were some limitations that should be mentioned. The results were limited to the conditions of this experiment. Other limitation was that the participants were all male and the female was not studied. Additionally, the experiments were limited to the analysis of the influence of noise levels 55- 80 dB, at speech frequency (500-1000Hz) that are suggested to be studied all the hearing frequency spectrum in future studies. It should also be noted that in realistic working conditions, there are other harmful physical agents such as heat and vibration that may also contribute to the development of various types of mental effects and should be considered.

5. Conclusion

The study achieved important insights about the role of individual and personality traits in occupational noise-induced perceptual and psychological effects. The results revealed that the perceptual and psychological effects were affected by personality traits. It seems that neuroticism, extraversion, and noise sensitivity are strong predictors of noise-induced perceptual and mental effects and they modify the mental load. Therefore, in selecting suitable individuals for occupations and sensitive job tasks requiring cognitive functions such as precision and reaction time, besides physical health, personality traits including noise sensitivity, neuroticism, extraversion, openness, should be taken into consideration.

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