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The Effect of Noise Exposure on Cognitive Performance and Brain Activity Patterns

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Keywords: Noise; Cognitive Performance; Attention; Brain Activity; Electroencephalogram

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Abstract

BACKGROUND: It seems qualitative measurements of subjective reactions are not appropriate indicators to assess the effect of noise on cognitive performance.

AIM: In this study, quantitative and combined indicators were applied to study the effect of noise on cognitive performance.

MATERIAL AND METHODS: A total of 54 young subjects were included in this experimental study. The participants' mental workload and attention were evaluated under different levels of noise exposure including, background noise, 75, 85 and 95 dBA noise levels. The study subject's EEG signals were recorded for 10 minutes while they were performing the IVA test. The EEG signals were used to estimate the relative power of their brain frequency bands.

RESULTS: Results revealed that mental workload and visual/auditory attention is significantly reduced when the participants are exposed to noise at 95 dBA level ($P < 0.05$). Results also showed that with the rise in noise levels, the relative power of the Alpha band increases while the relative power of the Beta band decreases as compared to background noise. The most prominent change in the relative power of the Alpha and Beta bands occurs in the occipital and frontal regions of the brain respectively.

CONCLUSION: The application of new indicators, including brain signal analysis and power spectral density analysis, is strongly recommended in the assessment of cognitive performance during noise exposure. Further studies are suggested regarding the effects of other psychoacoustic parameters such as tonality, noise pitch (treble or bass) at extended exposure levels.

Introduction

The influence of noise on human cognitive performance and brain activity has been often neglected [1]. Noise has different negative effects ranging from interference with cognitive processing to damaging mental and physical health [2]. The non-auditory effects of noise exposure include perceived disturbance, annoyance, cognitive impairment, cardiovascular disorders and sleep disturbance [1]. Noise exposure is a problem in many occupational and non-occupational environments. It is estimated that 22 million workers in the United States are exposed to hazardous noise [3]. It is also reported that 100 million people are exposed to dangerous environmental noise due to traffic, personal listening devices and other sources [4]. The World Health Organization (WHO) estimates that at least 1 million healthy life-years (disability-adjusted life-years) are lost annually as a result of environmental noise in high income western European nations (with a population of around 340 million) [1]. In any vital industry, optimising human performance is a key factor in accident prevention. Noise is one aspect of the work environment that affects workplace safety. Workers in vital occupational roles require high levels of cognitive skill and they need to maintain effective performance while exposed to higher levels of noise than Threshold Limit Values (TLV). Studies show that noise causes cognitive impairment and oxidative stress in the brain [5]. According to Wang et al., with further urbanisation and industrialisation, noise pollution has become a risk factor for depression, cognitive impairment and neurodegenerative disorders [5]. It has been observed that exposure to noise influences the central nervous system leading to emotional stress, anxiety, cognitive and memory defects [6]. Previous studies have suggested that the Limbic system in the brain is involved in emotional activities, The Amygdala and the Hippocampus are two of the main parts within the Limbic system that receives sensory information directly and indirectly from the central auditory system. Auditory stimulation itself can directly or indirectly affect these areas.

The active process of cognitive selection is called "attention" [7]. Attention plays a significant role in daily activities such as physical movements, emotional responses and perceptual and cognitive functions. When quantifiable information processing is limited, the attention system directs human behaviour based on geographic and temporal characteristics. Noise can affect performance either by impairing information processing or causing changes in strategic responses. In particular, noise increases the level of general alertness or activation and attention. Noise can also reduce performance accuracy and working memory performance, but does not seem to affect performance speed. The scope of cognitive and mental function is diverse, encompassing reaction time, attention, memory, intelligence and concentration, to name a few. Altered cognitive function leads to human error and subsequently increases accidents. This can ultimately lead to reduced performance and productivity. Some studies have shown that noise, improves performance, especially in sleep-deprived workers, mainly due to increased arousal. Certain individuals may be sensitive to noise even when it is lower than TLV. Sensitivity to noise which is referred to as environmental intolerance influence attention and recognition. There are conflicting reports regarding the effect of noise on cognitive performance in the relevant literature. The review study by Gawron regarding the effects of noise on cognitive performance revealed that among 58 studies, 29 reported a negative effect, 7 reported a positive effect and 22 reported no effect of noise on cognitive performance [8]. Noise as a sensory stimulus increases arousal which is believed to cause a reduction in the breadth of attention. In other words, loud noise causes alterations in the performance of attentional functions.

Smith believes that noise characteristics to be one of the influential parameters regarding the effect of noise on cognitive performance [9]. A study by Hockey showed that loud noise at 100 dBA (compared to 70 dBA) increased central visual stimuli processing but reduced peripheral stimulus processing [10]. Exposure to noise above 85 dBA intensity leads to many adverse auditory and non-auditory effects. The non-auditory effects of noise exposure depend on exposure duration, type of task, gender, age and sensitivity to noise. Physiological signals are comprised of: a) signals related to the peripheral nervous system, including heartbeat and Electromyogram and b) signals related to the central nervous system including electroencephalography (EEG). In recent years, interesting results have been obtained from the first group of signals, however, few studies have used EEG signals as a valuable tool for cognitive performance evaluation [11]. Cognitive theory suggests that the brain is highly involved in emotions. Basic emotions use specific cortical and subcortical systems within the brain and are different from the brain's electrical and metabolic activities. Therefore, EEG is one of the most effective and common methods of brain imaging used for Brain activity processing relating to human stress including noise [12]. EEG signals measure all fluctuations in the electrical fields resulting from nerve activity in millisecond resolutions. EEG signals are usually evaluated in multiple frequency bands to determine their relationship with stresses. These bands include the Alpha (8-12.5 Hz), Theta (4-8 Hz), Delta (1-4 Hz) and Beta (12.5-30 Hz) bands. Humphreys and Reveille suggest that fluctuations in the Alpha and Beta bands, in particular, are an indication of cognitive function. Increases in the Alpha frequency band along with decreases in the Beta frequency band causes increased cognitive function [13]. A reduction in the power of the Alpha band along with a rise in the power of the Theta and Beta bands is an indicator of neurological disorders. Marshal et al., have shown a reverse relationship in the prefrontal cortex between the Alpha power rhythm in an EEG and suffering from stressful conditions, meaning that the Alpha rhythm goes down with stress [14]. Choi demonstrated a positive relationship between the Beta power rhythm in an EEG and suffering from stressful conditions in the temporal lobe [12]. Other studies have shown a reduction in the relative power of the Alpha band when attention is reduced. Compared to other imaging techniques, Electroencephalography has certain advantages which include being non-invasive, low cost, comfortable, safe, mobile, and having high time resolution. Therefore, EEG can be a great tool not just for detecting stressors in the environment but also for predicting the negative effects of noise exposure.

Because noise level is one of the influencing factors regarding the effects of noise on cognitive function and brain signals, this study focused on 75, 85 and 95 dBA levels. Also, due to the conflicting results in other studies regarding cognitive function and its importance in many tasks and the few studies on the effects of various noise levels on brain activity patterns, this study was designed in two parts. The first part investigates the effects of various noise levels on mental workload and auditory/visual attention. The second part investigates the effects of noise on the relative power of brain frequency bands and their relationship with visual/auditory attention.

Material and Methods

Study Subjects and Selection Criteria

Study subjects were selected from university student volunteers. The including criteria was 23-33 years of age, normal hearing, no prior cardiovascular disorders, no alcohol and caffeine consumption 12 hours before testing, a BMI index of 18-28, no hypersensitivity to noise and no sleep disorders. After finalising the selection, testing procedures were trained to the study subjects. All participants had to complete ethical consent forms, General Health questionnaires (GHQ) and Weinstein's Noise Sensitivity questionnaires. The validity and reliability of the Persian version of these questionnaires had been approved in other studies [15].

Experimental Design

This experimental study was conducted in an acoustically insulated, climate-controlled room (H = 3 m, L = 3.5 m and W = 2.5 m). A total of 54 participants, including 27 males and 27 females, took part in this study. Study subjects were divided into 3 groups, each with 9 males and 9 females. All study groups were exposed to background noise (45 dBA), and three different noise levels (including 75, 85 and 95 dBA). Table 1 shows the experimental design in detail.

Table 1: Experimental Design

Study Groups	Number of subjects (Total No = 54)	Background Noise (dBA)	Exposure level (dBA)
1	18	45	75
2	18	45	85
3	18	45	95

The study protocol for each subject included a 10-minute relaxing phase before testing, followed by the Integrated Visual and Auditory Continuous Performance (IVA) test which was accompanied by background noise while EEG signals were being recorded. After a 30-minute rest, the subject was exposed to noise for 15 minutes, and at the 16th-minute mark, while the subject was being exposed to various noise levels, the IVA test was initiated, and EEG signals were once again recorded (Figure 1).

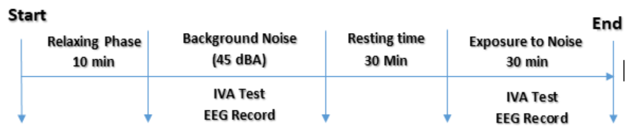

Figure 1: Study protocols timing

Noise Source and Presentation

In this study, the used noise was recorded in a household appliance factory using a B and K PULSE Multi-Analyzer System Type 3560. The recorded noise was then analysed using a B & K Sound Level Meter Type 2238. To modify the noise and obtain steady noise at 75, 85 and 95 dBA levels, the Gold Wave software version 4.26 was used. Finally, the noise was replayed using two Genius HF-2020 speakers situated on either side of the test table.

NASA-Task Load Index (NASA-TLX) Questionnaire

A NASA-TLX questionnaire is a well-known tool for evaluating subjective mental workload (as perceived by the subject). This multi-dimensional method assigns an overall score for mental load based on average weights obtained from six scales including mental demand, physical demand, temporal demand, effort, performance, and frustration. Every part of the task is assigned to a 100-point rating score. The mental load evaluation process using this indicator is comprised of three stages. In the first stage, the six scales are self-assessed by the study subject. In the second stage, after weighing the load of each scale, it is given a score by the subject. Finally, the score and the weight of the load are obtained, and the total mental load score is determined. The validity and reliability of this questionnaire have been approved by Mohammadi in Iran, and its Cronbach alpha score was 0.83 [16].

Integrated Visual and Auditory Continuous Performance Test

Integrated Visual and Auditory test, which was designed by Stanford et al., is part of the Continuous Performance Tests (CPTs) and used to evaluate auditory/visual attention [17]. It consists of a 13-minute continuous auditory and visual test that evaluates two factors of response control and attention. The task involves responding or not responding (response prevention) to 500 test stimuli. Each stimulus is presented for 1.5 seconds. The subject is asked to click once if he/she detects a 1 and not to respond if detecting a 2. This test has an appropriate sensitivity of 92% and a predictive power of 90%. The Persian version of this test has a validity index of 53% to 93% [18].

EEG Recording and Analysis

The EEG signals were recorded from 16 Ag/AgCl electrodes mounted in an elastic cap with the amplifier bandpass set to 1 – 40 Hz at a sampling rate of 250 Hz. The electrodes were placed at the frontal (Fp1, Fp2, F3, F4, F7 and F8), temporal (T3 and T4), central (Cz, C3 and C4), parietal (Pz, P3 and P4) and occipital (O1 and O2) regions. This is according to the international 10-20 system of electrode placement (Figure 2). The reference electrode was the left mastoid (A1 in Figure 2). Impedance was maintained at below 10 KΩ during the experiment. Both in the background noise condition and during exposure to noise levels of 75, 85 and 95 dBA, while the subject was performing the IVA + Plus test, EEG signals were recorded for 10 minutes with the subject's eyes open. First, the EEG data was pre-processed using an EEGLAB 2013a toolbox [19]. Then, using Independent Component Analysis (ICA) on each electrode, artefacts about blinking, eye movements or small body movements were eliminated.

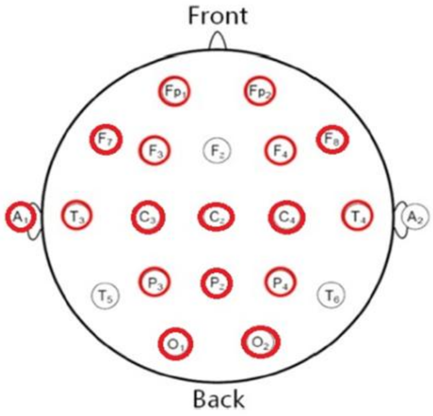

Figure 2: Electrode placement

In order to measure relative power, the filtered signals were separated into various frequency bands (Delta (1-4 Hz), Theta (4-8 Hz), Alpha (8-12.5 Hz), Beta (12.5-30 Hz) and Gamma (30 Hz upwards)) based on their power spectral density using the MATLAB software version 2017b. To calculate the relative power of the frequency bands, the following equations were used:

Let $x_{i\ (n)}$ denote the n^{th} element of i^{th} EEG channel after preprocessing and $X = [x_1, x_2 ... x_{nc}]$ where NC denotes the number of EEG channel. The Power spectrum of the EEG signal was calculated using Fast Fourier Transform (FFT) which transforms the EEG signal X from the time domain to the frequency domain Z. The FFT of each EEG channel was calculated separately given by the following:

$$z_i(f) = \sum_{n=1}^{N} x_i e^{\frac{-j2\pi fn}{N}} \quad (1)$$

Where f denotes the frequency, N is the sample size; *I* is the channel number and *J* is the imaginary unit. Then absolute power spectrum (PSD) of EEG was calculated using the following:

$$PSD_i(band) = \sum_{n=k_1}^{k_2} z_i^n z_i^{n\prime} \quad (2)$$

Where k_1 and k_2 denote the frequency range of the selected band. The relative power of the selected band was then calculated by the following:

$$R_{PSD_i}(band) = \frac{PSDi(band)}{PSDi(total)} \quad (3)$$

Statistical analysis of the mental workload and attention data was carried out using the SPSS 22 software solution. Before performing t-tests, data distribution norms were checked using the Kolmogorov–Smirnov test. A *p*-value of less than 0.05 was considered statistically significant. The Generalized Estimating Equations (GEE) statistical method was applied for data analysis.

Results

Demographic Characteristics of Participants

Table 2 displays the study subjects' demographic characteristics. A total of 56 individuals, 27 males and 27 females, were enrolled in the study. Average and standard deviation of age and Body Mass Index (BMI) was 26.56 ± 2.45 and 23.81 ± 1.43, respectively.

Table 2. Study subjects' demographic characteristics (N = 54)

Characteristic	M	SD	Max	Min
Age (years)	26.56	2.45	33	23
Weight (kg)	72.65	8.24	90	55
Height (cm)	173.66	7.93	192	158
BMI (kg/m2)	23.81	1.43	27	20

Effect of Noise levels on Mental Workload

Figure 3 illustrates the effects of various noise levels on average overall mental workload compared to background noise (45 dBA) for study subjects. The results show that 75 and 85 dBA noise levels, as compared to just background noise, does not follow a particular trend and does not cause a considerable change in the average mental workload (P > 0.05). At 70 dBA level, compared to just background noise, the mental workload had decreased while at 85 dBA it had increased. At 95 dBA level, compared to just background noise, the increase in mental workload was statistically significant (P = 0.03).

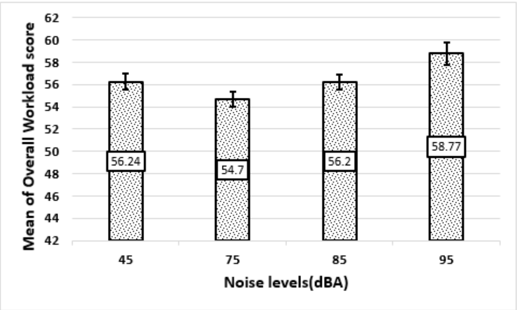

Figure 3: The effect of noise levels on mental workload. Background noise = 45dB (A)

The Effect of Noise levels on Visual and Auditory Attention

Figure 4 presents the average and standard deviation for the visual and auditory attention score at various levels of noise compared to background noise (45 dBA). The results show that the changes in visual and auditory attention under exposure to various noise levels are very similar in pattern. At 85 dBA levels, average attention scores are reduced, as compared to just background noise, but this is not statistically significant ($P > 0.05$). But at 95 dBA levels, average attention scores are reduced considerably compared to background noise; this was statistically significant ($P < 0.05$).

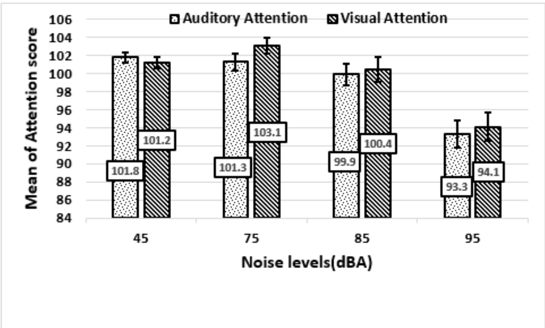

Figure 4: The effect of noise levels on visual and auditory attention

The Effect of Noise levels on EEG Fluctuations

The Kolmogorov – Smirnov test results indicated that the data were distributed normally. Therefore, the t-test was used in this part. The relative power of the intended brain frequency bands was used to analyse brain signals during exposure to various noise levels relative to background noise (45 dBA). The considered frequency bands include the Delta (1-4 Hz), Theta (4-8 Hz), Alpha (8-12.5 Hz), Beta (12.5-30 Hz) and Gamma (30 Hz upwards) bands.

Table 3: Average variation in the relative power of the Alpha band (μV^2) during exposure to noise relative to background noise (45 dBA)

Noise Level (dBA)	75		85		95	
Brain region	t-value	p-value	t-value	p-value	t-value	p-value
Fp_1	0.1273	0.9001	0.0122	0.9903	3.2470	0.0047
F_3	1.4088	0.1769	-0.9717	0.3448	-2.5478	0.0208
F_4	-0.8262	0.4201	0.0675	0.9469	2.4434	0.0257
F_7	2.4367	0.0261	2.2825	0.0356	-0.7458	0.4659
C_4	1.5379	0.1424	2.7946	0.0124	-0.6389	0.5313
P_3	0.3605	0.7229	2.0622	0.0548	2.4443	0.0257
O_1	-0.0213	0.9831	-1.3340	0.1997	5.8788	0.00001*
O_2	0.4069	0.6891	-2.8427	0.0112	2.2478	0.0381

* p < 0.05; FWE corrected.

The results show that among the mentioned frequency bands, the Alpha and Beta bands undergo considerable changes, as relative to just background noise, and are being affected by noise. Based on Table 3, going from 75 dBA to 95 dBA noise level causes a statistically significant average variation in the relative power of the Alpha band for the Fp_1, F_4, P_3, O_1 and O_2 regions of the brain ($P < 0.05$). Again, based on Table 3, at 95 dBA, the largest variation in the relative power of the Alpha band is observed for the O_1 region of the brain ($P < 0.001$).

A significant reduction in the relative power of the Alpha band was only observed for the F_3 region ($P<0.05$), though a slight reduction was observed for the C_4, F_7 and F_3 regions of the brain also. The most affected areas of the brain when exposed to noise seems to be the Occipital, Prefrontal, Frontal and Parietal regions of the brain. Figure 5A shows the Scalp Topographical mapping.

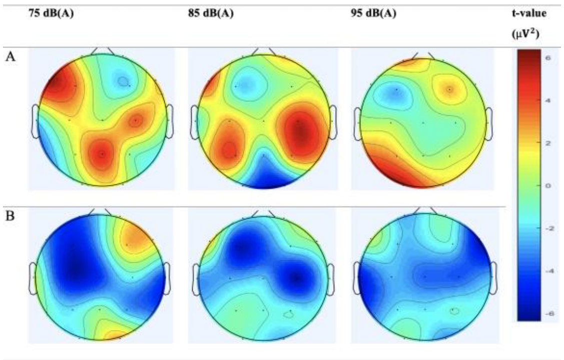

Figure 5: Topographical mapping of frequency bands' relative power during exposure to noise as relative to background noise (45 dBA)

Table 4 demonstrates average variation in the relative power of the Beta band during exposure to various noise levels relative to background noise. The results show a reduction in the relative power of the Beta band in all channels as a result of exposure to 75, 85 and 95 dBA noise, although this reduction was most prominent at 95 dBA. Based on table 4, this reduction is statistically significant ($P < 0.05$) and the order by which it occurs, and the affected areas are as follows: F8-T3-C4-Cz-O2-Fp1-T4-F3-C3. No significant effect was observed in the other areas of the brain under study ($P > 0.05$). Also, based on figure 5b, the reduction in the relative power of the beta band as a result of the increase in the level of noise occurs in the Frontal, Temporal, Occipital and Central lobes.

Table 4. Average variation in the relative power of the Beta band (μV^2) during exposure to noise as relative to background noise

Noise Levels (dBA)	75		85		95	
Brain region	t-value	p-value	t-value	p-value	t-value	p-value
Fp1	-1.4331	0.1699	-1.4425	0.1673	-2.7360	0.0140
F3	-1.8798	0.0773	-4.4633	0.0003	-2.2483	0.0381
F8	0.6888	0.5002	0.0489	0.9615	-6.0999	0.00001*
T3	0.2340	0.8177	-2.2907	0.0350	-5.6475	0.00002*
T4	-1.5475	0.1401	-0.8386	0.4133	-2.7236	0.0144
C3	-1.9134	0.0726	-2.2010	0.0418	-2.6735	0.0160
C4	-0.5552	0.5859	-4.8780	0.0001	-4.0165	0.0008
O2	0.9009	0.3802	-2.0361	0.0576	-3.1004	0.0064
Cz	-1.5521	0.1390	-1.8460	0.0823	-3.8259	0.0013
Pz	-0.1543	0.8791	-1.0180	0.3229	-1.9732	0.0649

* p < 0.05; FWE corrected.

Discussion

The results of this study showed that as a stressor, noise affects cognitive performance and brain signals. Also, noise pressure level is an important factor regarding impairment of cognitive function and power spectral density of the brain, meaning that low levels noise is not as effective compared to high levels of noise. It can be said that the results of this study are in agreement with the proposal that a relationship exists between low performance and high levels noise [20]. Previous studies have neglected to investigate cognitive performance during exposure to noise [21], [22]. Some studies have used qualitative measurements including subjective responses for the evaluation of the effects of noise exposure on cognitive function. In this study, however, quantitative indicators were used in combination, including the evaluation of mental workload, evaluation of auditory/visual attention and brain signals (power spectral density) analysis.

In a study by Yoorim Choi, EEG signals were used as a new method for environmental stressor analysis. This method is suggested to overcome the limitations in physiological evaluation techniques [12]. Share et al., also suggest that to improve cognitive and mental stress evaluation, a combination of these tools should be used [23]. Sabine et al. revealed that Stroop and mental arithmetic performance increased when exposed to 50 dBA levels noise compared to 70 dBA levels noise. Melamed et al. stated exposure to higher than 85 dBA intensity noise causes irritability, fatigue and stress which is consistent with the present study [24]. In previous studies, the effects of noise exposure on heartbeat and blood pressure at 95 dBA were compared to 75 and 85 dBA [25]. Elmenhorst et al. demonstrated that noise exposure causes increased reaction times and errors in field and laboratories study [26]. The result obtained by Patricia Tassi et al. indicated that noise exposure reduces attention in subjects which is also consistent with the present study [27]. The effects of high levels of noise exposure on cognitive performance can be amended to the Poulton arousal model which states that noise exposure increases cognitive performance at first. The reason for this is an increase in arousal to reduce the effect of noise on cognitive function. But gradually, the effect of arousal wears off, and the negative effects of noise exposure on cognitive function begin to show [28]. The results in the present study can be explainable using arousal theory. This theory states that the level of central nervous system activity (which alternates between being asleep and awake) regulates human response to stimuli. There is no overall consensus on the validity of this theory at present, and some have suggested that it cannot be used to describe the relationship between noise exposure and cognitive performance. In any case, considering this theory, it can be said that when arousal is high or low, or in other words, in both low stress and high-stress situations, performance is reduced [29].

There were conflicting results regarding the effects of noise on cognitive function in previous studies. Some studies determined that noise had improved cognitive function [30]. While others had concluded that noise had reduced cognitive function [31]. This is part of the reason why, in this study, quantitative measurements were used in combination. The results of the present study reveal that the reduction of cognitive function and brain signals was only significant when exposed to noise at 95 dB level and not at 75 or 85 dBA. This could be due to other psychoacoustic factors such as noise pitch, tonality, exposure duration, and noise type. The importance of noise pitch and its effects on cognitive function and brain activity has been emphasised in other studies. The results of the study by Kazempour et al., showed that “base” noise (low frequency) reduces computational accuracy and performance [32]. Pawlaczyk et al. observed a higher sensitivity to “base” noise that caused reduced cognitive function as compared to reference noise [33]. Naserpour et al., also exhibited that “base” noise at 500 Hz caused longer reaction times as compared to “treble” noise at 800 Hz [34]. The study by Allahverdy and Jafari showed the complexity of brain activity increases at midrange frequencies, showing the effects of the change in frequency on brain activity [35].

Another effective parameter regarding noise and performance is noise tonality. In the study by Joonhee et al., it was observed that performance was reduced with increasing noise tone strengths [36]. Type of noise is also important when evaluating the effects of noise on cognitive function. Studies have shown that the effect of fluctuating noise on cognitive function is higher than steady noise [37]. Steady noise was the only type used in our study. Also, exposure times used were rather short, which may result in a reduced effect of noise on performance and brain signals when exposed to lower than TLV noise. The lesser effect of lower than TLV noise (45, 75 and 85 dBA) on performance and brain activity may also be due to non-psychoacoustic parameters as well. For instance, scope and diversity are influential in the methods used for cognitive function evaluation [38]. Simplicity or complexity of the task is another example as a complex task cause a greater cognitive dysfunction when compared to simple tasks. Personal characteristics may also be a factor when subjects are exposed to noise. As some may experience reduced cognitive function while others may not, and some may even show increased cognitive function [38]. These factors may not be as influential in the present study as the subjects were prescreened for mental disorders, cardiovascular disorders and behavioural abnormalities before selection. Many aspects of brain function and behaviour can only be discussed in terms of neurons communicating with each other. All cognitive processes in the brain are carried out through neuronal activity such as synapses and spikes. Orientation and executive function which are involved in the processing of attention are specifically undermined to enable information processing. The disruption of attention likely occurs in subjects whenever there is a need for sustained attention.

Here, Brain signal analysis disclosed that the Alpha and Beta frequency bands were affected by noise. With an increase in noise levels, the relative power of the Alpha and increased while the relative power of the Beta band decreased. Topographical mapping of the scalp shows that all four lobes of the brain are usually affected by noise, but this is more pronounced in the frontal and occipital lobes, which is consistent with the results of other studies [39]. Other conclusions can be made from this study regarding the relationship between visual / auditory attention and the relative power of the Alpha and Beta bands. In this regard, it can be said that with increasing noise levels, participants' auditory / visual attention score went down while the relative power of the Alpha and Beta bands increased and decreased respectively. Topographical mapping of the scalp indicates that the area responsible for attention processing is located in the frontal, temporal and occipital regions of the brain which is consistent with the results of Liz et al., [40]. Therefore, the results of this study suggest that when one is exposed to various noise levels, mental workload, visual / auditory attention and the relative power of the frequency bands follow a similar trend. In studies that pertain to brain signals and cognitive performance, attention to artifacts such as eye and body movement, electrical interference, impedance fluctuations, sleep disorders, personality characteristics, age, sex and race are all important, and this has been reiterated in various studies [41]. The benefits of using the NASA TLX and IVA +Plus tests along with EEG signal recording in the psychological and neurophysiological evaluation include the ease of administration, non-invasiveness, short evaluation times and low cost. It is suggested that in future studies on the evaluation of the effects of noise, other psychoacoustic parameters such as noise pitch, tonality and also extended periods of exposure be considered. It is also suggested that more than 16 channels be used for the EEG recordings for better and more detailed evaluations of the various brain regions.

In conclusion, noise levels seem not to have the appropriate sensitivity at levels below 85 dBA on cognitive performance. Therefore, other psychoacoustic parameters that influence cognitive function, including noise pitch and tonality are suggested as candidates for future research. Scalp topographic mapping indicates that the frontal and occipital regions along with the Alpha and Beta frequency bands are most affected by exposure to noise considering the influence of task complexity, personality characteristics, the effects of other psychoacoustic parameters on cognitive and neuro-physiological functions, applying new methods such as the use of brain biosignals along with power spectral density in the evaluation of environmental and occupational stress, especially in the case of noise exposure is suggested. It can thus be concluded that the evaluation of mental workload, auditory / visual attention and brain signals (power spectral density) in combination can be considered as a useful indicator for the assessment of the effects of noise exposure on cognitive performance.

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Ethics Approval

The Research and Ethics Committee approved the study proposal of Shahid Beheshti University of Medical Sciences (Ethical code. IR. SBMU. PHNS.1396, 63). Written consent was obtained from the participants after the explanation of the purpose and benefits of research.

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