Original Article

The Analysis of the Cognitive Function Parameters in Exposure to Noise Using Emotiv-EPOC Electroencephalography Headset

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Abstract

Aim: Exposure to noise in different work and nonwork places is considered to be a problem. Noises impertinent to professional duties are highly dangerous to the safety, efficiency, and personal health of an individual. This study aims to analyze the electroencephalography (EEG) signals to reveal the effect of produced noises in a laboratory environment on the cognitive function of the brain. **Materials and Methods:** In this case/control study, the sample volume was determined based on similar studies and previous researches of 20 individuals. Fifty percentage of the individuals were male and the other half were female. Initially, the EEG device was connected to the students' heads. The duration of this test was 8 min; the student took it a number of times, while his cognitive performance was measured with the EEG device in the midst and at the end of the test. The fulfillment of cognitive duties (the daily quota of lessons) and the n-back test took place for the cohort in an environment in which a simulated noise was provided. **Results:** The age average in boys and girls were respectively 24 ± 4.2 and 23 ± 3.5. The results demonstrated that cognitive parameters of concentration, excitement, anxiety, calmness, commitment, and interest in exposure to low-frequency sound using an EEG Emotiv EPOC headset in different intervals. The parameters of commitment, concentration, and calmness decreased as the allotted time increased, and only the fall in commitment parameter was significant ($P = 0.006$). **Conclusion:** The findings of the present study demonstrate that the decrease in cognitive performance and brain signals in exposure to 85 dB noise was significant. This could have also been caused by psycho-acoustic factors such as sound level, tonality, duration of exposition, and the type of sound. In relation to exposure time, results have shown that in the presence of loud noise and in comparison, to quietude, the average response time to stimulants increase (slower response).

Keywords: Brain waves, cognitive function, noise

Introduction

The effect of noise on human brain activity and its cognitive function has often been taken for granted.[1] Noise has various detrimental effects, including interruptions in cognitive processing, negative effects on mental and physical health,[2] nonauditory effects such as interruptions in comprehension processes, cognitive disturbances, cardiac discomforts, and sleep issues.[1] Exposure to noise in different work and nonwork places is considered to be a problem. Noises impertinent to professional duties are highly dangerous to the safety, efficiency, and personal health of an individual.[3] A number of studies have demonstrated that exposure to noise could negatively affect the individuals' safety due to causing professional mistakes and interruptions in safety communications and alarms. Furthermore, cognitive effects resulting from noise such as losing attention and increase in anxiety might bring about a higher possibility of accident occurrence.[4-6]

The type of noise and its features, the amount of being exposed to it, personal characteristics, and sensitivity to noise determine the harmful effects of noise. Studies report that age, sex, genetic factors, underlying diseases, personal characteristics, and other personal features such as sensitivity to noise have a significant

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role in the nonauditory effects of noise.[4,7-9] Previous survey has shown that exposure to noise affects health, professional memory, consciousness, and being professionally content, which varies based on the complexity of the job.[10]

Until 1930, a common belief was that noise effects on health were limited to decreasing hearing ability. In a published study in US acoustic association magazine, it was concluded that noise effects on human beings go much further than decreasing hearing ability.[11] Subsequent to a meager improvement in this scientific field in 1960s, the 1970s brought about a number of research instances to evaluate the annoyance caused by environment noises.[12-14] Exposure to noise causes disturbance in calmness and increases physiological provocation and anxiety.[15] Exposure to noise could have early and later effects. One of the main effects is the decrease of cognitive function, which could lead to professional accidents to a great extent[16] Easterbrook "states that exposure to noise could elevate the threshold of sensitivity to noise, in a way that if noise exceeds the sufficient amount, it could cause the lowering of focus."[17] The annoyance resulting from environmental noise is under the effect of nonacoustic causes such as personal characteristics and an individual's stance toward the source of the noise. Noise sensitivity is considered to be a stabilizing element or an annoyance mediator, and among the other noise effects are mental interruptions during sleep or disruptions in function while awake.[18] Most probably, the noise will not only affect a worker's function through intense confrontation but also on the accounts of hazardous confrontations of higher levels.[19,20] According to Leather, Beale and Sullivan, it seems a decrease in environmental noise would lead to the fall in social and mental anxiety in workplaces.[6]

A number of various techniques could be utilized to measure the reflex of an individual's cognitive and physiological parameters in exposure to noise. Among these techniques, we can mention the continuous performance test to measure people's sustained attention and the paced auditory serial addition test to measure working memory capacity and performance.[21,22]

Another of these techniques is using electroencephalography (EEG), in which a series of indicators dependent on EEG have been used.[23] EEG performance is in the form of registering the brain's electrical activities, where the produced signals are sent to the neural cells of the brain. EEG could be measured noninvasively subsequent to the placement of electrodes on the surface of the head skin.[24-26] An advantage of using EEG is that one could use its results for determining the amount of an individual's confrontation with noise. One could also find out the constant psycho-physiological indicators of an individual, rendering the individual's explicit response unnecessary.[27]

Several studies exist on the effect of noise on brain's cognitive functions. Due to the fact that sound pressure level is one of the most effective causes regarding the effect of noise on cognitive performance and brain signals, the present study focuses on a level of 85 dBA. Furthermore, having considered the paradoxical results in other studies on cognitive performance and its significance in several duties, and in turn the rarity of studies on the effects of noise on brain activity patterns, this study aims to analyze the EEG signals to reveal the effect of produced noises in a laboratory environment on the cognitive function of the brain.

Materials and Methods

In this case/control study, the sample size was determined based on similar studies and previous researches of 20 individuals (10 men and 10 women); however, due to the break of COVID-19, the authors faced several discomforts in collecting data which led to the participation of 16 individuals in the study.[3] Fifty percentage of the individuals were male (8 men) and the other half were female (8 women). The current research was undertaken in 2022, aiming to analyze the effect of noise on such student cognitive performance as excitement, engagement, focus, relax, stress, interest in using EEG device, and measurement of professional memory using the n-back test. The individuals sampled for this study were those who were formerly tested for previous high exhaustion, and consumption of special drugs and caffeine, while these were considered as the inputs and outputs of the study. The duration of the study was 40 min. The study proceeded in the manner described below:

Initially, the EEG device was connected to the students' heads. The EEG Emotive EPOC + portable device, made in the USA, including 14 sensors was mounted on the head according to the manufacturer's instructions. Sensors were moisturized using brine. It was then connected to its software on the computer via a USB connection. Subsequent to the initiation of the focused parameters, the rate of anxiety received by the headset from Bluetooth waves was noted and recorded in the software.

Primarily, the student started his daily studying routine which included studying a textbook, Q/A, and searching for a scientific subject related to his very own major. His brain performance was recorded while doing the activities and then he began taking the n-back test. The duration of this test was 8 min; the student took it a number of times, while his cognitive performance was measured with the EEG device in the midst and at the end of the test.

In the end, the student filled out the noise annoyance questionnaire to determine his feeling toward the conditions of the experiment.

The fulfillment of cognitive duties (the daily quota of lessons) and the n-back test took place for the cohort in an environment in which a simulated industrial noise was provided. Industrial noises are such as those made by grinders, sandpaper machines, hammer, vehicles, and drills. The sound pressure level was adjusted to 85 dBA, set proportionately to the minimum level of hearing protection performance (for an 8-h workday) as suggested by EU (EC/10/2003 EU instructions).[28] Thus, we found out the degree of the effect of noise on the students' cognitive performances through changes in peak cognitive function indicated by EEG.

Bearing in mind the fact that this experiment was comprised of students and was undertaken in a laboratory, the sound pressure level was set lower than standard to observe ethical norms and ensure the safety of students. On the other hand, the duration of the exposition was determined in a way that the safety of students would not be compromised. The control cohort was studied under the same circumstances, however without any exposition to noise.

Brain waves were recorded using the Emotiv-EPOC + which has 14 active electrode channels: (i) Frontal lobe: AF3, AF4, F3, F4, F7, F8, FC6, FC5,[29] and Temporal lobe: T7, T8.[24] Occipital lobe: O1 and O2, and[30] Parietal lobe: P7 and P8. In a 14-channeled EEG device, the frequency of Theta waves is 4–8 Hz, Alpha's 8–12 Hz, Beta's 12–25 Hz, and Gamma's 25–45 Hz. The θ waves have a higher domain in a state of drowsiness. The α waves are of a higher domain in a state of tranquility. The β wave has signals with short domains which tend to appear while working when one is alarmed, and when one is engaged in an activity.[29]

N-back is a test that measures the cognitive performance related to executive function, which is normally used in neuroimaging studies to provoke the brain functions of the subjects. This test was first introduced by Kirchner in 1958.[31] The test proceeded as follows: A series of stimulants (often visual) would be offered to the subject step-by-step, and the subject would find out if the recent stimulant is in accordance with the one offered in the previous step. The test would take place with different *n* values and the higher the value of *n*, the more difficult the test was. Thus, in the 1-back (*n* = 1), the last offered stimulant would be compared with the previous stimulant, and also in 3-back (*n* = 3), the last offered stimulant would be compared with the last three stimulants (in this test, *n* could be 1, 2, 3).

This test has been deemed an appropriate method of evaluating professional memory and in the recent years has been widely employed in this field. Studies have shown that the various modes of this test could well be employed in laboratory studies on professional memory and other cognitive actions such as fluid intelligence.[32] Using this test as an evaluating indicator of professional memory performance is highly acceptable. While doing the tasks of n-back, executive actions such as controlling and focusing attention, decision-making, and planning the processing of peripheral information is engaged. Also in the field of professional memory, the highest rate of engagement in the performance of the central executive system is achieved while doing these tasks.[32] At the end of this test, the degree of sensitivity to noise was evaluated using a noise annoyance questionnaire. The questionnaire comprises three sections or three subscales: (1) The misophonia scale (measures the signs of misophonia and has 7 items) is Graded 0–4. (2) Behaviors and excitements caused by misophonia (measures the exciting and behavioral reactions caused by misophonia and has 10 items) and is Graded 0–4. The overall grade of the questionnaire is comprised of the items related to the misophonia subscale and the exciting and behavioral reactions caused by misophonia and the range is between 0 and 68. (3) Misophonia intensity scale, which includes a general question and is an adaptation of the obsessive-compulsive disorder demarcated by the National Institute of Mental Health, and evaluates the general intensity of misophonia from 1 (minimum) to 15 (very intense). A Grade of 7 or higher is a testimonial of significant clinical symptoms.[33]

Finally, continuous variables were reported in an average manner (standard deviation) and the qualitative variables were reported based on plenitude (percentage). The comparison of cognitive parameters and the n-back test results at different times and levels were tested, using repeated measures if the data were normal, and Friedman test if the data were not normal. The results of n-back test were used to measure the relation between cognitive parameters, the Pearson correlation coefficient was used to measure the intensity of normal data, and Spearman Coefficient was used for the abnormal data. All statistical analyses were done using SPSS software version 20.

Ethical clearance

Ethical approval for this study (Research Ethics Committee No.IR.MUI.MED.REC.1400.494) was provided by the Research Ethics Committees of School of Medicine - Isfahan University of Medical Sciences, on 20 September 2021.

Results

Based on the results, 50% of the students were female and the other half were male. The age average in boys and girls were respectively 24 ± 4.2 and 23 ± 3.5. Table 1 shows the results of cognitive parameters of engagement, excitement, focus, relaxation, stress, and interest in exposure to low-frequency sound using an EEG Emotive EPOC headset in different intervals. The parameters of engagement, focus, and relaxation decreased as the allotted time increased, and only the fall in engagement parameter was significant (*P* = 0.006).

Table 2 shows the results of the n-back test at various levels. The average number of unanswered or wrongly answered questions increase with the increase in levels, and this increase

Table 1: Results of cognitive parameters of engagement, excitement, focus, interest, relax and stress in exposure to noise using the Emotive-EPOC electroencephalography headset in various intervals

	Mean±SD			*P*
	Time 1 (*t*=15)	Time 2 (*t*=25)	Time 3 (*t*=40)	
Engagement	76.50±10.35	71.90±10.60	64.10±11.76	0.006
Excitement	55.70±32.37	42.20±24.09	50.30±33.67	0.638
Focus	51.10±15.06	49.60±16.48	44.80±19.92	0.370
Interest	65.80±13.47	66.30±13.60	66.00±12.22	0.974
Relax	40.10±15.82	39.20±14.77	34.60±19.27	0.578
Stress	47.90±20.45	50.20±19.63	41.10±23.44	0.520

SD: Standard deviation

Table 2: Comparing different levels of the n-back test

	Mean±SD			*P*
	Level 1	Level 2	Level 3	
False_response	2.00±3.06	2.50±4.53	3.50±5.87	0.430
Not_response	60.90±6.42	75.60±5.99	83.50±9.00	0.002
Result_truenmber	50.80±20.05	40.90±2.18	31.90±3.63	0.001
Result_darsad	47.80±8.28	33.50±2.27	26.60±3.06	<0.001
Responsetime_avg	700.20±184.16	726.10±195.62	629.00±177.48	0.001

SD: Standard deviation

was only significant in the average number of unanswered questions ($P = 0.002$). The average number of questions correctly answered and the result percentage decreases with the rise in levels, and the fall is significant in both cases (respectively $P = 0.001$ and $P < 0.001$). The increase in the average responding time is more in level 2 in comparison with the other 2 levels ($P = 0.001$). Table 3 shows the rate of sensitivity intensity in the participants; the average and the standard deviation of sensitivity intensity was 2.53 ± 5.20. Fifty percentage of the participants reported low sensitivities.

Table 4 shows the correlation between the cognitive parameters resulting from EEG headset in different intervals and levels of n-back test. Fifteen minutes after starting the excitement test, this parameter showed a negative relation with the number of correct choices in level 1. Furthermore, 25 min after the initiation of the test, it showed a positive relationship with the wrong choices in level 3. On the other hand, after 40 min there was a positive relation with the unanswered questions in level 1, a negative relation with the correct answers in level 1, and a positive relation with the wrong answers in level 3. The focus variable after 25 min had a negative relation with the results percentage in level 1. Focus in 40 min had a positive relationship with the unanswered questions in level 1 and the number of wrongly answered questions in levels 2 and 3. Fifteen minutes after the initiation of the test, the interest and relax variables had a negative relation with the number of correct choices and the results percentage in level 1. Interest after 25 and 40 min had, respectively, a positive relationship with the number of correctly answered question in level 3 and the results percentage in level 2. The relax parameter after 25 and 40 min had, respectively, a positive relation with the correctly answered questions in level 3 and a negative relation with the number of wrongly answered questions. The stress parameter after 15 min had a positive relationship with the number of wrong answers in level 2. Furthermore, after 40 min, it had a positive relationship with the correct answers and the result percentage in level 2. The remaining correlative coefficients were not significant in tables ($P < 0.05$). Table 5 shows the correlation between the intensity of sensitivity and the cognitive parameters which resulted from the EEG headset in different intervals. The intensity of sensitivity showed a positive and significant relation with a focus in 25 min and relaxation in 40 min.

Table 3: Grades of intensity of sensitivity in the participants

Intensity of sensitivity groups	Range	*n* (%)
Mean±SD	5.20±2.53	
Very low	1–3	1 (10.0)
Low	4–6	5 (50.0)
Medium	7–9	3 (30.0)
High	10–12	1 (10.0)
Very high	13–15	0

SD: Standard deviation

Discussion

Within this section, the effect of noise on the parameters of cognitive performance (EEG device and n-back test) was explicated and its probable causes were analyzed. Subsequently, the limitations and the participation in the study were discussed.

According to the findings of the present study, the parameters of engagement, focus, and relaxation descended with the increase in the exposition time. Over time, when the human body is exposed to a dangerous physical factor (noise), stress will in turn occur as a physiological response. Such a phenomenon could be explained using Walter Cannon's fight-or-flight response theory. This theory explains that when an individual feels stress, the autonomous nervous system is activated and a physiological provocation appears in response to it. At thatprecise time, negative feelings might be created.[34] On the other hand, these observations of performance disruptions in stressful circumstances are in direct accordance with the previous findings. Based on the findings of this study, the alpha waves are more sensitive to mental stress in comparison with other EEG waves.[35]

The findings of this research demonstrated that as a stress-inducing factor, noise impacts cognitive performance and brain signals. Also, sound pressure level is an important factor in causing an interruption in cognitive performance, meaning that a low sound pressure level is not as disruptive in performance as a higher sound pressure level. It could be claimed that the findings of this study are in accordance with the proposition that there is a relation between weak performance and sound pressure level.[36] In addition to increasing stress level, noise has a great impact on reaction

Table 4: Relation between the cognitive parameters resulted from the Emotive-EPOC electroencephalography headset in different intervals with the results of n-back

	Engagment 1	Engagment 2	Engagment 3	Excitement 1	Excitement 2	Excitement 3	Focus 1	Focus 2	Focus 3
Level_1_false_response	−0.15	0.42	−0.17	0.23	0.57	0.07	0.10	0.60	0.28
Level_1_not_response	−0.13	−0.23	−0.02	0.25	0.28	0.774**	0.20	0.43	0.683*
Level1_result_truenmber	0.04	0.29	−0.06	−0.678*	−0.20	−0.679*	−0.60	−0.46	−0.63
Level1_result_darsad	0.28	0.06	0.21	−0.55	−0.50	−0.47	−0.43	−0.812**	−0.56
Level1_responsetime_avg	0.05	0.11	−0.36	−0.23	−0.53	−0.07	−0.24	−0.55	−0.28
level_2_fals_eresponse	0.16	−0.34	−0.13	0.55	0.27	0.55	0.43	0.22	0.642*
Level_2_not_response	−0.33	−0.19	−0.22	−0.30	−0.17	0.38	−0.29	0.06	0.02
Level2_result_truenmber	−0.16	0.12	0.20	−0.07	0.28	−0.17	−0.01	0.33	0.06
Level2_result_darsad	−0.10	0.01	0.16	0.07	0.34	0.03	0.12	0.42	0.20
Level2_responsetime_avg	−0.01	0.00	−0.31	−0.26	−0.60	0.02	−0.27	−0.61	−0.21
Level_3_fals_eresponse	0.15	−0.17	0.25	0.18	0.661*	0.663*	0.16	0.49	0.769**
Level_3_not_response	0.03	−0.08	0.17	−0.11	−0.23	0.27	−0.01	−0.08	−0.09
Level3_result_truenmber	−0.34	−0.06	−0.19	−0.24	−0.23	−0.09	−0.24	−0.13	−0.03
Level3_result_darsad	−0.11	−0.04	−0.14	−0.09	−0.11	−0.02	−0.09	−0.10	0.04
Level3_responsetime_avg	0.13	0.03	−0.29	−0.13	−0.52	0.01	−0.15	−0.56	−0.21
	Interest 1	**Interest 2**	**Interest 3**	**Relax 1**	**Relax 2**	**Relax 3**	**Stress 1**	**Stress 2**	**Stress 3**
Level_1_false_response	0.18	0.36	−0.39	0.60	−0.09	−0.793**	0.42	0.40	−0.51
Level_1_not_response	0.46	0.54	0.44	0.60	−0.10	0.06	0.51	0.62	0.14
Level1_result_truenmber	−0.759*	−0.18	0.03	−0.855**	0.28	0.21	−0.60	−0.36	0.14
Level1_result_darsad	−0.710*	−0.27	0.07	−0.886**	0.38	0.38	−0.36	−0.42	0.15
Level1_responsetime_avg	0.21	0.01	0.12	0.08	0.38	0.38	0.39	−0.07	0.02
level_2_fals_eresponse	0.59	−0.03	0.05	0.60	0.04	0.08	0.678*	0.04	0.15
Level_2_not_response	0.03	0.17	0.19	0.01	−0.50	0.08	−0.22	0.29	−0.22
Level2_result_truenmber	−0.09	0.47	0.56	−0.12	0.36	0.23	−0.32	0.30	0.673*
Level2_result_darsad	0.12	0.39	0.691*	−0.01	0.21	0.39	−0.30	0.23	0.798**
Level2_responsetime_avg	0.13	0.10	0.04	0.10	0.43	0.27	0.52	0.08	−0.12
Level_3_fals_eresponse	0.02	0.44	0.58	0.15	−0.06	0.10	0.20	0.40	0.41
Level_3_not_response	0.05	−0.02	0.33	−0.16	−0.43	0.28	−0.32	0.03	0.03
Level3_result_truenmber	0.07	0.636*	0.35	0.13	0.712*	0.20	0.22	0.51	0.35
Level3_result_darsad	0.18	0.44	0.47	0.10	0.61	0.36	0.20	0.28	0.51
Level3_responsetime_avg	0.24	−0.05	0.07	0.10	0.33	0.35	0.44	−0.10	−0.02

**Correlation is significant at the 0.01 level (two-tailed), *Correlation is significant at the 0.05 level (two-tailed)

Table 5: Relationship between the cognitive parameters resulted from the Emotive‑EPOC electroencephalography headset in different intervals with the intensity of sensitivity caused by noise

EEG cognitive parameters in different intervals	Engagment 1	Engagment 2	Engagment 3	Excitement 1	Excitement 2	Excitement 3	Focus 1	Focus 2	Focus 3
P	−0.492	0.165	−0.467	0.092	0.544	0.191	−0.059	0.780**	0.375
Interest 1	**Interest 2**	**Interest 3**	**Relax 1**	**Relax 2**	**Relax 3**	**Stress 1**	**Stress 2**	**Stress 3**	
0.303	0.400	−0.099	0.636*	−0.203	−0.413	0.243	0.492	−0.203	

**The maximum amount of p. EEG: Electroencephalography

ability and focus. In other words, as the noise level rises, it will have a negative and more significant impact on focus. One of the explicable viewpoints avers that exposition to low‑ or high‑level noise is likely to hinder the brain's stability. Stress is any internal or external provocation that is perceived by human. When the provocation is more complex and intense, mental and physical performance might be impaired. Stress compromises human efficiency and has close ties with mental and physical issues. It could create negative feelings such as anxiety and depression, and more serious stress could cause mental disruptions such as anxiety issues and melancholy.[37] In an indoor situation and amidst a stressful situation, each individual has a different physiological, emotional, or behavioral reaction.[38,39] In a study by Selye H, the EEG signals were used as a new method for the analysis of stress‑inducing circumstantial factors. Using EEG to bypass the limitations of physiological evaluation methods is suggested[37] Melamed, Samuel *et al*. suggest an eclectic use of all the above to improve the evaluation of cognitive and mental stress.[40] Patricia Tassi *et al*. demonstrated that the Stroop effect and the performance of mental calculation in exposure to a 50 dBA noise has increased compared to a 70 dBA noise. Patricia Tassi *et al*. reported that exposition to noise higher than 85 dBA could cause vulnerability, exhaustion, and stress; a result in accordance with the present study.[41] The findings of Patricia E. C. Poulton *et al*. showed that exposure to noise decreases focus in people, a claim in concord with the study at hand.[42] The effects of exposure to high sound pressure level on cognitive performance could be linked to Poulton's provocation model, which claims that confronting noise will at first heighten cognitive performance, mainly to increase provocation to reduce noise's effect on cognitive performance. However, gradually, the provocation effect fades and the adverse effects of exposure to noise on cognitive performance begin.[43] The findings of the study at hand are explicable through the provocation theory. This theory poses that the activity level of the central nervous system (which alternates between sleep and vigilance) adjusts human's response to stimulants. Currently, there is no general agreement on the credibility of this theory, and some believe that it could not be used to describe the relation between exposition to noise and cognitive performance. Nevertheless, bearing this theory in mind, one could aver that however low or high provocation is, or with every degree of stress, performance faces a decline.[44] In previous studies, there were a number of paradoxical results about the effects of noise on cognitive performance. A number of studies posed that noise had improved cognitive performance,[45] while others concluded that it acted otherwise.[46] The findings of the present study demonstrate that the decrease in cognitive performance and brain signals in exposure to 85 dB noise was significant. This could have also been caused by psycho‑acoustic factors such as noise level, tonality, duration of exposition, and the type of noise. The importance of noise pitch and its effects on the brain's cognitive performance and activity has been emphasized in other studies.[47-49] Studies undertaken by

Allahverdy and Jafari demonstrated that the complexity of brain activity increases in medium frequencies and shows the effects of changes in frequency on brain activity.[50] The simplicity or complexity of the action is quite effective in the evaluation of cognitive performance. For instance, in comparison to simpler actions, more complex actions cause greater turbulence in cognitive performance. When individuals face noise, personal characteristics could be of noteworthy significance due to the fact that some individuals might experience a decline in cognitive performance while others might not, and some might even show symptoms of a rise in cognitive performance.[51] These causes are perhaps not so effective on this study to necessitate the analysis of the subjects' mental disruptions, cardiovascular disruption, and behavioral anomalies. Several dimensions of the brain's behavior and performance could merely be discussed based on the relation between neurons. All cognitive processes in the brain are undertaken via nervous activities such as synapses and spikes. Here, the analysis of brain signals demonstrated that frequency bands such as alpha and beta were affected by noise. With the increase in sound pressure level, the relative power of alpha increased and that of beta decreased. While various parts of the brain implement complex activities during the analysis and confrontation with noise, measuring changes in the temporal lobe was effective in evaluating stress. In the same vein, the relation of high-beta frequency which appears when individuals are negatively provoked was made clear. Studies have shown that the alpha and beta bands, respectively correlate with stress levels and rapid brain activities such as decision-making, analysis, and processing of data.[52] Increase in alpha demonstrates that the subject feels more relaxed after being exposed to noise, following which the decrease in alpha shows that he feels less tension or relaxation.[53] The comparison between alpha and beta bands in men and women and in 15, 25, 40-min intervals, shown in Figures 1 and 2, reveals a significant difference; after being situated in a noisy place, the decrease in the range of alpha bands and the increase in the range of beta bands were more in women than men. Because the alpha bands are in correlated with relaxation and the beta bands with focus, the results of our study show that men have more relax than women and the latter have more focus in noisy places than the former. Relax might come with stress and a noise-induced focus. Stress and relax signify emotional statements with opposite meanings.[54] A similar effect of noise on alpha and beta band have been reported in previous studies. This would mean that noise could induce stress in individuals. In fact, one of the ways of diagnosing stress is through brain signals, high range of beta bands and low range of alpha bands.[55]

In the study at hand, the average of unanswered and wrongly answered questions increased with a raise in n-back levels and extension of the duration of being exposed to noise, and this increase was only significant for the average number of the answered questions. The average number of correctly answered questions was reduced with a rise in n-back levels and the increase in the duration of exposition to noise. These results are in concord with the previous studies. For instance, Zheng-Guang Li *et al*. stated that exposition to noise causes an increase in reaction time and the possibility of error occurrence in field and laboratory studies.[56] Kristiane Roed Jensen *et al*. found a noteworthy effect of noise on memory.[20] A.Rabat *et al*. analyzed the impact of sound pressure level on the participants' short-term memory. They figured out the percentage of correct answers using a negative correlation.[57] Eva-Maria Elmenhorst *et al*. found that exposition to high sound pressure level, particularly when duties were medium or challenging in difficulty (levels 2 and 3 of n-back test), caused a major reduction in focus and professional memory.[58] Smith reported that the speed of encrypting new data and operating a response is interrupted when exposed to noise and therefore changes are caused in the individuals' performance.[59] Professional memory consists of encryption, summoning of data and appropriate conduct. Thus, as the complexity of an action grows, sound pressure level becomes responsible for distracting attention and processing of data within the memory, leading to a downfall in performance when undertaking cognitive duties. As a result, supervising several sources of information simultaneously in the presence of a distracting factor (noise) while doing a task becomes increasingly difficult. In simpler actions, a stimulating factor (noise), and on more complex levels, uniqueness, the newness of stimulant and distraction determine cognitive performance. In fact, when the burden on

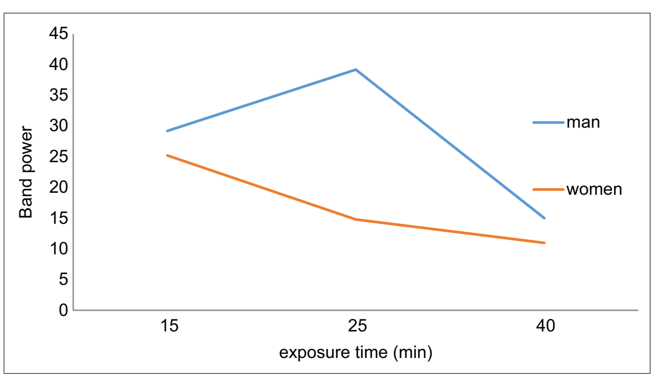

Figure 1: Comparison of the alpha band of men and women exposed to noise at different time intervals

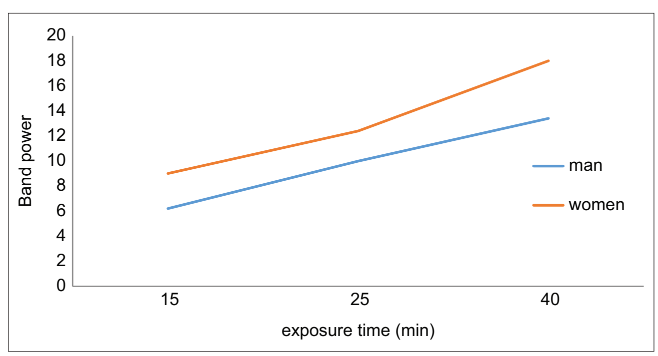

Figure 2: Comparison of the beta band of men and women exposed to noise at different time intervals

professional memory increases, focus and therefore resistance against distraction decreases and disturbing stimulants lead to the hindering of data processing. In relation to reaction time, results have shown that at the presence of loud noise and in comparison, to quietude, the average response time to stimulants increase (slower response), which could be the result of noise-induced stress and might have made the participant to respond with more latency. In a calm situation, focus and short-term's memory performance is better and reaction time grows faster. This is due to the absence of annoying noise.[60] These results are in accordance with Andrew P Smith *et al*.'s study, whereby the analysis of noise's effect on focus and short-term memory, they found that an increase in sound pressure level culminates in the extension of the duration of time to react.[61]

The strengths, weaknesses, and limitations of the study

Among the strengths of this study, we can mention the examination of cognitive performance parameters in the face of noise using the EEG Emotive-EPOC headset. In this study, there was no invasive method in conducting the tests, and the test was stopped when the subjects felt tired. There are better and more efficient tools to check the memory level such as simple, complex, and meaningful Stroop software tests, but in this research, we were not able to prepare them due to financial problems. In this study, due to the outbreak of COVID-19, some people did not attend the study and it was difficult to find the cooperation of some people.

Conclusion

The findings of the present study demonstrate that the decrease in cognitive performance and brain signals in exposure to 85 dB noise was significant. This could have also been caused by psychoacoustic factors such as sound level, tonality, duration of exposition, and the type of sound. In relation to exposure time, results have shown that in the presence of loud noise and in comparison, to quietude, the average response time to stimulants increase (slower response).

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Ethics code

The study was also approved by the Ethics Committee of Isfahan University of Medical Sciences, No. IR.MUI.MED.REC.1400.494.

Conflicts of interest

There are no conflicts of interest.

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