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THE INFLUENCE OF NOISE ON COGNITIVE PERFORMANCE

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ABSTRACT

Human performance is affected by several factors related to work and workplace conditions, including occupational noise. Work and mental performance measures including memory, attention, focus, and reaction time can be impacted by noise. Reaction time in response to a situation can significantly impact our lives because of its practical implications. Students' cognitive functioning is negatively impacted by environmental noise that invades the learning environment. The impact of noise elements on students' cognitive performance is examined in this study. High cognitive performance is needed by students, especially in lecture material that requires high memory. Aspects of cognitive ergonomics are included in this study because it examines how people interact with noisy environments. In this study, measuring cognitive performance was carried out by measuring reaction time, number memory performance, and sequence memory performance. The results of this study's statistical tests indicate that, both in the presence and absence of noise, gender had no discernible impact on reaction times, numerical recall, or sequence memory. The presence of noise can significantly reduce the performance of sequence memory. Number memory performance decreases in the presence of noise, but not significantly. The reaction time required to respond to the stimulus is longer in the presence of noise, but not significant.

Keywords: noise, cognitive ergonomics, number memory, sequence memory, reaction time.

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1. INTRODUCTION

1.1. Background

Environmental noise has numerous of effects on our daily life, ranging from emotional to motivational to cognitive. These effects are interrelated. Interference can arise when there is noise and simultaneous processing of visual and auditory information is required (Dohmen et al., 2023). The work environment can have an impact on memory performance in addition to body composition and general health. To promote improved memory performance, the settings and working atmosphere must be created appropriately (Putra et al., 2018).

Work and mental performance metrics including memory, attention, focus, and reaction time can be impacted by noise. Reaction time increases significantly after exposure to noise (Alimohammadi et al., 2015). Noise is considered a harmful factor to attention. It is hypothesized that exposure to noise will affect performance on attention, which can be measured by reaction time. Working memory activates the dorsolateral prefrontal cortex, while reaction time activates the brain stem. These two factors affect different sections of the brain.

Reaction time is the amount of time between the stimulus presented to the subject and their reaction to that stimulus (Cowart et al., 2021). Reaction time (RT) is a measure of how fast an organism responds to stimuli. RT in response to a situation can significantly impact our lives because of its practical implications. Fast RT can result in rewards (e.g. in sports) whereas slow RT can produce serious consequences, such as driving and road safety problems (Jain et al. 2015).

Human performance is affected by several factors related to work and workplace conditions, including occupational noise. One of the most prevalent workplace risks is noise, which has raised concerns due to potential health effects. It is also essential to understand that noise exposure has implications for more than just workers' health. It can also have negative effects on workers' well-being and performance. This can occur because noise reduces the amount of information processing resources available for the memory task, making it harder to accomplish complex tasks. Working memory has a limited capacity, thus noise raises the demand on it. Working memory processes are especially important when complex tasks are being performed, because participants need to process, store, and manage the necessary information (Monteiro et al., 2018).

Studies show there are potential adverse effects of noise on attentional cognitive function (Guo et al., 2023). One explanation for the effect of noise is that it can attract attention. When there are performance disparities between sound conditions and control conditions on serial short-term memory tasks, the sound effects become relevant (Sörqvist, 2015). Noise exposure is a problem in many work and non-work environments. Noise is known as an intruder in the work environment (Iranshahi et al., 2021). Environmental stimuli compete with cognitive stimuli that must be processed. Therefore, attention is divided between two stimuli, thus negatively affecting cognitive processing abilities (Jain and Wagani, 2019). Noise is one aspect of the work environment that affects work safety. Altered cognitive function leads to human errors and further increases accidents. Eventually, this may result in decreased productivity and performance. Noise can also reduce performance accuracy and working memory performance (Jafari et al., 2019).

The researchers came to the conclusion that prolonged exposure to noise at work might cause distraction from tasks and, as a result, cognitive impairment, which raises the possibility of mistakes. Noise, an unwanted and unpleasant phenomenon, causes physical and mental harm to human beings. The most important adverse effects of noise on humans include hearing loss, balance disturbances, cognitive dysfunction, and sleep disturbances. This unpleasant feeling may be associated with other feelings such as fear, anger, and reduced attention and concentration. According to Alimohammadi et al. (2019), noise can negatively affect employee health and organizational productivity due to its effects on individual cognitive function and disruption.

In a different study (Schlittmeier et al., 2015), background speech considerably decreased performance as compared to the silent condition. A lower performance is predicted by how

understandable the background speech is. When there's no understandable speech present, performance on memory tasks suffers. Furthermore, exposure to noise can have a negative impact on an employee's health and job happiness, as well as worse performance (Brocolini et al., 2016). Research indicates that people with reduced working memory and speech impairments are more vulnerable to the negative effects of noise (Liebl and Jahncke, 2021). The prefrontal cortex, which controls cognitive functions, can become dysregulated as a result of noise (Domhnaill et al. 2021).

Several studies consider sound to be distracting and worsen cognitive performance. To overcome obstacles at work and produce high-quality jobs, cognitive skills are required (Awada et al., 2022). But several other studies have shown an increase in response time to various stimuli. The effect is debatable (Prasad, 2014). Much evidence suggests that listening to sounds like music while performing cognitive tasks can negatively affect performance.

Previous research has shown that the sound of music played while information is being encoded has memory benefits if it is also provided while that information is being retrieved. This is also known as context-dependent memory (Echaide et al., 2019). Other research that supports this positive effect is white noise research. Compared to the silence group, the white noise group's average reaction time was noticeably faster. In that study, the Mann-Whitney test was applied to examine the potential effect of gender. There was no significant effect of gender on overall mean reaction time (Guo et al. 2023). There was an increase in performance on the subject's reaction time when recorded with both verbal heavy metal and instrumental music. With music volume that is in the comfort zone, it will increase performance in reaction time, but with an increase in sound volume, distraction effects may occur (Prasad, 2014).

However, in several other studies, the presence of music can have a negative effect. The results of the study (Echaide et al. 2019) show that listening to the same background music can have an impact on visual information's short- and long-term recall. The findings are explained by the struggle between brain hemispheres for few neurocognitive resources, with most tasks relying on just one. Therefore, in the context of capacity-limited cognitive systems, music can affect visuospatial memory more than verbal memory. When compared to volunteers who completed the memory task in silence, those who were listening to music performed worse on both immediate and delayed recall. These findings suggest that music significantly impairs visuospatial learning. There is a general trend of increasing reaction times (i.e. decreasing performance) with music. While statistical analysis proved the results were not significant, the trend found in case studies indicated that listening to music worsens reaction time (Cowart et al., 2021).

Exposure to noise will disrupt concentration through physiological responses to mental actions in the body and cause a significant increase in response time (Alimohammadi et al., 2019). High levels of noise intensity are observed to influence and diminish worker performance, as evidenced by the considerable difference in average reaction times between workers exposed to noise above and below the Threshold Limit Value (TLV) (Herqutanto et al., 2020). Noise can interfere with the concentration and focus of workers and can ultimately reduce productivity. The level of concentration reflects cognitive performance. Monteiro et al. (2018) found that errors escalate and reaction times extend in noisy environments. Other research, such as that by Jafari et al. (2019), corroborates these findings, demonstrating that noise exposure intensifies mental workload and diminishes visual/auditory attention.

Noise exposure affects the central nervous system causing emotional stress, anxiety, and cognitive and memory defects. A notable correlation exists between cognitive function and exposure to sound. Noise exposure is one of the factors that cause cognitive impairment in humans (Iranshahi et al., 2021). Noise directly affects subjective annoyance. Noise has a greater impact on performance in complex cognitive tasks compared to simpler ones, as indicated by Zhang and Ma (2022).

Zhang et al. (2018) found that environmental noise disrupts the learning environment, detrimentally affecting students' cognitive abilities, including reading, memory, and mathematical skills. Furthermore, regardless of their position, individuals performed significantly worse in working memory tasks when exposed to noise compared to quiet conditions. Tasks that

require more cognitive processing are negatively affected by noise. High noise levels can be detrimental to learning and academic performance (Sullivan et al. 2015).

Environmental noise has the potential to induce feelings of learned helplessness, particularly concerning motivation. The buildup of stress from inadequate environments and coping mechanisms may subsequently contribute to mental health issues in the future, as suggested by Dohmen et al. (2023). The children with typical development perform best in silent conditions and worst in noisy conditions (Chen et al., 2022). Prior studies have investigated how environmental noise influences individual attention within educational environments. It was found that higher environmental noise levels lead to lower accuracy and longer reaction times, as well as more serious attention disorders (Zhang et al., 2018). Zhang et al. (2021) discovered that moderate levels of noise, despite causing minimal stress, can significantly hinder learning and memory processes associated with the hippocampus.

In previous studies, the results showed that noise is one of the factors that can influence a person's performance. Humans will be able to carry out activities if they are supported by a good work environment to create effective, comfortable, safe, healthy, and efficient working conditions. A noisy work environment is not good for workers' health and can increase the length of working time (Padhil et al., 2018). In planning and designing work systems, it is necessary to pay attention to factors that can influence working environmental conditions, one of which is noise (Pawennari et al., 2018).

Based on these studies, the work environment can affect performance, especially in memory and reaction speed. Performance is a factor of success or failure of work activity. Good cognitive performance is needed and must be supported by a good work environment. The physical environment is an important factor, especially in jobs that require high concentration, memory skills, and reaction speed. The job requires a comfortable work environment free from distractions (noise). Hence, this study examines how the presence of noise factors affects students' cognitive performance. High cognitive performance is needed by students, especially in lecture material that requires high memory. The objective of this study is to ascertain whether the presence of noise diminishes, enhances, or bears no substantial impact on cognitive performance. Reaction speed and short-term memory serve as the metrics for evaluating cognitive performance in this research.

2. METHODS

This research begins by conducting a literature study. After the literature study was carried out, it was followed by making questionnaire instruments and conducting experiments. Questionnaires were distributed to respondents to obtain respondent profile data. The second stage is data collection, with noise and without noise conditions. Aspects of cognitive ergonomics are included in this study because it examines how people interact with noisy environments. Cognitive performance is measured by reaction time and short-term memory indicators. Reaction time is related to how long it takes the respondent after being given a stimulus in the form of an instruction. Short-term memory can be measured by measuring memory in the form of numbers or sequences where at each level the number of digits or sequences that must be memorized increases. The third stage is the stage of data processing, data interpretation, and drawing conclusions.

Respondents in this study were Industrial Engineering students aged 17 - 21 years. The students involved were 66 men and 66 women. Data was taken in two conditions, namely conditions without noise and conditions with noise. Only 119 of the 132 participants in this study completed the experiments for both the with and without noise conditions. The hypotheses in this study are that the presence of noise will reduce the performance of number memory and sequence memory, as well as the reaction time required to respond to a stimulus becomes significantly longer.

3. FINDINGS AND DISCUSSION

3.1. Findings

In this study, measuring cognitive performance was carried out by measuring reaction time, number memory performance, and sequence memory performance. Reaction time is calculated based on the time it takes the

participant to respond, which is calculated from the time the stimulus appears. When the red screen turns green, the participant has to click on the screen. Number memory is calculated by measuring the participants' short-term memory abilities. Participants are required to memorize digits. The higher the level the participants have passed, the more digits they have to remember. Sequence memory is calculated by measuring the participant's ability to remember the order of the square displayed, with a total of 9 squares. The higher the level that the participant has passed, the more sequences that have to be remembered. Reaction time, number memory, and sequence memory are measured when there is noise and without noise.

Based on the data that has been collected, the average reaction time needed to respond to the stimulus under conditions of noise is obtained as a result that women are higher than men, but not significant. Table 1 shows a comparison of cognitive performance in males and females.

Table 1. Comparison of Male and Female Cognitive Performance

	Male (Mean)	**Female (Mean)**	**p-Value**
Reaction time with noise	427.44	849.76	0.076
Number memory with noise	8.106	8.046	0.899
Sequence memory with noise	8.515	7.970	0.158
Reaction time without noise	656.88	555.71	0.267
Number memory without noise	8.301	8.300	0.650
Sequence memory without noise	9.051	8.469	0.166

The performance of male participants in remembering digits and sequences was higher than that of females, but not significant in conditions with noise and without noise. Table 2 shows the average performance of participants in conditions with noise and without noise.

Participants needed a longer average time to respond to stimuli in conditions with noise. Participants were able to remember digits better in conditions without noise compared to the presence of noise. Participants' average ability to remember sequences decreased when there was noise. This shows that the participants are distracted by the presence of noise, which causes the performance of remembering the sequence to decrease. Table 3 displays the results of the statistical test with and without noise conditions. Before determining the type of statistical test used to determine whether there is an effect of noise on cognitive performance, a normality test is needed.

Table 2. Average Participant Performance

	Mean
Reaction time with noise	601.87
Number memory with noise	8.1513
Sequence memory with noise	8.277
Reaction time without noise	496.487
Number memory without noise	8.303
Sequence memory without noise	9.08

Table 3. Statistical Test of Conditions with Noise and without Noise

	Positive Rank (Mean)	**Negative Rank (Mean)**	**p-Value**
Reaction time without noise-Reaction time with noise	57.73	59.98	0.167
Number memory without noise-Number	46.96	45.95	0.411

memory with noise			
Sequence memory without noise-Sequence memory with noise	53.12	45.59	0.033

The results of the normality test indicated that the data was not normal (p-value .000), so a non-parametric statistical test was performed. The data analysed were the same participant subjects but in different treatments, namely with noise and without noise. Because the research data is matched sample, the Wilcoxon Signed Rank Test was carried out. Statistical tests using the Wilcoxon Signed Rank Test were carried out to determine whether or not there is a significant effect of noise on reaction time, number memory, and sequence memory. The positive rank value at reaction time is smaller than the negative rank. The reaction time needed to respond to a stimulus in conditions without noise is smaller than the reaction time with noise but not significant. The positive rank value in the number memory is greater than the negative rank. The ability to remember digits was higher in the no-noise condition than in the noise condition but not significant. The positive rank value in the sequence memory is greater than the negative rank. Participants' ability to remember the sequence was significantly higher in the no-noise condition compared to the noise condition.

3.2. Discussion

Based on the data that has been collected, the average reaction time needed to respond to the stimulus under conditions of noise is obtained as a result that women are higher than men, but not significant. However, in conditions without noise, it was found that the reaction time for males to respond to stimuli was higher than for females, but not statistically significant.

The performance of male participants in remembering digits and sequences was higher than that of females, but not significant in conditions with noise and without noise. These data show that the overall the cognitive performance of male participants is higher than that of female participants, but not statistically significant. Hence, it can be inferred that there is no notable disparity in cognitive performance between men and women in both noisy and noise-free conditions. Based on Table 2 it can be concluded that the average performance of the participants decreased in the presence of noise.

In the absence of noise, participants exhibited notably better ability to recall the sequence compared to when noise was present. Sequence memory requires a high cognitive level because, in addition to remembering the location of the stimulus, participants also have to remember the sequence of the stimulus. Therefore, in conditions with noise, it can disrupt the participants so that the ability to remember the sequence decreases significantly at the 0.05 significance level.

4. CONCLUSION AND SUGGESTION

Drawing from the experimental findings and statistical analyses in this study, it can be deduced that gender does not exert a significant influence on reaction time, number memory, and sequence memory, regardless of the presence or absence of noise. In addition, there is a decrease in the average performance value of number memory and sequence memory in conditions with noise compared to conditions without noise. The average reaction time to respond to a stimulus with noise conditions is longer than without noise conditions. Based on the results of statistical tests, it shows that the presence of noise can significantly reduce the performance of sequence memory. Number memory performance decreases in the presence of noise, but not significantly. The reaction time required to respond to the stimulus is longer in the presence of noise, but not significant. This research encourages students to create a comfortable and noise-free environment when studying because noise can reduce students' cognitive performance, especially in sequence memory performance in students.

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