Original Article

Effect of Music on Working Memory of Female Operators Working in a Medical Infusion Set Assembly Company

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Abstract

Aim: With the increasing presence of individuals, particularly women, in the workplace, it becomes imperative to prioritize the well-being of employees. Numerous interventions exist to enhance working conditions, and one such intervention is the incorporation of music. This research aims to investigate the correlation between music exposure and the working memory of female operators employed in a medical infusion set assembly company. **Methods:** The study involved the assessment of 81 employees from the assembly unit of a company specializing in the production of infusion sets. The current research is an interventional study, the data of which were collected by the method of interview and cognitive tests (N-back test). The evaluation was conducted under two conditions: with background music and without background music. The research focused on assessing the working memory and productivity (task performance) of the participants. **Results:** The mean age of the participants in this study was 37 ± 33.09 years, with a mean work history of 0.2 ± 1.3 years. Furthermore, 56.7% of the participants were married. The results of the study showed that productivity was significantly better in the music-playing mode ($P = 0.005$). Furthermore, the results of the N-back test significantly showed an increase in correct answers in the condition of playing music ($P < 0.05$). **Conclusions:** The integration of background music in the workplace emerges as a beneficial factor, contributing to enhanced working memory and improved performance among female employees.

Keywords: Female worker, music, working memory

Introduction

Ergonomics encompasses a broad spectrum within the realm of human sciences. Within this scientific discipline, it is crucial to ensure that the workload aligns proportionally with an individual's physical capabilities, cognitive abilities, and inherent limitations.[1] Ergonomics is the scientific discipline that studies the interaction between people and other elements of a system.[2] Workload is typically classified into two categories: physical workload and mental workload. Physical workload arises when the demands of the task exceed the physical capabilities of the workers. On the other hand, mental workload pertains to the disjunction between the cognitive demands of a task and the mental capacities of the workers, often linked to their fatigue.[1]

The exploration of mental workload falls under the purview of cognitive ergonomics, a specialized field that places emphasis on understanding and optimizing cognitive performance. Within the study of cognitive ergonomics, particular focus is directed toward various cognitive functions integral to human tasks. These functions encompass sustained attention, comprehension, reaction speed, accurate information processing, and sound decision-making, all of which are pivotal in the execution of numerous tasks.[3] Among these cognitive functions, continuous attention and reaction time stand out as particularly crucial.[4]

Continuous attention involves the capability to analyze pertinent data while disregarding incorrect or irrelevant information.[5] Attention can be quantified by considering the frequency of errors made during a test. In this context,

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heightened attention during a test correlates with a decreased number of errors. Reaction time, on the other hand, signifies the duration it takes for an individual to comprehend a situation and formulate a response.[6] Numerous professions are closely associated with this branch of ergonomic science, including but not limited to petrochemical industries,[7] the aviation sector,[8] the automotive industry,[9] drivers,[10] and assembly of parts.[11]

The assembly of parts constitutes a production process wherein components, often replaceable, are sequentially added to the final product during each stage. This production line represents an area where cognitive ergonomics significantly influences both performance and work quality. Assemblers are not confined to a mere sequence of construction tasks; their responsibilities extend to interpreting new information, solving problems, navigating social interactions, prioritizing, and engaging in continuous on-the-job learning.[12] Ensuring a consistent, timely, and high-quality assembly of products is of paramount importance for manufacturers to meet customer satisfaction. Simultaneously, the imposition of high physical pressure poses a threat to the quality of the assembly process.[13-16]

In summary, cognitive load can hinder task performance, leading to assembly errors, wasted time, and increased frustration. Unfavorable working conditions may contribute to distractions, stress, and exhaustion, posing a threat to successful assembly outcomes and the well-being of workers.[11]

One of the determinants influencing cognitive performance in work environments is the impact of auditory stimuli. Unpleasant auditory stimuli, exemplified by the adverse effects of workplace noise, detrimentally affect cognitive performance, potentially exacerbating attention and reaction time disruptions for operators.[7] Conversely, favorable auditory stimuli, such as music, exhibit diverse effects on cognitive performance.[10,17,18]

The technological advancement in music playback has led to widespread use in various settings, including cars, stores, and offices.[19,20] In recent years, workplace music has garnered increased scientific attention, with research demonstrating a positive correlation between workplace music and task performance as well as various components of employee performance.[21] Contrarily, studies have indicated that background music can impact cognitive factors like attention, concentration, and memory.[17-22]

For instance, a study involving 100 operating room workers revealed that a majority acknowledged the benefits of music, such as enhanced cognitive functions, increased happiness and mood, and a calming effect on surgeons, leading to improved work efficiency and reduced stress responses.[23] In general, it is suggested that programs requiring memory or tasks involving active memory should be undertaken while playing music to enhance cognitive performance.[24] However, research outcomes regarding the effect of music on memory are not uniformly positive, as demonstrated by Huang and Shih's study, which found no significant relationship between background music and focused attention in workers.[25] Despite extensive investigations into the impact of music on human performance across various disciplines, the consequences of playing music in the workplace remain uncertain.[21] Conclusions about the effect of background music on attention require further research and in-depth investigations.[24]

Research findings also indicate that music has the potential to alleviate stress and fatigue. Music and music therapy approaches are extensively employed in both clinical and nonclinical settings to enhance psychological well-being, cognitive functions, and behaviors, and overall improve people's mental health.[26]

However, most studies in this domain have been conducted in controlled environments, such as hospitals or among students and drivers at predetermined times. Notably, there has been a notable absence of specific studies on the impact of music on assembly workers, particularly female workers.

In the assembly industry, characterized by the monotonous and repetitive nature of tasks, the significance of cognitive ergonomics becomes paramount, given the combination of repetitive physical work and worker fatigue. Given the established importance of music in reducing stress and fatigue in previous studies, the current research aims to investigate the impact of music as a positive auditory stimulus on the memory and task performance of employees in the workplace. The goal is to potentially enhance the well-being and overall performance of employees, with a specific focus on female workers. By managing cognitive performance improvement, alongside stress and fatigue reduction, there is an intention to take proactive measures for employee health within workplace settings.

Materials and Methods

Study design

The present study is an interventional research, conducted among female assemblers employed in the medical equipment manufacturing industry, specifically in the production of infusion sets in Isfahan city. Within this industry, 92 female assembly workers are engaged in an 8-h work period. According to Taheri *et al*.'s study,[24] which was conducted to investigate the effect of music on cognitive performance, the mean and standard deviation of hand skill score in the first group (without music) was 1.74 ± 16.5, and hand skill in the second group (with music) was 1.84 ± 17.75 (26), and by calculating the effect size of 0.69 according to these parameters, the minimum sample size required in the study in terms of the first type error of 0.05 and the test power of 80%, using G*Power software (latest ver. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düs- seldorf, Germany; http://www.gpower.hhu.d) and paired *t*-test in this software, at least 20 people were determined for each group (a total of 40 people).

Participants were selected based on adherence to entry and exit criteria, which included abstaining from caffeine consumption for 8 h before the test, refraining from medication, being

right-handed to eliminate the dominant hand effect, ensuring adequate rest and sleep the night before the test, maintaining general health, and not being in the menstrual period. A total of 81 workers met the specified criteria and participated in the implementation stage of the study. Data collection employed various methods, including direct observation of the work process, interviews with both assembly workers and unit supervisors, and cognitive tests. The research methodology unfolded through the following steps:

- Collection of demographic information from the participants
- Assessment of cognitive status using the active memory test (N-back)
- Measurement of task performance by quantifying the number of quality products and gathering information from the quality control unit of the industry.

The procedure involved initially gathering demographic information from the participants. Subsequently, the employees carried out their regular work routine. During this period, classical music (specifically Mozart) was played through a loudspeaker in the production unit, and the sound pressure level was adjusted within the range of 55–65 dB. The N-back cognitive test was administered on-site at the participants' workstations both at the beginning and end of the work shift. Finally, the assessment of task performance was conducted by tallying the number of products assembled with quality, adhering to the quality criteria set by the quality control unit of the industry. This entire process was executed in two distinct modes: one with the presence of music and the other without music.

The intervention in this study involved utilizing a piece of classical music without lyrics, which was played through a loudspeaker with uniform loudness for all participants during the intervention phase. Considering the serene and quiet nature of the study environment in the target industry, a frequency range of 55–65 dB, encompassing both the music played and background noise, was employed. The equivalent sound pressure level was measured using a calibrated sound level meter (specifically CEL 110/2 calibrator manufactured in the UK), model TES 1351B, and in accordance with the ISO 9612–2009 standard.

Infusion set parts assembly industry

The medical equipment manufacturing company in question was founded in 2009. The company has expanded its operations by establishing a cleanroom production unit. This development has enabled the production of high-quality infusion sets that adhere to international standards. Within the industry, individuals are responsible for assembling and packaging the components of the incoming infusion set from the injection department during an 8-h work shift. The average time allocated for each step in this process is illustrated in Figure 1.

Evaluation of cognitive status using active memory test (N-back)

The N-back test, primarily employed to measure memory, will be utilized in this study to evaluate working memory. This test is designed to assess executive function, a cognitive process frequently investigated in neuroimaging studies to stimulate brain function and was initially introduced by Kirchner in 1958.[27] The N-back test evaluates the ability to process, select, and store information within a very brief timeframe. During the test, a total of 120 digits are displayed on the screen over a 5-min period, with an interval of 1500 ms between each digit. The N-back test can consist of 1 to N steps. For instance, in a two-stage N-back test, the first stage, known as 1-back, requires participants to immediately compare two consecutive digits displayed on the screen. If the two numbers are identical, participants press the designated answer button on a specialized keyboard. The dependent variables recorded in this test include reaction time and the average correct answers.[28] The output of the N-back test comprises the duration of completion and the accuracy of responses. In this study, the 1-back type of this test was used. In this way, by looking at the monitor screen, the participant must make sure that the number shown in the image is the same as the previous number between the two numbers displayed. Press the desired button on the keyboard, and finally, the output of the system will be determined as the number of correct answers and the test time for each participant.

Evaluating productivity through task performance measurement

At the conclusion of the work shift, task performance was assessed in two test modes: one with the presence of music and the other without music. The evaluation involved counting the number of quality products assembled during the shift. Information for this assessment was gathered from the quality

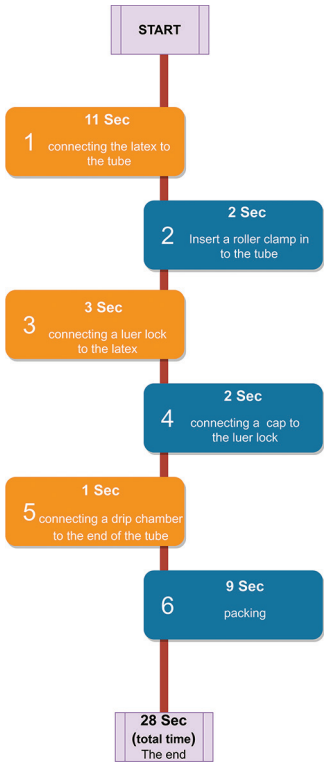

Figure 1: Production process

control unit of the industry under study. This approach aimed to compare and analyze the impact of music on the quantity and quality of the products assembled by the participants during their work shifts.

Data analysis

Data analysis was done through SPSS V.22 (made by SPSS Inc. in USA) software. Descriptive statistics indicators (frequency, percentage, mean, and standard deviation) were used for data analysis. Furthermore, the Kolmogorov–Smirnov test was used to check the normality of the data. In addition, Pearson's correlation coefficient test was used for normal variables, and Spearman's correlation coefficient was used for non-normal variables. Furthermore, the Chi-square test was used to evaluate the relationship between two qualitative variables, an independent *t*-test was used to compare a quantitative variable between two different groups, and a one-way analysis of variance was used to evaluate quantitative variables among different groups. The significance level for this study was set at < 0.05 ($P \leq 0.05$). In addition, it was noted that all variables in the present study exhibited a normal distribution.

Results

Demographic information of participants

The mean age of the participants in this study was 37 ± 33.09 years, with a mean work history of 0.2 ± 1.3 years. Furthermore, 56.7% of the participants were married. The results presented in Table 1 indicate that the average cognitive performance and working memory initially decreased at the beginning of the working hour under conditions with music. However, these measures increased by the end of the working hour, coinciding with the continuous playing of music.

Investigating the relationship between playing music and working memory

The findings presented in Table 2 reveal a significant difference between the conditions with and without music at the end of the work shift, with improved results observed when music was played. While there was no significant difference in the time spent at the beginning of the work shift between music and no music, a notable difference emerged at the end of the work shift, indicating a reduction in time in the music mode. Specifically, in the music mode, there was a significant improvement in results between the beginning and end of the work shift. Furthermore, in the absence of music, there was a significant difference in the results between the start and end of the shift, with a decrease in correctness rates. In addition, there was a significant difference in the test duration, which increased without music.

Investigating the relationship between music and productivity

The outcomes presented in Table 3 demonstrate a significant difference in productivity between conditions with and without music, with a significance level below 0.05. Productivity was found to be higher in the mode where music was played compared to the nonmusic mode. This suggests that the presence of music during the work shift is associated with increased productivity among the participants in the study.

Table 1: Scores of N-back test

	Working memory	
	With music	Without music
Beginning of working hours (mean±SD)	926.53±137.51	902.63±114.31
At the end of working hours (mean±SD)	897.73±110.34	977.81±113.85
Total (mean±SD)	912.3±114.09	940.72±95.00

SD: Standard deviation

Table 2: The results of the relationship between playing music and working memory

	Without music, mean±SD	With music, mean±SD	*P*
N-back test			
N-back_output			
Beginning of time	56.51±2.47	56.74±2.48	0.446
End of time	55.25±2.09	58.29±2.09	0.000**
P (time work)	0.004**	0.000**	
N-back_duration			
Beginning of time	847.12±113.67	869.79±138.03	0.325
End of time	922.57±113.17	839.43±110.29	0.000**
P (time work)	0.000**	0.100	

**Significance level was considered $P<0.05$. SD: Standard deviation

Table 3: The results of the relationship between productivity and playing music

	With music	Without music
Efficiency		
Mean±SD	1001.85±40.50	1006.79±29.53
P	0.005	

SD: Standard deviation

Discussion

The findings from the N-back test indicated a clear improvement in results when music was played. In addition, in the absence of music, the test duration increased at the end of the shift. These outcomes align with the hypothesis that music enhances the working memory of participants in the workplace. The results of this study are consistent with the findings of Shirin Taheri *et al*. In their research, Taheri *et al*. investigated the impact of background music on cognitive and skill performance in the workplace, taking into account gender and personality type (introvert/extrovert). They concluded that music significantly enhances working memory, resulting in an increase in the number of correct answers and a decrease in response time when music is played.[24] Furthermore, Bugter and Carden explored the effect of different music genres and silence on a memory task involving 60 participants. Their findings indicated that silence had no impact on performance,

while classical music improved performance compared to rap.[29]

However, Christopher and Shelton's study did not identify a significant relationship between working memory and the presence of music.[30]

The examination of participants' productivity in two modes, playing music and not playing music, revealed that playing music improved the performance of workers and increased productivity in assembly operations. These results are in line with the findings of Jamshidzad *et al*. In their study, conducted with 64 students, a 2-hand coordination test was performed in both music and nonmusic conditions. The study concluded that listening to music enhances the speed of performance, with faster-paced music, such as pop music, leading to even greater speed improvement.[31] However, it is worth noting that not all studies consistently support the positive impact of music on performance. For example, one study focusing on simulated endoscopic surgery tasks found that surgeon performance was worse in a musical environment, where the primary task involved surgery simulation and the secondary task was a modified speech-in-noise test.[32] These mixed results suggest that the influence of music on performance can be task-specific and influenced by various factors, including the nature of the task, the type of music, and individual differences.

The focus of the present study on female workers provides an opportunity for future comparisons with male workers. However, it is essential to acknowledge certain limitations in the study. First, the investigation involved only one type of music, and the participants did not have the opportunity to express their preferences regarding the type of music played or the intensity of the music. These limitations highlight potential avenues for future research that may explore the impact of different music genres or individual preferences on cognitive and task performance in the workplace. A more diverse range of music options and the consideration of individual preferences could contribute to a more comprehensive understanding of the potential effects of music interventions in various work settings.

Conclusions

The findings of the present study suggest that music can positively impact the cognitive performance of female workers. Specifically, the results indicate that in tasks involving active memory and repetitive activities, incorporating music can contribute to enhanced working conditions and cognitive performance. The research also highlights the potential benefits of music in improving skill performance, suggesting that playing music in workplaces where tasks involve manual skills may be advantageous. However, it is important to note that the study focused exclusively on female workers, and the potential impact of music on the ergonomic abilities of male workers remains unexplored. In addition, the role of personality type in influencing the effects of music on cognitive and task performance was not investigated, presenting areas for further research. Future studies that include a broader range of participants, explore the gender-specific effects of music, and consider individual differences such as personality type could provide a more comprehensive understanding of the nuanced relationship between music and workplace performance.

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Ethics code

This study received approval from the Ethics Committee of Isfahan University of Medical Sciences under the reference number IR.MUI.RESEARCH.REC.1402.107 and IRCT20231220060479N1 code.

Conflicts of interest

There are no conflicts of interest.

Authors' contributions

Melika Abbasi: Data curation, Investigation, Visualization, Writing original draft, Writing review and editing; Reza Esmaeili: Formal analysis, Methodology, Supervision, Validation, Visualization, Writing original draft, Writing review and editing; Siamak Pourabdian: Conceptualization, Methodology, Writing review and editing; Mahnaz Shakerian: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Supervision, Validation, Writing review and editing;

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