The Effect of Music on Working Memory Performance in Noisy Simulated Open-Plan Offices: An Experimental Study

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Abstract

Background: In open-plan office environments, irrelevant speech noise (ISN) is a common complaint among employees, leading to reduced performance. This study aimed to assess the impact of music on the working memory performance of individuals exposed to ISN in simulated open-plan offices. Additionally, we sought to examine any differential effects of music between male and female participants.
Methods: In this experimental study, participants were selected through convenient sampling. Their working memory performance was evaluated using n-back (n=1, 2) tests conducted with software while they were exposed to irrelevant speech noise (ISN) alone and a combination of ISN and music. Sampling took place over one month during the spring season in the acoustic laboratory of the Faculty of Health in Shiraz, Iran.
Results: Thirty students, including 15 females, with an ags range of 18 to 38 (Mean=25.27, Standard Deviation=6.03), participated in the study. The results showed a significant increase in the accuracy of participants' responses to both simple and difficult tasks of the n-back (n=1, 2) test when music was played compared to the ISN-only condition. However, there was no significant difference between the conditions regarding reaction times in the working memory test.
Conclusion: In the present study, the inclusion of music, specifically "For Elise," emerged as a crucial factor in enhancing working memory amidst the presence of open-plan office noise. This finding underscores the potential of utilizing music as an effective strategy for improving cognitive performance in such environments. Given its cost-effectiveness and simplicity of implementation, incorporating background music like "For Elise" can be recommended as a favorable method for mitigating the negative impacts of noise in open-plan offices.

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Introduction

Open-plan offices have become popular in developing countries due to financial problems and the optimal use of available space.[1] Shared offices are joint offices between two and six employees, while open-plan offices refer to joint offices of more than six employees.[2] Consequently, people face the same environmental factors.[3] The open-plan design in office environments has valuable benefits, such as facilitation of communication and interactions between employees, enhancement of job satisfaction, job performance, and teamwork effectiveness.[4] There is no personal space or wall between individuals in open-plan offices, and the workplace is separated only by partitions.[5] Although this open-plan design of offices has facilitated communication between the staff and clients, it has led to's the staff dissatisfaction due to exposure to background noise and lack of privacy.[6, 7] Background sounds cause distraction and impair the focusing of attention in open-plan environments.[8-10] In particular, irrelevant speech noise (ISN) has been reported as the most annoying source of noise by office workers.[11] ISN is the noise generated from conversations between colleagues, telephone calls, and laughter.[12]

Noise is a common complaint of employees in open-plan office environments which reduces the employees' performance.[9] Noise at work is often caused by telephones ringing, air conditioning equipment, office machinery, the individuals' voices,[10] and exterior traffic noises.[13] In particular, irrelevant speech noise (ISN) has been reported as the most annoying source of noise by office workers.[11] ISN is the noise generated from conversations between colleagues, telephone calls, and laughter.[12] Results from a study on the effects of ISN in the workplace with 1078 individuals, among whom 55% worked in shared offices and 45% in open-plan offices, indicated that ISN increased noise annoyance, decreased work performance, and increased symptoms relating to mental and physical health in open-plan offices compared to shared offices.[9]

Memory is the process through which acquired information is stored and retrieved via learning.9 Working memory involves retaining and processing information over a short period.[14] Previous studies have indicated that continuous exposure to irrelevant speech noise (ISN) in open-plan offices hampers information retention in working memory.6 Additionally, exposure to background noise in such environments can lead to complications like fatigue, headaches, difficulty concentrating, psychosocial stress, reduced motivation, and increased cognitive workload among employees.[9] Therefore, studies have been conducted on reducing the effects of ISN in open-plan offices. Some studies have turned to ways to reduce and control the annoying ISN, while others have focused on using other intervention techniques such as music to enhance employees' working memory and performance in open-plan office environments.[15-17] Previous research has shown that music can affect individuals' attention, learning, and working memory.[18, 19] However, the study findings were on the effect of music on working memory. For example, the results of one study showed that three categories of sound (human, animal, and music) affected the n-back (n=1, 2) working memory tests.[20] Likewise, the positive effect of playing music during surgery on the working memory performance of the surgical team was observed.[21] However, comparison of the mean n-back parameters revealed no significant difference in working memory performance in the three activities of eyes-open resting, listening to music, and playing the video game.[22]

Practically, it is essential to reduce and control the detrimental effects of ISN on employees' working memory and job performance in open-plan office environments. Accordingly, interventions have been made using noise isolators[1] or noise absorption[10] to reduce and control the effects of the annoying ISN. However, these are costly interventions and challenging to install in developing countries, such as Iran, because of financial problems.

The objective of this study is to assess the impact of music, a cost-effective and easily implementable intervention, on the working memory performance of individuals within simulated open-plan offices exposed to irrelevant speech noise. Additionally, we aimed to examine any differential effects of music between male and female participants.

Methods

Participants

This is an experimental intervention study conducted from 17 April to 19 May 2021 during the spring season in the acoustic laboratory of the Faculty of Health at Shiraz University of Medical Sciences (SUMS), Iran. The sample size, estimated at 30 participants, was determined based on a 0.5 effect size and 0.90 power. To ensure unbiased distribution, participants were randomly assigned to two groups: one exposed to irrelevant speech noise with music and the other without music. The convenient sampling method was used to select the participants from among students at the Faculty of Health, based on self-reported eligibility criteria.

Inclusion criteria were good hearing and mental health, absence of drug or alcohol addiction, and right-handedness to eliminate the dominant hand effect. Exclusion criteria included ear surgery within six months of the study, recent cold symptoms to ensure good hearing health, and abstention from caffeine, alcohol or drugs within 24 hours prior to the study. Participants received a gift as a token of cooperation.

The study was reviewed and approved by the ethics committee for research on human experimentation at Shiraz University of Medical Sciences (IR.SUMS.REC. 97-01-21-17470). Before the test, participants were briefed on the study objectives and procedures, provided written informed consent, and were free to withdraw from the experiment at any time. The research was conducted in accordance with relevant guidelines and regulations.

Working Memory Test

The n-back test, designed by Sinapsycho in Iran, is widely used for evaluating visual memory performance. This instrument assesses individuals' ability to process, select, and retain information in a short period. In the current study, the computerized version with n=1 and n=2 was utilized. During the test, 120 digits were sequentially displayed at the center of a computer screen, with intervals of 1500 ms, and the entire process lasted for four minutes. Participants were instructed to press the response button on the keyboard immediately when two consecutive numbers were the same. The dependent variables were the number of correct answers and the mean reaction time (for both true and false responses).[23, 24]

Karolinska Sleepiness Scale

The Karolinska Sleepiness Scale (KSS) was completed to measure sleepiness on a self-reported basis. This test has good validity and reliability.[25] The KSS spans 9 levels (1=extremely alert, 2=very alert, 3=alert, 4=rather alert, 5=neither alert nor sleepy, 6=some signs of sleepiness, 7=sleepy, but no effort to keep awake, 8=sleepy, some effort to keep awake, and 9=very sleepy, great effort keeping awake, fighting sleep.

The Music

This study used the familiar and popular instrumental classical music "For Elise" (It is the English translation of the song originally titled, "Für Elise") by the famous composer Ludwig van Beethoven as the intervention. This instrumental piece is arranged and played on a solo piano. The one-minute audio track of this music was played repeatedly with a rhythm of 120 beats/min during practice and intervention sessions.

Experimental Design

In the present interventional study, a simulated laboratory environment was prepared. An acoustic chamber with dimensions of 5×3×3 m and an absorption coefficient of 0.9 was chosen as a laboratory environment to control the external noise. It is important to note that the background noise level within this controlled environment was consistently maintained at approximately 40 dB, ensuring a standardized auditory background throughout the study. The laboratory temperature was moderate (about 25°C), and other environmental variables, including light and humidity, were also controlled. Participants could wear what they wanted. The recorded noise of open-plan office environments was used to simulate the pre-intervention conditions (ISN of open-plan offices). In a study by Pierrette et al., the mean noise intensity of open-space offices ranged from 49 dB (7.9×10^{-8} W/m^2) to 56 dB (3.9×10^{-7} W/m^2).[26] Accordingly, the intensity of ISN of open-plan office spaces was set at 56 dB (A) to represent the noise peak during busy working times. Therefore, before each session, the noise level was measured so as not to deviate from this level. The noise was played through 2 speakers (1 m height from the floor) with 3D playback and response frequency of 150 Hz-20 Khz within 1 m of the participant. Music was also played as an intervention by two speakers (1-meter height from the floor) connected to a laptop at a distance of 5 meters from the participant. Figure 1 shows the results of the frequency analysis of music and ISN.

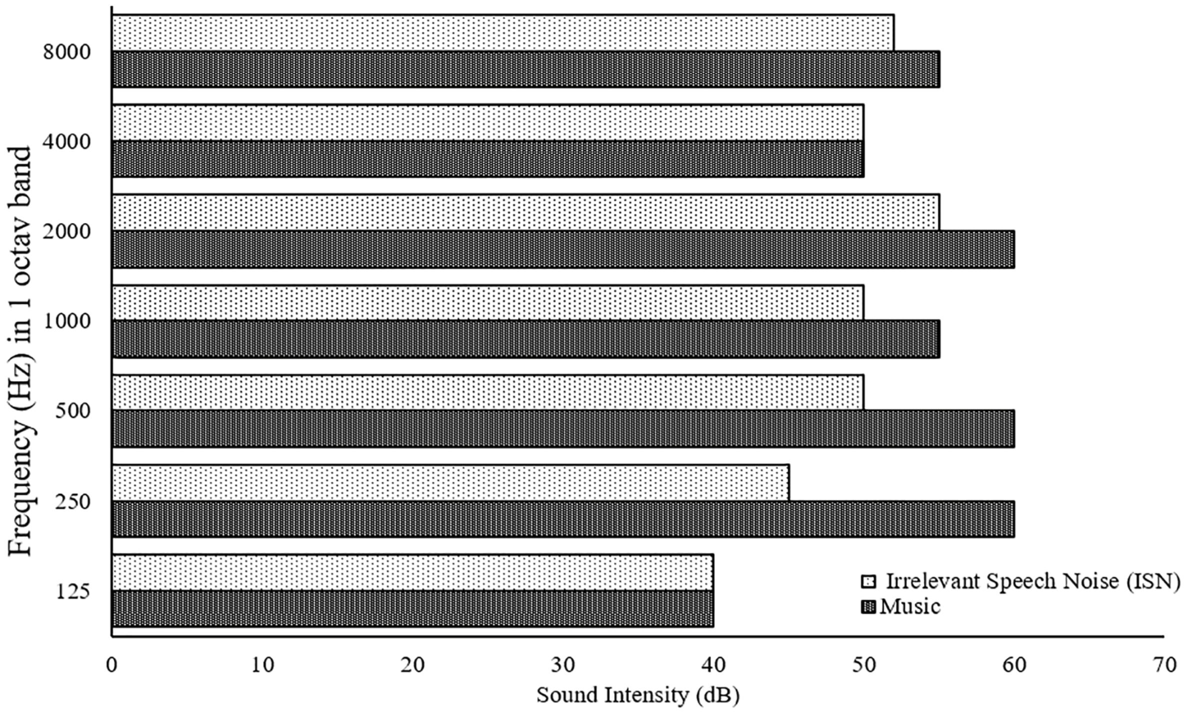

Figure 1: Frequency spectrum of music and Irrelevant speech noise (ISN)

To avoid masking, the music was played with a pressure level of 5 dB more than the background ISN (simulated open-plan office noise). The sound intensity before each test was measured using a CEL-430 sound level meter. The n-back working memory test at two levels, simple (1-back) and complex (2-back), was displayed on the computer platform (Lenovo laptop). Figure 2 shows the laboratory environment and set-up of equipment used in the study.

Procedure

Before starting the test, the participants filled out the Karolinska Sleepiness Scale (KSS). If participants reported a score of more than 3, the test was postponed to the next day, or the participants were excluded from the study. First, the demographic characteristics form was completed by each person. Then, participants were trained in how to perform each of the one and 2-back working memory tests (before performing any of these tests). Moreover, to ensure complete learning of the method and the readiness of the participants to start the test, each individual did the 1-back practice test once or twice and the 2-back practice test three to four times (Figure 3).

After ensuring the participants were ready, each individual performed the first stage of the experiment, which included 1 and 2-back tests with or without music in a random crossover to control the effect of confounding variables, including learning and fatigue (Figure 3). Hence, the participants performed the first stage (one of the paths A or B depicted in Figure 3) by pressing Enter (on the keyboard) with a 5-minute break between the two tests. At the end of the first phase, the participants rested for 5-10 minutes and then completed the second phase of the experiment, which consisted of the 1 and 2-back tests in the remaining laboratory condition (with or without music), and the experiment ended.

Each participant spent 16 minutes (8 minutes at each phase) performing the n-back tests (1 and 2-back), 22 minutes practicing (specific to the first phase), and 10-20 minutes completing the form or resting. In total, the length of the experiment (including both phases) was 45-60 minutes (Figure 3).

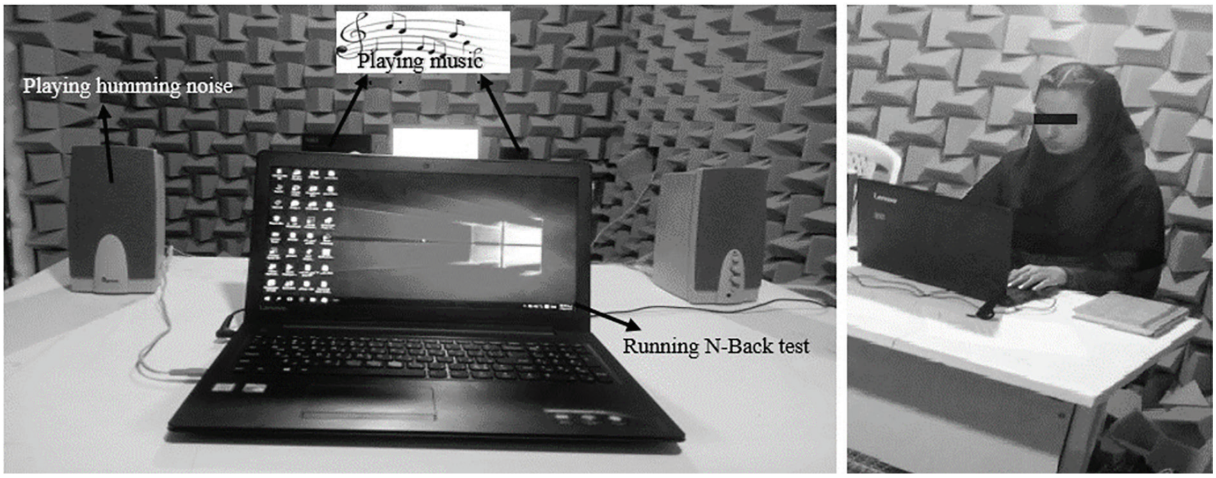

Figure 2: Simulated specifications in acoustic laboratory. This image was obtained by the authors

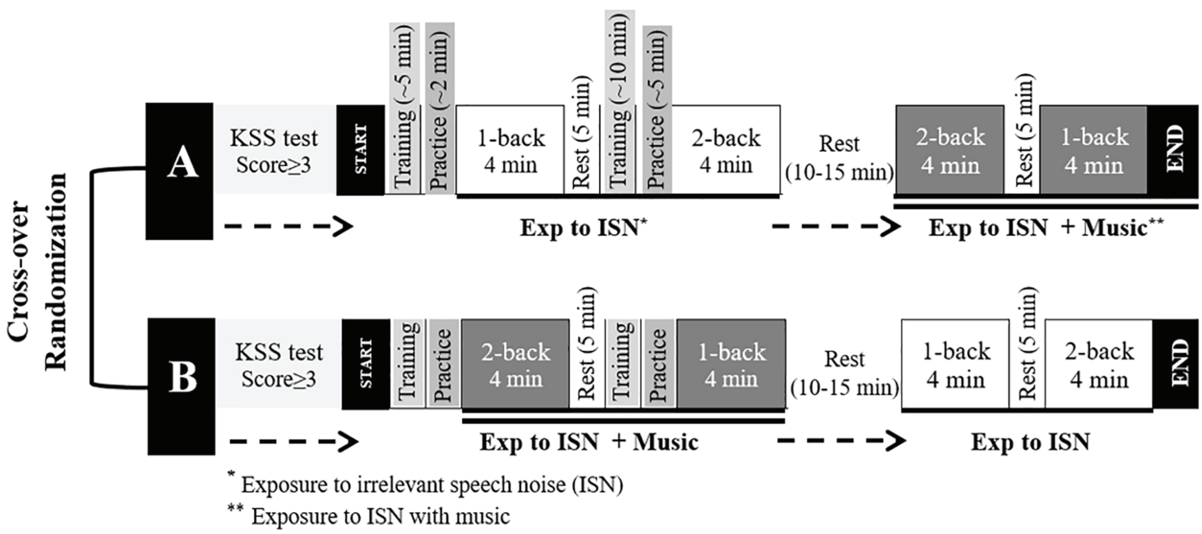

Figure 3: Chart of experimental design and protocol. KSS: Karolinska Sleepiness Scale; This figure was created by the authors

Table 1: Description of central indexes and distribution of working memory performance of participants exposed to ISN and music

Working Memory tests		Male (n=15)		Female (n=15)		Total (N=30)	
		Exp to ISN[a]	Exp to ISN+Mus[b]	Exp to ISN	Exp to ISN+Mus	Exp to ISN	Exp to ISN+Mus
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
1-back	CR[c] (n)	113.12 (2.3)	115.67 (3.3)	115.64 (2.15)	116.85 (2.5)	113.92 (3.5)	116.26 (2.9)
	ER[d](n)	6.40 (2.3)	5.27 (3.1)	4.67 (5.2)	3.20 (2.8)	5.53 (4.1)	4.23 (3.1)
	NA[e](n)	7.60 (28.3)	0.07 (0.26)	13.67 (24.4)	11.93 (24.5)	10.63 (26.1)	6.00 (18.1)
	RT (ms)[f]	517.57(139.5)	503.17(102.6)	567.53(114.6)	539.97(88.4)	542.55(128.0)	521.57 (95.9)
2-back	CR(n)	92.33 (14.73)	99.44 (7.87)	81.53 (30.3)	101.7(4.9)	86.93 (24.1)	100.56 (6.53)
	ER(n)	21.80 (13.0)	21.27 (12.6)	11.33 (9.1)	12.80 (10.1)	16.57 (12.2)	17.03 (12.0)
	NA(n)	9.67 (21.0)	1.93 (3.1)	27.13 (37.3)	27.87 (37.3)	18.40 (31.0)	14.90 (29.1)
	RT (ms)	644.40(228.8)	662.93(209.3)	689.13(111.5)	657.67(133.8)	666.77(178.3)	660.30(172.6)

[a]Exposure to irrelevant speech noise (ISN); [b]Exposure to ISN with music; [c]Number of Correct Response; [d]Number of Error Response; [e]Number of No answer; [f]Reaction Time (millisecond)

Table 2: Results of the analysis of the effect of music intervention on individuals' working memory in the laboratory with simulated ISN

Working Memory tests		Exposure to ISN[a]	Exposure to ISN[b] with music	P value[c]
		Mean (SD)	Mean (SD)	
1-Back	Correctness Response	113.92 (3.5)	116.26 (2.9)	0.002
	Reaction Time (millisecond)	542.55 (128.0)	521.57 (95.9)	0.273
2-Back	Correctness Response	86.93 (24.1)	100.56 (6.53)	0.004
	Reaction Time (millisecond)	666.77 (178.3)	660.30 (172.6)	0.783

[a]Exposure to irrelevant speech noise (ISN); [b]Exposure to ISN with music; [c]Paired t-test

Statistical Data Analysis

The variables were described by central tendency and dispersion indices. Then, the normality of quantitative variables was investigated using the Shapiro-Wilk test. Accordingly, the paired t-test was used to analyze the differences in working memory examined (using accuracy and reaction time parameters) with and without music. An alpha level of .05 was used for all statistical tests.

Results

Thirty students (15 females) in the age range of 18-38 (M=25.27, SD=6.03) participated in the present study. The central and dispersion indices of working memory test parameters (1 and 2-back) are presented in Table 1.

The results of paired t-test showed that the number of correct answers of the participants to the n-back test (1 and 2-back) in the music condition was significantly higher than the no music condition, 1-back: $t(29)=-3.38$, $P<0.05$, Effect size (Cohen's D)=0.62; 2-back: $t(29)=-3.11$, $P<0.05$, and Effect size (Cohen's D)=0.66. However, there was no significant difference in reaction time of the working memory tests between with and without music conditions, 1-back: $t(29)=1.12$, $P<0.05$, Effect size (Cohen's D)=0.22; 2-back: $t(29)=0.28$, $P<0.05$, and Effect size (Cohen's D)=0.24 (Table 2 and Figure 4).

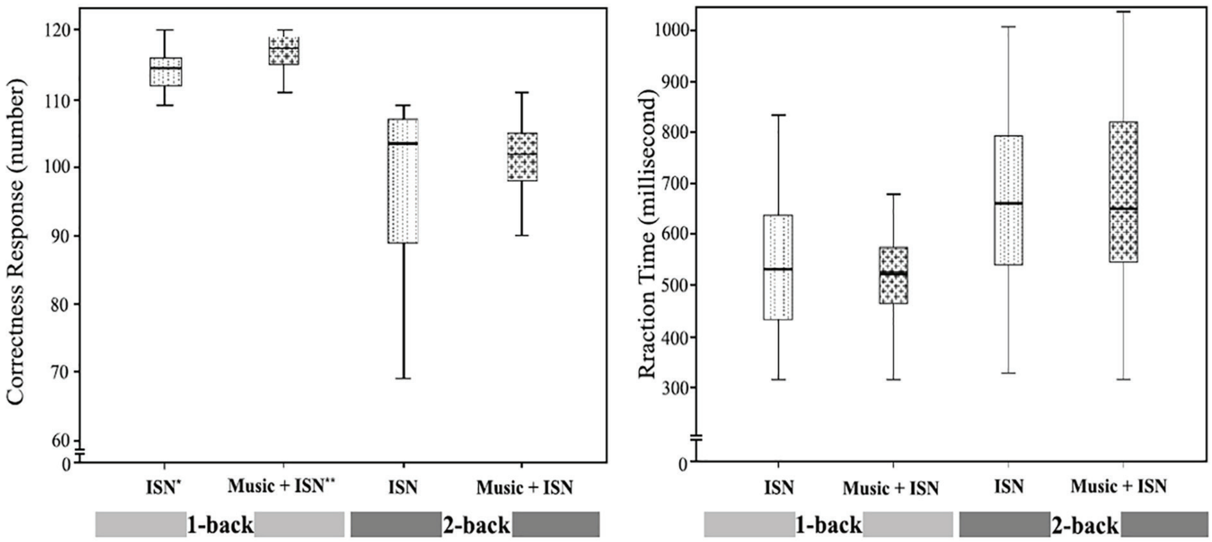

Figure 4: Mean Correctness response and reaction time of participants' responses in the n-back test. *Exposure to irrelevant speech noise (ISN); ** Exposure to ISN with music

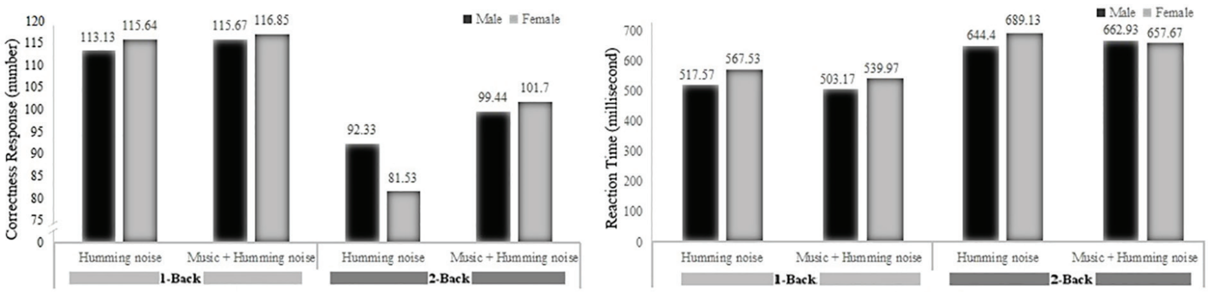

Figure 5: Mean correctness response and reaction time of participants in the n-back test under differentiation of gender

No significant difference was observed in evaluating the correctness response and reaction time parameters in terms of gender using the Independent t-test (P>0.05). Women only had a lower mean correctness of response to 2-back while facing the humming noise (before intervention) than men, but men had lower mean time of reaction to working memory test before and after the intervention (except for 2-back test in music playing) (Figure 5). The effect of music on working memory was also independent of gender, and the Paired t-test indicated no significant difference.

Discussion

Researchers have proposed two approaches to noise control of the environment based on the type of noise (uniform or variable), so that the uniform annoying noise can be decreased by high-frequency filtering, a method called low-pass filtering. A new source of sound can be created for variable noise that can compete with the background noise (babble-effect).[10] The present study used the babble-effect theory for the competition of the pleasant sound of music with office noise due to the variability of the ISN in open-plan office environments. Based on the present results, the correctness of participants' responses to working memory tests (1-back and 2-back) was significantly higher under music playing conditions than non-music playing conditions, and the effect of music on improving working memory in participants was gender-independent (Table 2 and Figure 4). This result is in line with a study that examined the effects of music on individuals' memory.[27] However, other research has found no effect of music on students' performance and working memory, which contradicts the results of the present study.[28] In the present study, the mean reaction time (gender-independent) was lower in both tests (1-back and 2-back) in the music compared to the noise condition, but the difference was not statistically significant (Table 2 and Figure 4). In general, the increased working memory load reduced the individuals' accuracy and speed of response to the n-back test.

In the present study, there was no significant difference in the correctness response and reaction time in terms of gender. Despite the fact that the women's mean correctness response in the 1-back test under both laboratory conditions (with and without music) was better than men, their working memory was more affected by humming noise and decreased significantly in the 2-back test in comparison with men (Figure 4). Women again underwent the complex working memory test better than men in terms of music playing.

Moreover, another study evaluated the effect of music training on working memory and concluded that musicians were more successful in performing working memory tasks than non-musician participants.[29] In the present study, instrumental and popular music were used along with ISN (recorded from open-plan office space), and the music was effective in increasing accuracy despite the existence of ISN.

This study has a few limitations that warrant consideration. Firstly, the music selected for the study was not tailored to individual preferences or acceptance; instead, a non-verbal and widely recognized music piece was used for all participants. Another limitation pertains to the laboratory setting in which the research was conducted, which may not fully replicate real-world open office environments. Additionally, participants were selected based on self-reported health status although efforts were made to ensure their adequate health levels. Nevertheless, it would have been advantageous to objectively measure certain health parameters, such as hearing, to enhance the rigor of participant selection. Given these limitations, future studies could explore the impact of music on employees within authentic open office settings for more comprehensive insights.

Conclusion

The study demonstrated that playing music, specifically "For Elise," had a notable impact on enhancing working memory performance in the presence of open-plan office noise. This finding is significant as it suggests that music can serve as a beneficial intervention to counteract the negative effects of noise in such environments.

Notably, the accuracy of participants' responses in both simple and difficult n-back tasks (with n=1, 2) significantly improved when music was introduced compared to when only office noise (ISN) was present. This improvement in accuracy indicates that music can help individuals maintain focus and cognitive control, even when faced with distracting background noise.

Moreover, although there was no statistically significant difference in reaction times between the music and ISN conditions in the working memory test, there was still an observable trend towards improved response speed with music. This suggests that while music may not drastically alter the response times, it can contribute to a subtle yet noticeable enhancement in processing speed.

Authors' Contribution

All authors read and approved the final manuscript. RK and MM contributed to the Conceptualization, Project administration, Formal analysis, and Writing – original draft. SM, AS and MM contributed to the Methodology and Writing – review & editing.

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Ethical Consideration

The ethics code (97-01-21-17470) was obtained from the Ethics Committee of Vice Chancellor for Research in SUMS.

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Conflict of Interest: None declared.

References

1 Shafiee Motlagh M, Golmohammadi R, Aliabadi M, Faradmal J, Ranjbar A. Acoustic Problems and Their Solutions in a Typical Open-Plan Bank Office. Ergon Des. 2020;28(1):24-32.doi: 10.1177/1064804618824897.

2 Pejtersen JH, Feveile H, Christensen KB, Burr H. Sickness absence associated with shared and open-plan offices—a national cross sectional questionnaire survey. Scand J Work Environ Health. 2011;37(5):376-82.doi: 10.5271/sjweh.3167.PMID:21528171.

3 Hong T, Chen C-f, Wang Z, Xu X. Linking human-building interactions in shared offices with personality traits. Build Sci. 2020;170(1):1-31.doi: 10.1016/j.buildenv.2019. PMID:106602.

4 Golmohammadi R, Aliabadi M, Nezami T. An Experimental Study of Acoustic Comfort in Open Space Banks Based on Speech Intelligibility and Noise Annoyance Measures. Arch Acoust. 2017;42(2):333–45. doi: 10.1515%2Faoa-2017-0035.

5 Edlom J, Skalen P. Understanding tensions in strategic communication practices: a strategy-as-practice study of the music industry. J Commun Manage. 2024. doi:10.1108/JCOM-02-2023-0021.

6 Ueda K, Nakajima Y, Kattner F, Ellermeier W. Irrelevant speech effects with locally time-reversed speech: Native vs non-native language. J Acoust Soci Am. 2019;145(6):3686-94.doi: 10.1121/1.5112774.

7 Henderson TL. Being in the Fishbowl: A Model for Complexity-Informed Emotional Intelligence in Open-Plan Office Spaces. World Sci Encycl Bus Story. 2024;3(2):233-54.doi: 10.1142/9789811280924_0012.

8 Acun V, Yilmazer S. A grounded theory approach to investigate the perceived soundscape of open-plan offices. Appl Acoust. 2018;131:28-37.doi: 10.1016/j.apacoust.2017.09.018.

9 Di Blasio S, Shtrepi L, Puglisi GE, Astolfi A. A Cross-Sectional Survey on the Impact of Irrelevant Speech Noise on Annoyance, Mental Health and Well-being, Performance and Occupants' Behavior in Shared and Open-Plan Offices. Int J Environ Res Public Health. 2019;16(2):280-97.doi: 10.3390/ijerph16020280.PMID: 30669442; PMCID: PMC6351961.

10 Seddigh A, Berntson E, Jönsson F, Danielson CB, Westerlund H. The effect of noise absorption variation in open-plan offices: A field study with a cross-over design. J Environ Psychol. 2015;44(4):34-44. doi:10.1016/j.jenvp.2015.08.004.

11 Hongisto V, Haapakangas A, Varjo J, Helenius R, Koskela H. Refurbishment of an open-plan office–environmental and job satisfaction. J Environ Psychol. 2016;45(3):176-91.doi: 10.3389/fpsyg.2015.01683.PMID: 26579055; PMCID: PMC4626555.

12 Kaarlela-Tuomaala A, Helenius R, Keskinen E, Hongisto V. Effects of acoustic environment on work in private office rooms and open-plan offices–longitudinal study during relocation. Ergon. 2009;52(11):1423-44. doi: 10.1080/00140130903154579. PMID:19851909.

13 Yu B, Chai Y, Wang C. Effect of the Exterior Traffic Noises on the Sound Environment Evaluation in Office Spaces with Different Interior Noise Conditions. Appl Sci. 2024;14(7):3017.doi: 10.3390/app14073017.

14 Kuschpel MS, Liu S, Schad DJ, Heinzel S, Heinz A, Rapp MA. Differential effects of wakeful rest, music and video game playing on working memory performance in the n-back task. Front Psychol. 2015;6(Article 1683):1-11.doi: 10.3389/fpsyg.2015.01683.PMID: 26579055; PMCID: PMC4626555.

15 Bharath M. Effects of Jazz Instrumental Music and Other Genres on Interaction between Reading Comprehension and Working Memory. Front Psychol. 2024;14(1140959).doi:10.31234/osf.io/8dsq9.

16 Nie P, Tillmann B, Wang C, Tervaniemi M. Impact of Native Language on Musical Working Memory: A Cross-Cultural Online Study. Music Percept An Interdiscip J. 2024;(41(4:262-74.doi: 10.1525/mp.2024.41.4.262.

17 Piccardi L, Palmiero M, Nori R. The Role of Sounds and Music in Emotion and Cognition. Brain Sci. 2024;14(3):192.doi: 10.3390/brainsci14030192.PMID: 38539581; PMCID: PMC10968495.

18 Chew AS-Q, Yu Y-T, Chua S-W, Gan SK-E. The effects of familiarity and language of background music on working memory and language tasks in Singapore. Psychol Music. 2016;44(6):1431-38.doi: 10.1177/0305735616636209.

19 Tumuluri I, Hegde S, Nagendra H. Effectiveness of music therapy on focused attention, working memory and stress in Type 2 diabetes: An exploratory study. Int J Yoga. 2017;10(3):167.doi: 10.4103/0973-6131.213471. PMID: 29422748; PMCID: PMC5793012.

20 Alain C, McDonald KL, Kovacevic N, McIntosh AR. Spatiotemporal analysis of auditory "what" and "where" working memory. Cereb Cortex. 2008;19(2):305-14.doi: 10.1093/cercor/bhn082.PMID: 18534993.

21 Oomens P, Fu VX, Kleinrensink GJ, Jeekel J. The effect of music on simulated surgical performance: a systematic review. Surg Endosc. 2019;33(9):2774-2784. doi: 10.1007/s00464-019-06868-x. PMID: 31140001; PMCID: PMC6684803.

22 Liu S, Kaufmann C, Labadie C, et al. Short-term effects of video gaming on brain response during working memory performance. PloS one. 2019;14(10). doi: 10.1371/journal.pone.0223666.PMID: 31600305; PMCID: PMC6786602.

23 Kazemi R, Alighanbari N, Zamanian Z. The effects of screen light filtering software on cognitive performance and sleep among night workers. Health Promot Perspect. 2019;9(3):233-40.doi: 10.15171%2Fhpp.2019.32.PMID: 31508344; PMCID: PMC6717920.

24 Kazemi R, Choobineh A, Taheri S, Rastipishe P. Comparing task performance, visual comfort and alertness under different lighting sources: An experimental study. EXCLI J. 2018;17(Oct 29):1018-29.doi:10.17179%2Fexcli2018-1676.

25 Kaida K, Takahashi M, Åkerstedt T, et al. Validation of the Karolinska sleepiness scale against performance and EEG variables. Clin Neurophysiol. 2006;117(7):1574-81.doi: 10.1016/j.clinph.2006.03.011. PMID: 16679057, PMCID: 16679057.

26 Pierrette M, Parizet E, Chevret P, Chatillon J. Noise effect on comfort in open-space offices: development of an assessment questionnaire. Ergon Des. 2015;58(1):96-106. doi: 10.1080/00140139.2014.961972. PMID: 25267561.

27 Ferreri L, Bigand E, Bugaiska A. The positive effect of music on source memory. Music Sci. 2015;19(4):402-11. doi: 10.1177/1029864915604684.

28 Christopher EA, Shelton JT, Cognition. Individual differences in working memory predict the effect of music on student performance. J Appl Res Mem Cogn. 2017;6(2):167-73.doi: 10.1016/j.jarmac.2017.01.012.

29 Gagnon R, Nicoladis E. Musicians show greater cross-modal integration, intermodal integration, and specialization in working memory than non-musicians. Psychol Music. 2020;49(4):718–34. doi: 10.1177/0305735619896088.