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The Effect of Music on Working Memory Performance in noisy Simulated Open-Plan Offices

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Abstract

The present study aimed to investigate the impact of music on working memory performance in noisy simulated open-plan offices. A simulated laboratory environment was prepared to evaluate the effect of music on individuals' working memory when exposed to irrelevant speech noise (ISN) conditions in open-plan office environments. Thirty students (15 females) aged 18–38 (M = 25.27, SD = 6.03) participated in the study. The participants' mental performance was evaluated when exposed to the ISN only and a combination of the ISN and music. The n-back working memory software was used to evaluate the individuals' working memory. The results indicated that the accuracy of individuals' responses to both simple and difficult tasks of n-back (n = 1, 2) significantly increased when music was played compared to the ISN only condition. However, there was no significant difference between conditions for reaction times in the working memory test. Using music is an easy and inexpensive intervention to increase work performance in open-plan office environments.

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, and 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 facilitating communication and interactions between employees, enhancing 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. Although this open-plan design of offices has facilitated communication between staff and clients, it has made the staff dissatisfied due to the exposure to background noise and lack of privacy [5]. Background sounds cause distraction and impairs the focusing of attention of focus in open-plan environments. Employees often use headphones to deal with annoying noise in the office [6]. In other research, a significant inverse relationship was found between background noise and employee satisfaction in open-plan environments [7]. Open-plan staff said in interviews that they suffered not only from noise but also from silence. The sound of the keyboard and mouse signifies that they are working, and silence causes managers or clients to perceive that they are not [6]. Other studies have reported reduced employee autonomy [2] and even burnout due to the stress of lack of freedom to work in open-plan environments [8,9].

Noise is a common complaint of employees in open-plan office environments that reduces the employees' performance [10]. Noise at work is often caused by telephones ringing, air conditioning equipment, office machinery, and the individuals' voices [11]. In particular, irrelevant speech noise (ISN) has been reported as the most annoying source of noise by office workers [12]. ISN is the noise generated from conversations between colleagues, telephone calls and laughter [13]. Results from a study investigating 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 [10].

Memory is a process by which the acquired information is stored and retrieved through learning [10]. Working memory is the concept of retaining and working on information over a short period [14]. According to previous studies, employees' continuous exposure to ISN in open-plan offices interferes with retaining information in the working memory [5]. In addition, exposure to background noise in open-plan office environments can lead to complications such as fatigue, headache, difficulty in concentrating, psychosocial stress, loss of motivation, and increased cognitive workload in employees [10]. 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. Previous research has shown that music can affect individuals' attention, learning and working memory [15,16]. Although, the study findings 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 [17]. Likewise, the positive effect of playing music during surgery on the working memory performance of the surgical team was observed (Oomens, Fu, Kleinrensink, & Jeekel, 2019). But in comparing the mean n-back parameters found no significant difference in working memory performance in the three activities of eyes-open resting, listening to music, and playing the video game [18].

From a practical point of view, 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 [11] 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. Therefore, the present study sought to reduce the effects of ISN and increase the employees' performance through an easy and inexpensive intervention, namely music. The following hypothesis was tested: Music will be effective in improving working memory performance in open-plan office environments with ISN.

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) were 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, $p < 0.05$, Effect size (Cohen's D) = 0.66. However, there was no significant 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: $t(29) = 0.28$, $p < 0.05$, Effect size (Cohen's D) = 0.24 (Table 2 and Fig. 4).

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

Discussion

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 Fig. 4). This result is in line with a study that examined the effects of music on individuals' memory [19]. However, other research has found no effect of music on students' performance and working memory, and it contradicts the results of the present study [20]. However, one study (Tumuluri et al., 2017) found music effective in improving the working memory of diabetics; however, the results indicated a higher reaction time to n-back than before the music intervention (silent mode). 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 Fig. 4). In other words, the speed of responding to a working memory test under music playback condition did not increase significantly. In general, the increased working memory load reduced individuals' accuracy and speed of response to the n-back test.

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) [11]. 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. Among the previous studies, some studies consider the music style a determinant of music effectiveness and report that classical music had a more significant impact on performance improvement than other styles such as rap [21]. In this regard, a research has studied the impact of incidental music on comprehension performance and tested 30 metal music-interested students under four experimental conditions of arbitrary, non-arbitrary, instrumental music, and silence. The results showed that their performance was higher in silence and instrumental music than in the other conditions, and there was no significant difference between silence and instrumental music [22].

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 [23]. In the present study, instrumental and popular music was used along with ISN (recorded from open-plan office space), and the music was effective in increasing accuracy despite the existence of ISN. The present study suffers from some limitations. In the present study, music was not selected based on people's preferences and acceptance, and a non-verbal and popular type of music was used for all participants. Another limitation of this study was conducting the research in a laboratory setting. Therefore, it is suggested that the effect of music on employees in a real open office environment should be investigated in future studies.

In the present study, the music ("For Elise" is Ludwig van Beethoven's composition) was an influential factor in improving working memory in the presence of open-plan office noise. Furthermore, the individuals' accuracy in the n-back working memory test significantly increased, and their response speed also improved. Music is thus an easy and inexpensive intervention to reduce the harmful effects of noise and increase working performance in open-plan office environments.

Methods

Participants

Participants in the present experimental intervention study included students of the Faculty of Health recruited according to advertisements published on online social networks (WhatsApp). G-Power software was used to determine the sample size. The sample size was estimated to be 28, considering a 0.5 effect size and 0.90 power. The final sample size was 30 (15 females). The average age of participants was 25.27 years (*SD* = 6.03). The inclusion criteria were as follows: having a good level of general health; hearing health; mental health; non-drug and alcohol addiction; and right-handedness (to eliminate the dominant hand effect). The exclusion criteria were ear surgery six months before the study and having a cold to ensure hearing health and good sound sensation and perception, and also drowsiness, caffeine, alcohol or drug consumption within 24 hours before the study. The study was approved and monitored by the Ethics Committee of Shiraz University of Medical Sciences. Before performing the test, informed written consent to participate in the research study was obtained from all the subjects and they were free to leave the experiment at any stage. The participants were given a gift of cooperation. The research study was performed in accordance with relevant guidelines and regulations.

Working Memory Test

The n-back test, which Sinapsycho, Iran, has designed, is widely used to evaluate visual memory performance. This instrument is used to determine individuals' ability to process, select, and save information in a short time. In the current study, the computerized version and n=1&2 was employed. In this test, 120 digits were displayed at the center of a computer screen with 1500 ms intervals, with the entire process lasting for four minutes. The participants were required to press the response button on the keyboard immediately when two consecutive numbers were the same. The number of correct answers and the mean reaction time (true and false response) was the dependent variables [24,25].

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 [26].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, 9 = very sleepy, great effort keeping awake, fighting sleep.

The Music

This study used the familiar and popular instrumental classical music "For 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 intervention study, a simulated laboratory environment was prepared to evaluate the effect of music on individuals' working memory in open-plan offices. An acoustic chamber with a dimension of 5×3×3 m and an absorption coefficient of 0.9 was chosen as a laboratory environment to control the external noise. 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) [27]. 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. 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 of the participant. Figure 1 shows the results of the frequency analysis of music and ISN.

In order 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 amplitude of 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) to evaluate the participants' working memory before and after the intervention. Figure 2 shows the laboratory environment and set-up of equipment used in the study.

Procedure

The participants' data were collected daily from 9:00 to 15:00 for two months (7 October to 6 December 2021) in the acoustic laboratory. Before starting the test, the participants performed 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. This ensured that the participants were alert. First, the demographic characteristics form was completed by each person. Then, participants were trained on 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 3-4 times (Figure 3).

After ensuring the participants were ready, each individual performed the first stage of the experiment, which included one 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). The participants were also asked to calmly start and continue the test to reduce their stress and excitement. 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 one and 2-back tests in the remaining laboratory condition (with or without music), and the experiment ended.

Due to the length of the experiment (45-60 minutes), the researchers sought to attract the participants' optimal collaboration during the study by giving them gifts. In total, each person spent 16 minutes (8 minutes at each stage) performing the main test n-back (1 and 2-back), 22 minutes training and practising (specific to the first stage), and 10-20 minutes completing the form or resting (between two tests in each stage and between the two stages) (Figure 3).

Statistical data analysis

In order to analyze data, descriptive data were calculated by n-back software using central and dispersion indices. Data included the accuracy of response based on the number of correct answers of participants in the whole test and the average reaction time of responding to each item (correct and incorrect answers). Then the relationships of factors were analyzed according to parametric data using appropriate statistical tests. Differences in working memory were examined (using accuracy and reaction time parameters) with and without music. An alpha level of .05 was used for all statistical tests. All analyses were performed using SPSS version 25.

Declarations

Data Availability

The data that support the findings of this study are available upon request from the corresponding author [MM].

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Author Contributions

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.

Competing Interests:

All authors have no conflicts of interest to declare

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Figures

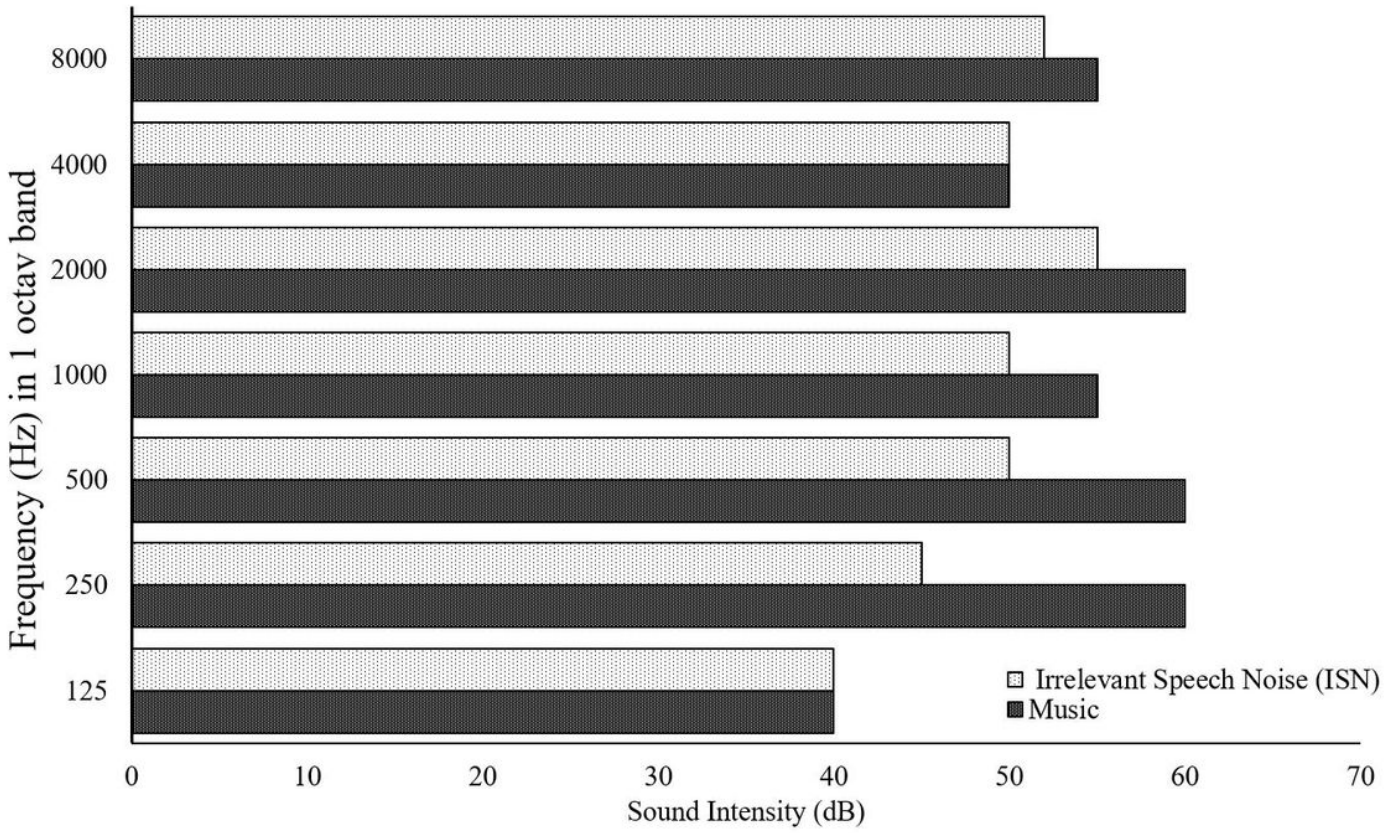

Figure 1

frequency spectrum of music and Irrelevant speech noise (ISN)

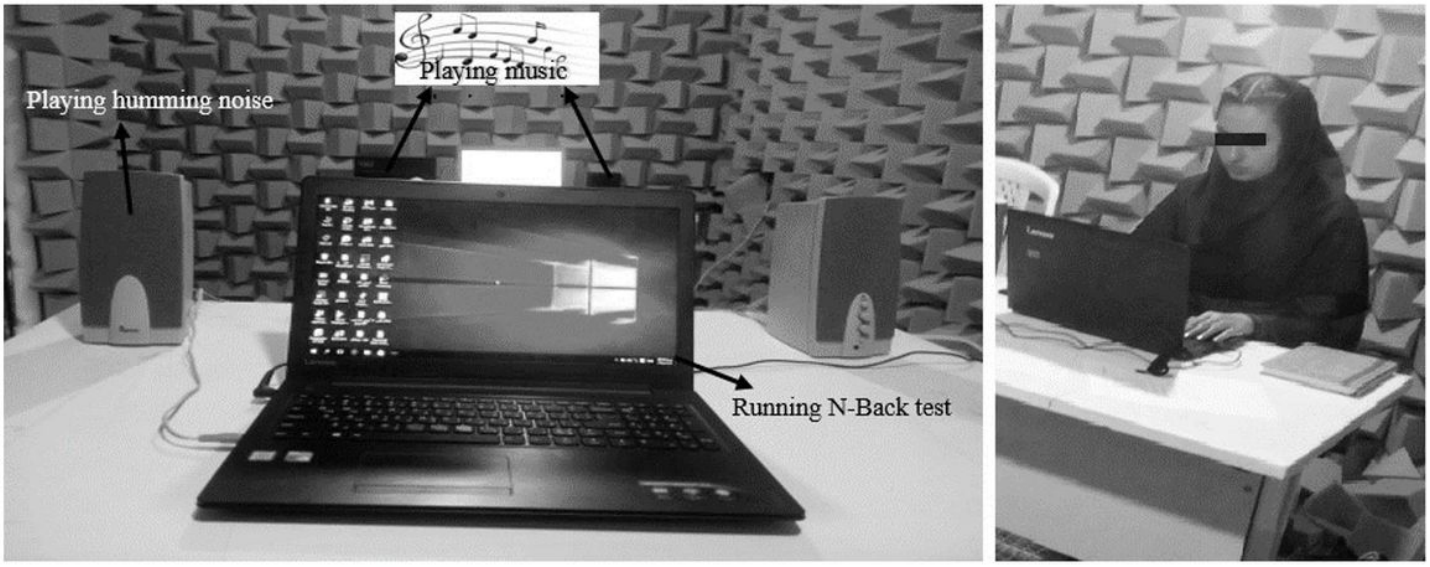

Figure 2

Simulated specifications in acoustic laboratory

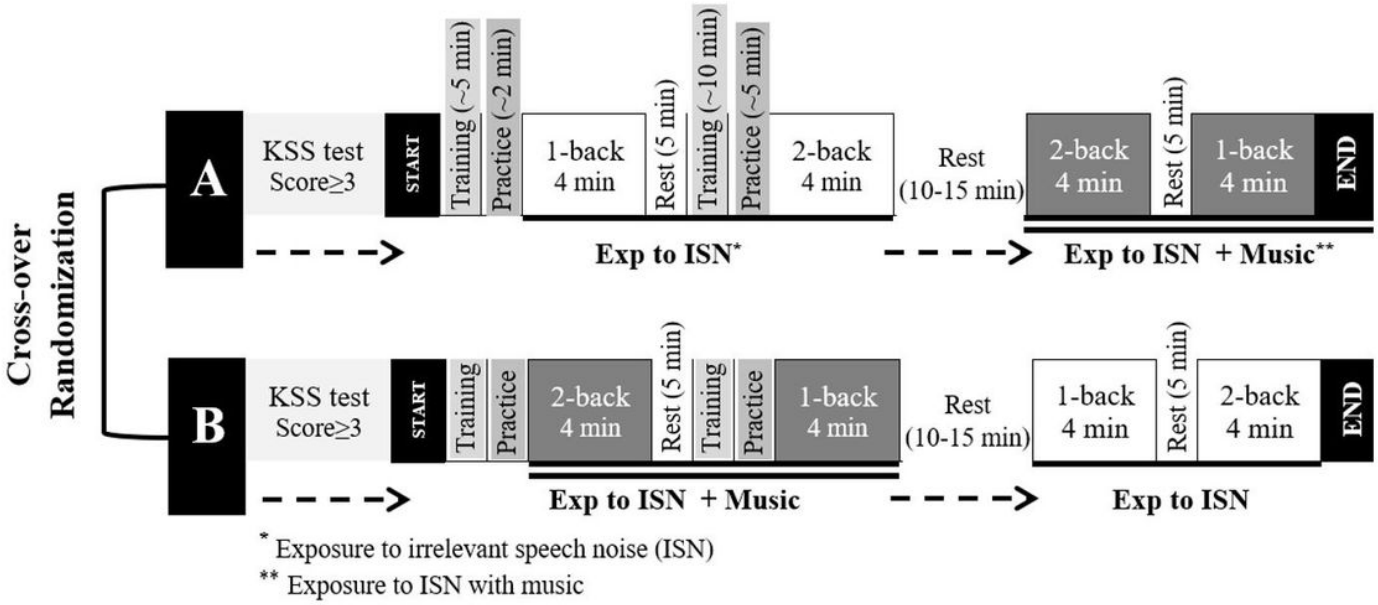

Figure 3

Chart of experimental design and protocol

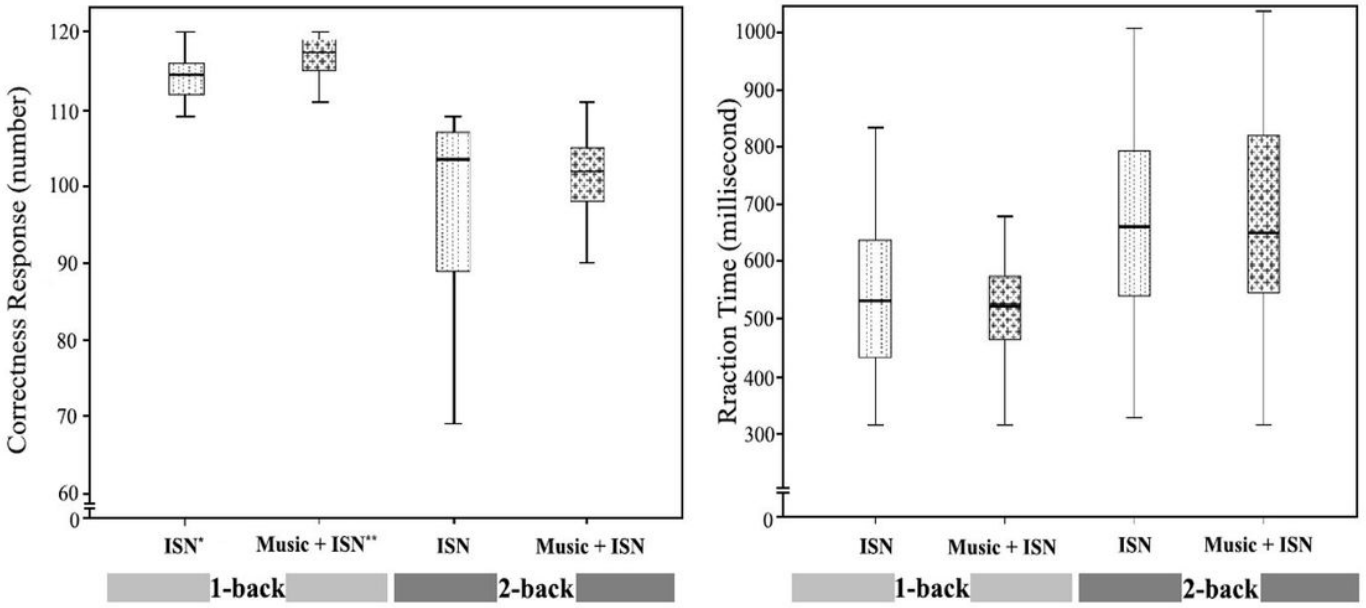

Figure 4

Mean Correctness response and Reaction time of participants to response in the n-back test. (*Exposure to irrelevant speech noise-ISN; ** Exposure to ISN with music)

Supplementary Files

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- BagatelleinAminorFurElise.mp4