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RESEARCH ARTICLE

Experiencing polyphonic music may enhance memories retention

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Abstract

Background and Aim: Early experience, provide opportunity for later associative experiential learning by affecting multisensory systems. This phenomenon may because of the influences which sensory stimuli as sounds would have on non-auditory neural centers rather than just deploying hearing system, so the question is whether music as a kind of complex sound source, could help in general cognitive functions such as memory circuits or, conversely, it acts as a distracting factor. This study was investigated the effect of auditory experience with special kind of music, called polyphonic music, on auditory, visual and logical memories function.

Methods: Forty volunteers with normal hearing, aged 18 to 40 years, were participated in this experimental study. They were performed with Ray auditory verbal learning test, Kim Karad visual memory test, and Wechsler logical memory subtest in two states: no-music condition and music condition with a polyphonic piece as background music. Memory functions in these two conditions, and the effect of gender on performances, were compared between conditions.

Results: Polyphonic music significantly increased auditory, visual and logical memory performance compared with the no-music conditions ($p < 0.05$). No significant difference between genders was found in memory tasks in both music and no-music conditions ($p > 0.05$).

Conclusion: It seems that presence of polyphonic music while people had enough auditory experience about it, impress memory performance. It is possibly owning to multisensory functions of brain and the effect of auditory experiences on cognitive system.

Keywords: Auditory experience; polyphonic music; auditory-verbal memory; visual memory; logical memory

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Introduction

Memory is an available hypothetical storage, for saving sensory information and reminding them in case that they are needed. Usually, categories of functional patterns which are responsible for conceptualization, are encoding in memory system. The combination of patterns depends on the type of our need to categorized information and function of our brain. Therefore, memory records how to combine concepts and it is updated by changing the patterns based on previous experiences and incoming information [1].

It has been suggested different classification methods for memory system in literature. A common method is assorting, memory according to the length of time it will store a piece of information. In this method, memory system is divided into three subsets; short-term memory (STM), working memory and long-term memory (LTM). STM is a storage with simple mechanism that has limited capacity (about 20 or 30 seconds) and data will be easily disappear, if they are not repeated [2]. It is assumed that working memory includes components of short-term part which are limited by selective attention. In fact, STM is a subset of working memory that the role of attention is very poor in it [2]. On the other hand, a storage part with much more capacity and the ability of saving data from couple of days to many years is called LTM. Stored information would not be lost easily in this memory [3].

According to the importance of entered information and their repeating times, sensory information store in accordance with the required memory systems. For instance, auditory stimuli, received in peripheral auditory system and processed in auditory cortex, then the outcomes traveled to areas like prefrontal cortex to make appropriate responses, Precuneus to percept semantic components, Thalamus as a reserve area [4], superior temporal gyrus that contains the primary auditory cortex and specialized for processing combinations of frequencies, and processing the changes of amplitude or frequency [5]. The superior temporal gyrus includes the Wernicke's area, which is an important region for speech processing and has a role in comprehension of language [6]. This region also is involved in perception of emotions [5]. The other region is Cingulate gyrus which is involved with emotions formation and responses, processing [7], learning, memory [8] and also has a role in executive function and respiratory control. For encoding and recognizing the environmental scenes (rather than the faces) [9], auditory memory encoding and retrieval [10], Parahippocampus has been known as an important region. Moreover, visual data that processed in visual cortex, reserved in anterior parts of Hippocampus, Cingulate gyrus, Cuneus, Precuneus, Angular gyrus, inferior parts of medial temporal lobe and parietal lobe [4]. Finally auditory, verbal, visual and other kinds of sensory information, combine in anterior part of left temporal lobe that is used as a region for storing logical materials, so the logical memory is formed here. In fact, logical memory has got a role in linking processed information and stored concepts, in other parts of memory [11-13]. This multisensory function between sensory memories which auditory-verbal, visuospatial and other sensory information are cooperated, leads to improve the learning process [11].

Various experiences including auditory, visual, tactile, etc. can affect memory system functions [14,15]. A touching factor could be an experience. The memory system gets involved with frequent triggers. Therefore, sustainability of a gained experience and its confirmation depends on amount of repetition. About auditory stimuli, a single encountering or listening over and over to an stimulus, create an auditory experience and make indelible pathway in auditory memory [16]. This phenomenon has been colloquially called mere exposure effect which helps in improving the perception of repeated stimulus [17]. Gilliland and Moore, relying on mere exposure effect and using repetition time of 25, proved that people prefer to listen to a classical piece of music that was not popular among the participants at first. The results, also demonstrated the improvement in people's reaction time and comprehension of the track [18]. This is because of the reorganization in neural circuits and new plasticity that is made by repeatedly experiencing the stimuli.

Auditory experience is formed in cortical and subcortical regions. It has deep and long lasting influences on individual's auditory development, sensory processes and performances in adolescence. It begins from fetal period; newborns have distinguished responses to stimuli that they had heard before (like their mother's voice or music notes that they had heard in fetal time period) [19]. An interesting fact is that the neural pathways in different parts of memory system are activated by receiving sounds in auditory system. It means that sensory stimuli like a sound would affect non auditory neural centers rather than activation of hearing system pathway. Therefore, it will develop language and experiential learning in future, particularly in children [20]. Strait and Kraus, suggested that musical experiences, shapes top-down auditory corticofugal mechanisms as auditory attention and also visual attention [21]. Connection between different parts of sensory memory and multisensory action, leads to an impressive improvement in learning process [11]. It might because of the reservation processes that different sensory information, stored in same regions of memory system.

Electrophysiological studies have demonstrated that auditory experience affects wave forms [16,22]. For example, auditory experience that formed by repetitive frequency, had impressive influences on amplitude and latency of auditory brainstem response (ABR) waves. It increases the amplitudes and decreases the latencies of ABR waveforms [23]. Furthermore, event related potentials (ERPs) like mismatch negativity (MMN) that partly indicates cognitive and memory system functions, was modified by auditory experiences, as it has been proved that frequent stimulus could not prompt proper waves [16], but the question is whether using complex sound sources as music, have an influence on cognitive functions?

George and Coch examined the effect of long-term musical training on working memory by behavioral and electrophysiological methods. The results indicated that musicians had better performances during visual, phonological and executive memory tasks than non-musicians. They demonstrated faster updating of working memory with shorter latencies of P300. Musicians allocated more neural resources to auditory stimuli (larger amplitudes of P300), showing increased sensitivity to auditory standard/deviant differences [24]. The same result was found by Besson and Faita. Musicians performed better in recognizing familiar melodies rather than non-musicians in behavioral tasks and also N400 waves showed shorter latencies and larger amplitudes [25].

Functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) investigations have provided evidences that whether general regions of brain were activated during listening to a music track [26]. Platel et al., utilizing PET, indicated regional overlapping between anatomic areas of auditory and visual zones with neural areas that are activated for processing and storing of music; left hemisphere's role is in processing familiar music tracks, pitch and rhythm. Familiar tracks are processed in left inferior gyrus, Brodmann (BA) 47 area and superior temporal gyrus, BA 22. These areas also presumably play a role in lexico-semantic perception. Pitch perception activates BA 18 and 19, Cuneus and Precuneus, which are regions for visual mental imagery. Right hemisphere is involved with processing timber [26]. According to Mozart effect, there is no dissociation between activated regions for music and areas that are involved in spatio-temporal abilities [27].

Music makes a complex auditory scene and activates more neural regions in processing centers. Janata et al., using fMRI method, believed that the particular type of music called polyphonic, recruits general attention and working memory circuits [28]. Polyphonic music is a composite of multiple streams which different musical notes are played simultaneously, with a related pattern, via various instruments.

Regarding the effects of music on general attention, working memory and executive functions, there is not a strong agreement among researchers. Some of them believed that music helps people to concentrate more and remind memories better, while others has opposite opinions and believed that music can distract people and disturbs their attention [29]. Considering different ideas, it is unclear whether auditory experience with a complex sound source as polyphonic music can improve memory functions or not? According to the limited studies on effect of auditory experience on memory functions, this study aimed to assess the results of auditory, visual and logical memory tasks, among people with polyphonic musical auditory experience and people who do not receive any music and also between different genders.

Table 1. Demographic and clinical characteristic of the participants (n = 40)

	Group A (n = 20)	Group B (n = 20)
Gender (n) Male/Female	**10/10**	**10/10**
	Mean (SD)	**Mean (SD)**
Age	23.40 (2.70)	23.70 (2.40)
PTA	3.80 (3.00)	3.80 (3.10)
MMSE	28.40 (0.90)	28.30 (0.80)
Beck	5.60 (3.40)	5.70 (3.60)
Raven IQ	10.90 (1.00)	11.20 (0.80)

PTA; pure tone audiometry, MMSE; mini mental state examination

Methods

Participants

Using results of 40 participants in pilot study, the effect size of 1.1 (the maximum difference between the means, from their standard deviations, which is calculated to evaluate the effectiveness of intervention) was calculated. Therefore 40 participants (20 males and 20 females), had been chosen by systematic random sampling method from 60 volunteers, ranging in age from 18 to 40 years old (M= 23.4 (SD = 2.7) for group A & M = 3.7 (SD = 2.4) for group B) for this experimental study (Table 1).

They were monolingual Persian speakers with normal motor abilities and they had not any professional artistic and musical activities, but they had universal educations and according to Raven's Advanced Progressive Matrices test, their IQ scores were higher than average (more than 6 scores). Participants had normal hearing thresholds, ≥ 25 dB HL at octave frequencies from 250 to 8000 Hz based on Goodman's criteria, 1965, assessed by Harp Inventis audiometer. Their eyes sights were normal or with refractive errors under 6 which were corrected. Furthermore, normal psychological performance in Beck Depression Inventory-1A list (BDI-1A), and normal cognitive functions in Mini Mental State Examination (MMSE) were observed (Table 1). Participants were asked about any special disease or even allergies and they were all physically healthy, during experiments. Participants were referred to Audiology Clinic of Rehabilitation School affiliated by Tehran University of Medical Sciences (TUMS) to complete the tasks in a place with minimum amount of noise. The protocol used in this study was approved by Tehran University of Medical Science's Ethics committee's Code No. IR. TUMS.FNM.REC.1397.151. All volunteers signed the informed consent to participate in the study after explaining the details of the research.

Participants were classified into two groups (A & B); group A had no auditory experience with the special polyphonic track that we used during tasks and they completed memory tasks in silence (no- music condition), but group B listened to the track for 25 times (5 times a day for 5 days, about 15 min each day) at their preferred times before the day of assessments (according to Gilliland and Moore, method [18]) and complete the task while the polyphonic piece was played as background music (music condition). This was necessary as musical mere exposure to make sufficient auditory experience [18,30,31]. Moreover, we asked them not to listen to other music in this 5-day trail.

Memory tasks

Ray auditory-verbal learning test (RAVLT)
The Persian version [32] of this test was used to evaluate, short- and long-term auditory memory and it was a reliable test to assess verbal information encoding, consolidation, storage and retention [33]. There were 2 lists of 15 single syllable words, lists A & B and a list of 50 words for recognition assessment, list C that presented at speed of one word per second. This test had 9 steps; at first list, list A, presented for 5 times and each time participants had to write down everything they recall, just after the list was finished. When they announced that they could not remember anything further, the list was played once more. The average of words that they could recalled in 5 steps, was calculated and the result indicated the short auditory memory score [34].
Then, list B or intervention list was played once and individuals had to write down what they recall. Then again we asked them to remember what they had heard in list A immediately and wrote them for 6th time. After 20 minutes they had to write down all they remember of list A again for 7th time. It was necessary for assessing long-term memory. At last list C was presented. This list consisted of 20 new words and also the words of lists A & B. People had to select the words that they had heard before and marked them. This step was for checking the learning process and also phonological discrimination [34,35].

Kim Karad visual memory test
This test consisted of 2 collections of pictured and blank pages. Participants received a pictured page with 20 colored pictures with special directions. They had to look it for one minute. Then they were given a blank page and 20 picture pieces and were instructed to recreate the colored page with same pictures and also in same directions. Correct places with true directions had total scores and each mistake took 0.5 point. In first part of this test the STM was examined. Next part was begun after 15 minutes and we checked the long-term memory as before, but this time people didn't see the colored page and they had to complete the blank page using their memory [36].

Wechsler logical memory subtest (WMS-III)
This test was one of Wechsler memory subtests which prepared for adults and it measured logical data retrieval. It consisted of two texts (A & B) and each, included, 23 semantic parts. Participants had to read the texts and then they had to iterate what they remember. Each part had a grant and it was accepted just as if participant directly pointed out the actual words in the text but words shifting were not deduce any score. Finally, we calculated the average scores. It has been investigated that this test can evaluate short- and long-term memory. Therefore the next level for participants was to remember what they had read before, in first level, after 20 minutes [37,38].
Procedure
For preparing auditory memory tasks, we used musical piece named Double Concerto in D minor, BWV 1043 Largo ma non Tanto, a polyphonic track of Bach's music [39], as a background music. Then, single syllable words of Persian Ray auditory-verbal learning test (RAVLT) [32] which were recorded by Zoom Handy Recorder H5, was super imposed on music piece, using Cool Edit pro 2.1. Intensity of music was 16.4 dB lower than the expression intensity of words, therefore the acceptable noise level (ANL) in music was proper [40]. It should be noted that the quality of music, was 320 kbps and it was played by TM006 Beats headphone (made by Beats Electronics company, USA), at participant's psychophysical listening comfort level (the level of loudness, tuned-up by participants) [37]. Unlike the first group, visual and logical memory tasks were completed by participants of second group while the same polyphonic music was played in background.
Memory tasks were completed by all members of two groups at their preferred time; hence they could concentrate and had sufficient attention. Participants had to complete auditory, visual and logical memory tasks. After completion of each part, they had 10 minutes of inter-assessment interval for their recoveries from

Table 2. Mean (standard deviation) score of memory tasks in male and female in group without any auditory experience (group A) and group with polyphonic musical auditory experience (group B)

	Mean (SD) scores in group A			Mean (SD) scores in group B		
Memory tasks	**Female**	**Male**	**p**	**Female**	**Male**	**p**
Auditory STM	8.74 (0.74)	8.88 (0.91)	0.71	12.77 (0.81)	11.75 (0.82)	0.26
Auditory LTM	11.30 (1.41)	10.80 (1.39)	0.43	13.50 (1.26)	13.30 (1.15)	0.71
Logical STM	7.90 (1.15)	8.45 (1.17)	0.30	13.90 (0.96)	13.72 (0.80)	0.66
Logical LTM	8.22 (1.06)	8.35 (0.87)	0.77	13.72 (0.77)	13.85 (0.72)	0.71
Visual STM	5.45 (0.95)	5.15 (1.20)	0.54	12.15 (1.66)	11.40 (1.46)	0.30
Visual STM	6.80 (1.13)	6.70 (1.08)	0.84	15.15 (1.58)	14.50 (1.61)	0.37

STM; short-term memory, LTM; long-term memory

conducted test. In the case that they were tired or could not focus, the assessments were stopped and postponed to another appropriate time.

Data analysis

Applying Kolmogorov-Smirnov test for the data, they were normally distributed ($p > 0.05$). Hence, t-student was applied for dependent variables (we compare auditory, visual and logical short- and long-term memory between two groups of people which were different from each other in having polyphonic musical auditory experience, groups A and B, and also the effect of gender on these memory functions). Statistical analysis was accomplished with SPSS version 25.0 statistic software package and significance level was set at 0.05.

Results

First we compared the results of memory tasks, between males and females in each group. As it is indicated in Table 2, females had better performances in visual short-term (STM) and long-term memory (LTM) tasks. Males group was performed better in auditory short-term and long-term and logical short-term and long-term tasks, but comparing the effect of gender on memory tasks, revealed no significant differences between mean scores of males and females of control group (group A) in memory tasks ($p > 0.05$). In addition, similar to the first group, males and females in the second group that had polyphonic musical experience (group B), revealed no significant differences between mean scores of memory tasks ($p > 0.05$). Even though females had higher scores in all memory tasks except logical long-term task that males were performed better (Table 2).

Investigating the effect of auditory experience with polyphonic music, on auditory, visual and logical memories functions, significant differences between mean scores of control and experienced group in the memory tasks, were indicated ($p < 0.05$) (Table 3). Overall, experienced group had higher mean scores in all the memory tasks.

Discussion

The purpose of this study was to examine the effect of gender and auditory experience with polyphonic music, on performance of auditory, visual and logical memories of a group those who had not any musical auditory experiences and complete the tasks in silence condition and the group those who had 25 times of polyphonic musical auditory experience before evaluation session and performed the tasks during listening to the same music.

Results indicated that there was no significant difference between performances of two gender

Table 3. Mean (standard deviation) score of memory tasks in group without any auditory experience (group A) and group with polyphonic musical auditory experience (group B)

	Mean (SD) scores		
Memory tasks	**Group A**	**Group B**	**p**
Auditory STM	8.81 (0.81)	11.96 (0.82)	< 0.001
Auditory LTM	11.05 (1.3)	13.40 (1.1)	< 0.001
Logical STM	8.17 (1.1)	13.81 (0.86)	< 0.001
Logical LTM	8.28 (0.95)	13.78 (0.73)	< 0.001
Visual STM	5.30 (1.0)	11.77 (1.5)	< 0.001
Visual LTM	6.75 (1.0)	14.82 (1.5)	< 0.001

STM; short-term memory, LTM; long-term memory

groups in auditory, visual, and logical memory tasks. Therefore, it is obvious that gender has no effect on auditory, visual, and logical memory performances.

These findings are not consistent with Bolla-Wilson and Bleecker, who used Ray auditory-verbal test, and showed higher scores for male population [41]. However, the results of the current study are in agreement with Matloubi et al. who used Persian version of Rey auditory-verbal learning test, and demonstrated that there was no significant differences between males and females performances [42]. Likewise, we used the Persian version of Rey test, thus the differences between the words which are used in English and Persian versions of the Rey test, may cause this controversy in the results. On the other hand, McGivern et al. assessed the effect of gender on visual recognition memory. In this study, in cognitive tasks, females' performances was better than males' performances [43]. Herlitz et al., stated that females' performances were better in visuospatial and verbal memory functions [44], nevertheless Gresack and Frick had a different opinion however in an animal study. They indicated better performance of visuospatial memory in male rats [45]. According to another study by Janowsky et al., sexual hormones had an impressive effect on working memory functions. Steroidal hormones are known to modulate cortical activities; for example, estrogen hormone improves verbal memory function in females and higher level of testosterone hormone in males group, leads to improve memory performances [46]. We assumed that complex factors may influence memories, among them; one could put emphasis, is the secretion level of different hormones in males and females which is a contradictory factor and may lead to differences in various studies. Moreover, performing different memory tasks, behavioral or electrophysiological techniques, could be another critical factor.

A significant difference was found between group with musical experience and control group, with higher scores obtained by musical experienced group than control group (Table 2). Another interesting finding was that the mean scores of long-term auditory and visual memories were higher than mean scores of STM memory in both groups. These results may due to scoring system that average STM score in 5 levels. This average includes initial levels low scores and also final levels high scores, so it is always lower than score of LTM, because LTM score just includes the score of a single level and it is attained after that the learning process is occurred. The solution could be using of a longer interval between short- and long-term auditory tasks. LTM also had better function in visual memory tasks. Furthermore, the higher score of visual long-term memory may be the result of learning process that happened after correction stage. When it comes to logical memory, the result were same between short- and long-term memories, because the texts were not presented again between two levels of experiment, so participants could not read them again and had not enough time to complete learning process. Nevertheless, the current experiment does not enable us to determine which of these mechanisms is responsible for findings observed in short- and long-term memories hence, further studies are needed to address these issues.

Crawford and Strapp studied the effect of light and vocal background music on verbal and visuospatial memories. They concluded that people's performances who usually didn't listend to music during study, got worst by listening to background music during performing tasks. In addition, they reported that people who usually listened to music while studying, had no more better performances than the other group [29]. This finding contradicts the results that we have found in the current study. The reason is that Crawford et al. utilized the intensity of 75 to 80 dB as the background music level. According to Thompson et al. high intensity as 66 dB and more leads to decrease reading comprehension performance of participants [37]. Despite Crawford findings, Bialystok and Depape [47] and Skoe and Kraus [22] believed that music recruits auditory, visuospatial and executive functions. Therefore, musical experience improves auditory reserve and influence sensory processing.

This study used behavioral methods to evaluate the effect of auditory experience with special kind of music on group of Persian monolinguals, therefore it is obvious that using this method to investigate the effect of auditory experience on bilinguals memory functions and also using other kinds of music as people's favorite music could be helpful to use musical auditory experience as a factor for improving memory retrieval. It is suggested that future researches will be addressed these postulations.

Conclusion

The present study was conducted to assess the effect of auditory experience with polyphonic music on auditory, visual and logical memories function. Our findings revealed that musical auditory experience with polyphonic music had an impressive effect on retrieval of auditory, visual and logical memories and can enhance the maintenance of information and reminding them. In addition, we found that gender does not have an effect on the memories function. We suggest that using background music in the classroom settings or in any other learning situations can improve memory functions hence increase academic outcomes and achievements. Further studies are required for children and adults with hearing impairment before our suggestion can be implemented clinically for improving auditory training programs.

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Conflict of interest

The authors declared no conflicts of interest.

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