



Original Article

Impact of music on reaction time, attention, short term memory and verbal fluency: A gender-based study

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Abstract

Background: Music is beneficial for adults, it enhances psychological comfort, self-confidence, self-esteem, and lowers the symptoms of anxiety, pain and depression, relieving stress by improving life quality and thus providing satisfaction. It holds the capacity to initiate a multitude of cognitive processes in the brain. We aim to evaluate and compare the effects of music on reaction time, attention, working capacity of short-term memory and verbal fluency of male and female subjects.

Methodology: An observational study was conducted on a sample of 300 subjects either males or females between the age groups of 19 to 30 years, affiliated with different universities and institutes. After inclusion, these subjects were divided into two groups, standard and experimental group with 150 subjects in each group. Ruler & Drop method test and Stroop test with or without music were used to test the reaction time (RT) and attention, respectively. Whereas, working capacity of short-term memory was tested using the George A. Miller rule of memory. And verbal fluency was evaluated using semantic verbal fluency (SVF) and phonological verbal fluency (PVF) tests. The data was analyzed using SPSS Version 22.

Results: The comparative mean values between the groups for RT, attention, short-term memory and verbal fluency scores were greater among the subjects in the experimental group as the tests were performed in association with musical interference. Mean reaction time for both visual and tactile cues were significantly increased in the experimental group i.e. 0.151 ± 0.034 (males) and 0.124 ± 0.050 (females) for tactile cues and 0.150 ± 0.042 (males) and 0.152 ± 0.033 (females). Moreover, Stroop interference also increased in both genders while short-term memory score declined from high to average and verbal fluency was also compromised due to musical interference.

Conclusion: It is concluded from the study results that music holds both positive and negative effects on brain activity. It imparts positive effect on both RT and attention but in case of the working capacity of short-term memory and verbal fluency, the effects are negative.

Keywords

Reaction time, Stroop Test, Verbal Fluency, Short-term Memory, Music.



Introduction

Music is an art form which is now being used as a therapeutic tool for individuals of all age groups and both genders, as it has been known for its social nature of healing. Music upregulates the working efficiency, boosts the productivity levels, enhances psychological comfort and self-confidence^{1,2}. It also helps with complex cognitive functioning like critical thinking, reasoning and problem solving³. Music activates the deep parts of the brain including amygdala, ventral striatum and hippocampus which in turn activates the euphoric stimulation. Where amygdala responsible for expression and perception of fear and the development of fear conditioning, regulates additional cognitive processes like memory or attention⁴. It is a known fact that intellectual abilities can be improved by fragrances or certain music (i.e., the Mozart Effect)⁵. Literature suggest that exposure to music, specifically Mozart, improves the performances and also increases spatial skills⁶.

Apart from reaction time and concentration, music also has effects on the memory. The memory retained for a duration of 15 and 30 seconds is short term memory. It can be verbal or visual, items can be kept in short term memory by repeating them verbally (acoustic encoding)⁷. While Visual Short-term Memory involves the ability to temporarily retain a small amount of visual information like shapes, colours, relative locations, or movement directions available for a limited time period⁸. Music also influences stress-related cognitive processes and alters numerous physiological responses⁹. From a functional point of view, the acoustic data is processed in the motor and auditory areas of the brain through the auditory neural pathways connecting the amygdala and auditory cortex¹⁰. Several interconnected neural pathways associated with memory, music and emotions are working parallel to each other to create detailed layered memories.

Verbal fluency is another cognitive function that is enhanced through music listening, it helps in recovering information from memories. However, recovery of information is successfully executed when an individual has control over mental processes like mental set shifting, selective attention, self-monitoring and internal response generation¹¹. Verbal fluency involves both semantic and phonologic contents which engage distinct cognitive processes and brain circuits¹². The phonologic content requires functioning of left inferior, middle frontal cortices, putamen and thalamic networks, and also verbal element in addition to executive functions which later involves the unusual generation of strategies based on categorical representations¹³. In contrast, semantic requires temporal lobe functions and impose a smaller demand on executive processing because performance rely on common and established verbal strategies¹⁴.

Based on the previous literature it is evident that the music improves cognitive abilities and hence contribute better results in memory and language tasks. Therefore, this study aims to evaluate the contribution of music on working capacity of short-term memory and verbal fluency of male and female subjects and its effect on reaction time and attention.

Methodology

This observational study was conducted on general population. A sample of 300 subjects between 19-30 years of age affiliated with different universities and institutes were enrolled in the study. Subjects suffering from any pathological condition at the time of sampling were excluded. After receiving informed consent, the subjects were divided randomly into two groups i.e. standard and experimental group. In standard group there were 150 subjects including 60 males and 90 females. In this group, all parameters were tested without music. Experimental group also contain 150 subjects including 80 males and 70 females. In this group, all parameters were tested with music.



For reaction time, ruler and drop method was used, subject was asked to sit on the table with their dominant hand over the edge. To test the visual response, the ruler was placed at the 30 cm mark so that the 0 cm end is just at the subject's index finger. Soon after this the investigator releases the ruler without making any noise or gesture. The subject will react to the visual stimulus of seeing the ruler being released. The experiment is repeated three more times and the centimetre mark is taken for each time. For tactile response, the subject is asked to sit at the table wearing the eye shade and touch the shoulder of their non-dominant arm as the investigator release the ruler. The subject will be given a simple touch while releasing the ruler without any auditory cue. The measurement is recorded and the experiment is repeated thrice switching places. The reaction time was calculated using following formula: $t = \sqrt{2y/g_0}$. Where, y is the distance measured in cm, g_0 is the acceleration due to gravity constant (980 cm/sec²); and t is the time in seconds. The average reaction time for humans is 0.25 seconds to a visual stimulus, 0.17 for an audio stimulus, and 0.15 seconds for a touch stimulus.

Stroop effect test was used to assess attention, the subject was made to read out the word printed in black, same words printed in congruent colours, colours printed in incongruent shades and colour of ink from which the word is written and the time was recorded each time. Stroop interference and facilitation were calculated using the formula:

Stroop Interference = Incongruent - Control

Stroop Facilitation = Congruent - Control

For working capacity of short-term memory assessment, George A. Miller rule of memory score was used. Harvard-based psychologist George A. Miller found that in our short-term memory, the average number of 'chunks' of information (names, numbers, etc) that can be stored is 7 ± 2 . According to which a score between 5 and 9 of the words on the list

indicate average working capacity of short-term memory, if less than 5, short term memory is working at low capacity and if the score is above 9 indicates high working capacity of short-term memory. Thereby, subjects were provided with a list of words which they can learn for a short period of time (30 seconds - 1 minute), then they were asked to recall the list with or without listening to music.

Both semantic verbal fluency (SVF) and phonological verbal fluency (PVF-FAS) tests were performed. In SVF test, the participants were asked to evoke and speak as many animal names as they could over a period of 60 seconds. The total number of correct items mentioned by the subject was recorded. Moreover, in PVF-FAS test, the participants were asked to mention as many words as they could starting with the letter's "F", "A" and "S", over a period of 60 seconds for each letter separately, proper names and numbers were avoided. The total number of correct items mentioned for each letter was recorded. The results in the FAS test were computed for the number of the word generated with the initial letter, i.e. F, A, S, and the sum of the all three letters was calculated i.e. F, A and S (Σ FAS). All of the above mentioned tests were performed on the enrolled study subjects in accordance to the ethical guidelines and the tests were run twice, with and without music and the results were displayed gender wise. Data was analysed using SPSS Version 22 and displayed using mean and standard deviation.

Result

Based on the results the mean reaction time for both visual and tactile cues was significant improved in both genders. But for attention the Stroop interference was prolonged among subjects of experimental group. Moreover, the working capacity of short-term memory was decreased from high to average and verbal fluency both semantic and phonologic was compromised while listening music as shown in table 1.

Table 1: Changes in mean reaction time, attention, short term memory score and verbal fluency among subjects in both standard and experimental group

Parameters		Standard		Experimental	
		Male (n=60)	Female (n=90)	Male (n=80)	Female (n=70)
Reaction Time	Tactile	0.1488 ±0.036	0.118 ±0.043	0.106 ±0.034	0.124 ±0.050
	Visual	0.148 ±0.036	0.153 ±0.040	0.150 ±0.042	0.152 ±0.033
Attention	IF	35.68 ±7.69	33.584 ±7.978	40.816 ±11.65	38.57 ±11.53
	FT	-0.93 ±3.10	-0.50 ±3.22	-2.033 ±3.53	-1.211 ±3.54
Short term memory score	Below 5	6±2.831	1±4	6±3	2±4
	5 to 9	39±2.7004	37±3.3	45±2.9	46±4.1
	Above 9	15±2.591	52±3	9±3	42±4
Verbal Fluency	Semantic	15.03±4.40	41.32±10.55	13.566±3.48	34.18±9.58
	Phonologic	16.15±3.89	48.21±12.75	14.65±3.15	38.088±11.43

*Values are given as mean ± SD

*IF-Stroop Interference; FT-Stroop Facilitation

*Standard Group – Without Music; Experimental Group – With Music

Discussion

Exposure to music stimulates brain areas, but the process occurs differently among males and females which are attributed to various genetic, hormonal and environmental factors. However, both genders are equal in intelligence, but tend to work in a different manner. This is because both male and female use different parts of their brain to recognize faces, sense emotions, encode memories, make decisions and solve certain problems. According to our results, reaction time was much faster among females as compared to males in the control group as well as experimental group (Table 1). However, it is generally accepted that males have faster reaction time as compared to females. Men tend to have larger diameter of axons than women. Larger diameter of axons causes signals to be transmitted faster up to the nerve fibres, leading to a shorter latency between stimulus and response¹⁵. But our results are contradictory to previous researches. This might be due to the neuroanatomical differences among both the genders. That is female have bigger Corpus callosum as compared to males which is the larger tract of neural fibres that allows the free flow of communication between both hemispheres of the brain¹⁶. Furthermore,

regions for frontal lobe that are responsible for problem solving and decision making were larger in women¹⁷.

In addition, our graphs also showed that both the genders took more time in Stroop interference (Table 1) it is because, there are two brain regions involved in the processing of Stroop task cingulated cortex and dorsolateral prefrontal cortex. Hemisphere difference has also been proved by a study that right cerebral hemisphere reads the colour, the left cerebral hemisphere insists to read the words. When the meaning of a word and its colour are congruent, it is easy to recognize the actual colour of the word. But when the meaning of the word is incongruent with the colour, it creates a conflict between the colour and the word's meaning. The "conflict" between two brain processes is word-recognition and colour-recognition. Thereby, extra time is required by brain to process and resolve this conflict. It turns out that we are so fluent in our language that word-recognition is slightly faster/stronger than colour-recognition¹⁸. Most people will recognize the meaning of the word before recognizing the colour. In order to name the colour correctly, the two processes compete for the final decision-making process. The brain has to inhibit the faster/stronger word-



recognition process in order to allow the colour-recognition to win in the final response. This inhibition requires "selective attention" (attention focus) to inhibit the competing conflicting process. The reaction time is an indicator of the "attention process" in the brain it increases with attention fatigue and/or inattentiveness¹⁹. However, when comparing between both the genders, it was found out that females perform somewhat better than males this is because the neurons in the pre frontal cortex of female's brain are more closely packed together than male's brain²⁰. And the prefrontal cortex is involved in Stroop task and problem-solving ability.

Many researches have been done proving different effects of music on psychological parameters, all with contradictory conclusions to one another. Like authors have concluded that music does not have any effect on memory²¹. On the other hand, some have also reported that sound in the background actually enhances the learning ability²². In our study, the overall working capacity was decreased along with the verbal fluency (Table 1). This can be due to the perspective proposed by Kahneman as Cognitive Capacity model. In this model it is demonstrated that cognitive processing can be done only for a limited pool of resources at a given moment. When multiple tasks occur at the same time, they compete for the limited resources and thereby exceeding the available capacity due to combined demand. And ultimately capacity interference occurs. This causes the processing of only portion of the task and thereby performance deteriorates. Thus, increasingly complex distractions due to music cause decline in cognitive performance²³. This might be the possible reason that the working capacity of our participants decreased from high to average, in addition to the verbal fluency. This is similar to other researches which demonstrated that background music has small but continuous negative effect on memorizing words or nonsense syllables (especially when listening to loud music)²⁴, remembering advertisements²⁵ and also in memorizing earlier read texts and reading

performance²⁶. Listening to music has also been reported to hinder with many other cognitive processes, including multimedia learning, performance on diagrammatic, numerical and verbal analysis, the ability to perform arithmetic, reading, performance inhibition on Stroop task and also in the learning of new procedures²⁷⁻²⁹.

This study provides the positive effects of music on attention, verbal fluency, and short-term memory and also on reaction time. However, more significant data is required in future in support of the positive effects associate with music. Moreover, the negative effects were not evaluated in this study which play a significant role in one's health and well-being, thereby, future researches should also focus both the negative and positive aspects of the music and comparative data must be represented in order to evaluate the overall significance and outcomes of musical interventions.

Conclusion

Limited data is in favour of positive effect of music on psychological parameters but it is firmly demonstrated that music consistently and reliably interferes with the mental performance, also indicated by our study. But it is recommended that further studies should be performed to compare the positive or negative impacts of music or the specific type of music causing either positive or negative effect on memory and attention.

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