The effects of binaural beats stimulation compared to classical music on the memory of senior high school students: A randomized controlled trial

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Abstract

Introduction Several studies have suggested that music has a significant effect on memory. Classical music has been studied extensively. However, there are studies on other types of music like binaural beats which involve the introduction of tones of different frequencies. This study aimed to determine the effects of binaural beats stimulation compared to classical music on memory among high school students.

Methods This was a randomized single-blind controlled trial among senior high school students in a selected private school assigned to listen to either binaural beats stimulation or classical music to determine their effect on memory as measured by the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS). Pre- and post-intervention RBANS scores were compared within and between the two study groups.

Results RBANS scores in both classical music and binaural beats stimulation groups improved with an increase of 20.58 ± 10.33 and 20.26 ± 12.06, respectively. The difference between the increase in scores was not significant.

Conclusion Exposure to either binaural beats stimulation or classical music provided statistically and clinically significant increases in memory. Binaural beats stimulation increased memory to the same degree as classical music.

Keywords: Binaural beats, music, memory, RBANS

Due to the advancement of science and technology, new discoveries challenge a person's capacity to remember information. There is a search for options to enhance memory, most especially for students. Among these options, classical music has been established as a memory enhancer, particularly of specific memory.[1] On the other hand, binaural beats stimulation is a type of auditory sensory stimulation which involves tones of different frequencies in each ear producing waves affecting cortical functioning similar to waves that are present in learning and memory encoding processes.[2,3] The Repeatable Battery for the Assessment of

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Neuropsychological Status (RBANS) is a standardized screening tool for assessment of neuropsychological status that includes domains like immediate and delayed memory.[4,5]

The general objective of the study was to determine the effects of binaural beats stimulation and classical music on the memory of senior high school students in a selected private school with the use of RBANS scores. The study also aimed to determine if there is a significant change in the pre-test and post-test scores of each group and if there is a significant difference in the change in scores between the classical music and binaural beats stimulation groups.

Methods

This was a randomized single-blind controlled trial among senior high school students in a selected private school assigned to listen to either binaural beats or classical music to determine their effect on memory as measured by the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS). Pre- and post-intervention RBANS scores were compared within and between the two study groups. The study was approved by the UERMMMCI Research Institute for Health Sciences Ethics Review Committee. Informed consent and assent, when applicable, were obtained from the participants.

Binaural beats stimulation was a 15-minute sound recording composed of a two-toned auditory sound at 130 Hz tone on the right ear and a 125 Hz tone on the left ear. Listening to such frequencies produced a 5 Hz difference in brain wave activity. Classical music was a 15-minute excerpt from Vivaldi's Four Seasons "Spring Movement". Memory was measured using RBANS index scores as converted by a clinical psychologist (CDM) to a total scale index score ranging from 40 - 160.

Participants were selected from senior high school students enrolled for school year 2018-2019 under the STEM program of a selected private school who were 15 to 19 years old, had a minimum sleep of seven hours, and a Mini Mental Status Examination score of at least 24. Those who were repeaters, had taken alcoholic beverages within the previous 24 hours, had known neurological disorders, or had ear/hearing problems were excluded. The minimum required sample size was 33 per group based on 95% confidence, 80% power, variation of 52.85 (S1) and 33.41 (S2) and mean scores of 83.93 (μ1) and 79.4 (μ2) based on the pilot study on 30 students conducted by the researchers. The 30 students in the pilot study were included in the sample.

The participants were randomly allocated using Random Allocation Software version 1.0.0 to listen to 15 minutes of binaural beats stimulation or classical music for five consecutive days under the supervision of the researchers. The listening sessions were continued unless an adverse effect was experienced or there was withdrawal of consent. All underwent a pre-intervention RBANS administered by researchers blinded to the group assignments. A licensed clinical psychologist (CDM) trained the researchers to administer the RBANS, which was conducted in a controlled airconditioned room, free from noise and distraction, provided by the school. Daily monitoring of sleep and substance use was conducted prior to each listening session. To ensure safety of the participants, monitoring for headache and dizziness prior to each listening session until two weeks after the study was done. A post-intervention RBANS was administered by researchers blinded to the group assignments after the last listening session on the fifth day.

The RBANS is a standardized tool commonly used to assess neurological and cognitive function among those who had suffered traumatic head injuries, strokes, and for elderly assessed for dementia.[5] It is also used as a screening tool for the cognitive performance of younger individuals. This is composed of five major cognitive appendices (immediate memory, visuospatial, language, attention and delayed memory) with consequent subtests for each index. The sum of the raw index scores were computed and converted to an RBANS total scale index score from 40 to 160. Index scores were classified as follows: very superior (130 and above), superior (120-129), high average (110-119), average (90-109), low average (80-89), borderline (70-79) and extremely low (69 and below).

It has a split-half reliability coefficient of 0.80 for internal consistency. It was also reported to have a total reliability score of 0.82 to 0.88 in different test-retest studies. RBANS total score correlated at 0.79 to composite z scores from 22 standard measures of IQ, memory, motor, attention, language and executive function.[6] The subtests immediate memory, attention, language and delayed memory had test-retest reliability scores of 0.71 to 0.80 with the visuospatial component being an outlier with a score of 0.63. The total, corrected for age test-retest reliability, remains adequate at a corrected coefficient of 0.85.[6,7]

To determine comparability of the two groups, a chi-square test was used to detect significant differences in sex and year level, and an independent t-test was done for the age and average pretest RBANS score. The RBANS raw scores obtained from the pre-test and post-test were submitted to a psychometrician (CDM) who converted them to RBANS index scores per major cognitive appendix which were added to get the total index score and then converted to the total scale. The pre-test RBANS scores were further grouped according to classification. In comparing the pre-test and post-test RBANS scores of the classical and binaural groups, statistical significance was measured using a two-tailed paired t-test. In comparing the change in RBANS scores of binaural beats and classical music, statistical significance was measured using an independent t-test. The level of significance was set at $\alpha = 0.05$.

Results

Seventy-six senior high school students were randomly assigned to either binaural beat stimulation or classical music group. The mean age for both groups was 16 years. There were more male than female participants in the binaural beat stimulation group, while the opposite was true for the classical music group. More than half of the participants in both groups were in the 12th Grade. The baseline RBANS scores of both groups ranged from average to extremely low. The mean pretest RBANS scores of the binaural beats stimulation group was higher (84.37 vs 79.16). There was no significant difference between the two groups, in terms of age, sex distribution, grade level as well as majority of the pretest RBANS score strata except for the average stratum as seen in Table 1.

For the pre-test of classical music stimulation, the mean RBANS score was 79.16, with the highest at 94 and the lowest at 60. The mean posttest RBANS score was 99.74 with the highest at 127 and the lowest at 79 with one outlier (Figure 1). For the pretest of binaural beats stimulation, the mean RBANS score was 84.37 with the highest at 102 and the lowest at 66 with four outliers. The mean posttest RBANS score was 104.60 with the highest at 128 and the lowest at 75 with one outlier (Figure 2).

As shown in Table 2, the posttest test scores for both binaural beats stimulation and classical music groups were significantly higher than their respective baselines. There was no significant difference in the improvement in RBANS scores between the two groups ($p > 0.05$). There were no significant

Table 1. Baseline demographic characteristics of the participants

Characteristic	Binaural beats n (%)	Classical music n (%)	p-value
Age (yr ± SD)	16.7 ± 0.79	16.8 ± 0.86	0.677[1]
Sex			
Male	20 (52.6)	15 (39.5)	0.250[2]
Female	18 (47.4)	23 (60.5)	
Grade level			
11	17 (44.7)	15 (39.5)	0.642[2]
12	21 (55.3)	23 (60.5)	
RBANS pretest score	84.37 ± 8.41	79.16 ± 8.59	
A	96.72	91.75	0.015[1]
LA	84.87	84.00	0.291[1]
B	75.40	75.10	0.860[1]
EL	66.67	66.00	0.781[1]

[1] Independent t-test for two-sample means
[2] Chi-square test of independence
A = Average; LA = Low average; B = Borderline; EL = Extremely low

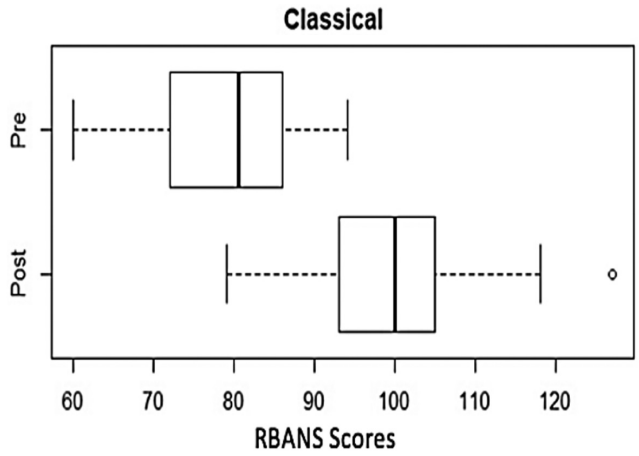

Figure 1. Boxplot of pretest and post-test of classical music stimulation

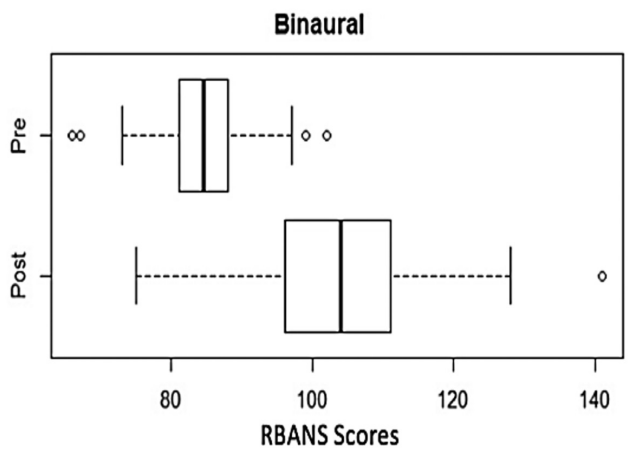

Figure 2. Boxplot of pretest and post-test of binaural beats stimulation

Table 2. Comparison of pretest and posttest RBANS scores of binaural beats stimulation and classical music groups

Group\RBANS score (mean ± SD)	Pretest	Posttest	Difference	p-value
Binaural beats	84.37 ± 8.41	104.60 ± 12.79	20.26 ± 12.06	< 0.001
Classical music	79.16 ± 8.59	99.74 ± 10.63	20.58 ± 10.33	< 0.001
			p > 0.05	

differences between binaural beats stimulation and classical music participants who obtained low average, borderline, and extremely low RBANS scores.

Discussion

Binaural beats stimulation is an auditory sensory stimulation which involves the introduction of tones of different frequencies in each ear. The difference of these two frequencies would have a resultant frequency like that of a theta wave, affecting cortical functioning. To illustrate, 5Hz stimulation would result from listening to 130 Hz on one ear and 135 Hz in the other ear.[2] In a study by Ortiz, the 5Hz stimulation showed a significant increase in the number of words recalled.[8] Theta waves present in learning and memory encoding fall at the range of 4-7Hz. Stimulation using binaural beats resulted in an increase in the RBANS score of the participants.

This may be attributed to the simulation of theta waves preserved along the pathway towards the auditory cortex by virtue of periodic neural firing with respect to the binaural beat frequency.[9] Theta waves oscillate through different parts of the brain.[3] Interactions between these areas of the brain have been strongly associated with working memory performance and retrieval.[9]

The effect of classical music on memory has been studied to a greater extent compared to binaural beats stimulation. This is known as the Vivaldi or Mozart effect: a belief that when a person is exposed to classical music, there would be increased cognitive performance on measures of spatial reasoning and autobiographical memories (e.g., recall).[10] This is further supported in a study that found an increase in autobiographical memories after listening to Vivaldi's "Spring" movement.[10] Nicolas Sulicki concluded that participants who listened to classical music were able to recall more words than participants who had silence as their background, supporting previous suggestions that the short-term effects of listening to classical music on spatial ability are an artifact of

arousal and mood.[11] This can be correlated to this study, where classical music stimulation led to an increase in the RBANS score of the participants. This may be explained by the link between increased levels of dopamine, its effect on positive moods, and the production of norepinephrine with which arousal is strongly associated. Therefore, enjoyable stimuli induce a positive affect and a heightened level of arousal, which lead to modest improvements in performance on a variety of tasks.[12]

The results of this study are consistent with existing literature in documenting that stimulation with either binaural beats or classical music can increase memory.[13,14] An analysis of the improvements in scores between binaural beats stimulation and classical music gives depth to this data since both means are greater than 15 which makes them clinically significant, and it supports the findings in memory enhancement.[4]

The results show that binaural beats stimulation is comparable with classical music at improving memory. With the extensive literature on the utility of classical music on improving memory, it is then promising that binaural beats may be a comparable alternative to the already proven classical music. To the authors' knowledge, there are no published studies yet that compare binaural beats to classical music.

Exposure to either binaural beats or classical music provided statistically and clinically significant increases in memory. Binaural beats increased memory to the same degree as classical music.

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