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Executive Functions among Guitarists and Non-Guitarists

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Abstract

The aim of the study is to assess the executive functions among guitarists and non-guitarists. The components of the executive functions that were included in the study are cognitive flexibility, inhibitory control, working memory, and planning ability. PEBL software was used to test these components. Four computerized tests namely, Berg's Card Sorting Test (BCST), Stroop Test, Corsi Blocks, and Tower of London were used to measure cognitive flexibility, inhibitory control, working memory, and planning ability respectively. 48 guitarists and 48 non-guitarists participated in the study from all over India. The performance of guitarists and non-guitarists on these tests was compared using Independent sample t-test. The results were analysed using SPSS software. The study revealed that the guitarists performed significantly better in Corsi Blocks and Tower of London. No significant difference was observed in BCST and Stroop test. In conclusion, no significant difference was observed in cognitive flexibility and inhibitory control of guitarists and non-guitarists. There was a significant difference in the working memory and planning ability with guitarists performing better.

Keywords: Executive Functions; Cognitive Flexibility; Inhibitory Control; Working Memory; Planning; Music Training

Abbreviations: EFS: Executive Functions; WM: Working Memory; NMP: Neurologic Music Therapy; PEBL: Psychology Experiment Building Language.

Introduction

Executive functions (EFs; also called executive control or cognitive control) refer to a family of top-down mental processes needed when you have to concentrate and pay attention, when going on automatic or relying on instinct or intuition would be ill-advised, insufficient, or impossible [1-3]. Working memory (WM), cognitive flexibility, and inhibitory control [(self-control (behavioural inhibition) and interference control (selective attention and cognitive inhibition)] are generally recognised as the three fundamental EFs. Higher-order EFs like reasoning, problem solving, and planning are constructed from these [4,5]. Executive functions (EFs) include high-order cognitive abilities such as working memory, inhibitory control, cognitive flexibility, planning, reasoning, problem solving, fluency, set shifting ability, set maintenance, error detection, abstraction and organization. For the current study, 4 components of executive functions have been included, namely inhibitory control, cognitive flexibility, working memory and planning. The variables are further discussed below.

Inhibitory Control

The ability of being able to control one's attention, behaviour, thoughts, and/or emotions allows one to ignore a strong internal tendency or external enticement and choose to do

what is more suitable or necessary is known as inhibitory control and is one of the key executive functions [6]. People can selectively attend to stimuli, thanks to inhibitory control of attention, focusing on what they want to pay attention to while blocking out other stimuli. Suppressing prepotent mental representations is another component of interference control. This entails putting up a fight against extraneous or undesired thoughts or memories, including intentional forgetting [7], as well as against proactive interference from knowledge gained in the past and retroactive interference from information provided in the present [8]. Another important factor of inhibitory control is self-control. This involves the ability to control one's behaviour and emotions, along with being able to resist temptations. It also includes staying focused on tasks despite external stimuli or distractions.

Working Memory

Working memory is another essential executive function. Working memory refers to the capacity to hold and manipulate information for the ongoing processes. Even though working memory is a subcomponent of executive functions, some researchers use it synonymously with executive functions.

Cognitive Flexibility

It is the ability to be flexible in the way one thinks about how to solve a problem, shifting behaviour when necessary. It is the ability to modify actions in light of a shifting environment. Both the creation of a conceptual set and its subsequent change require cognitive flexibility. A mental set is created when the environment does not change, which is a circumstance that necessitates a standard response to a standard stimulus. When a mental set is created, responding to a typical stimulus becomes simple because the mental set can be viewed as the predecessor of habit. Another aspect of cognitive flexibility involves changing how we think about something, or in other words, thinking out of the box.

Planning

Planning has been defined as the identification and organization of the steps and elements needed to carry out an intention or achieve a goal [9]. Planning is the mental process that helps us to decide which actions are necessary to complete a task, determine the optimum order, allocate the proper cognitive resources to each activity, and develop a plan of action. Music is universal and can be considered a way that connects humans across countries, cultures and communities.

Studies conducted over time on groups of children provide the most persuasive evidence of the benefits of musical training. Continued music training has been linked to better cognitive functioning in older persons, just as it has been with children, according to research [10,11]. Previous literature shows that prefrontal cortex is crucial for cognitive flexibility. Additionally, research shows that musicians' prefrontal activity is significantly modulated while they actively perform music. In addition, there is some evidence that musicians have improved executive functioning [10], and musicians and non-musicians have different prefrontal anatomical and functional characteristics. With age, individuals experience cognitive decline. To prevent the same, there are various activities that can be adopted starting from childhood. Playing instruments has been proved to be one of the effective ways to do the same. Inculcating music training in curriculum should be essential as a part of a holistic education.

The effect of piano lessons for a duration of 4 months on cognitive function, affective states, and quality of life of older adults showed significant improvement in the Stroop test in the domains of inhibitory control and divided attention [12]. Sustained music training can improve cognitive functioning in older adults [11]. Musicians performed significantly better on the task that measured working memory than non-musicians [13]. Consistent with the same picture, musicians outperformed nonmusicians in working memory as reflected in the reaction times and error rates [14]. The duration of musical practice and found that the longer the musical practice, the better performance on working memory was displayed [15].

The effect of sustained music training was also found in preschool children [16]. Children who learn music have stronger cognitive inhibitory control [17]. A study focused on finding the link between musical training, executive functions and intelligence. They discovered that musicians have higher verbal, general, working memory, and attention than non-musicians. In addition to that, they revealed that long-term musical training is associated with executive functions and intelligence [15]. Musical training can increase the efficiency of people in the ability to shift between mental sets flexibly [18]. Neurologic music therapy (NMP) is a promising method to show a significant improvement in executive functioning in the form of mental flexibility. Adult musicians performed better in cognitive flexibility and working memory than non-musicians, promoting the idea that exposure to music training aids in the preservation and development of a few executive functions.

There are contradictory studies for the cognitive flexibility and musical training as well. No significant correlation was seen between musical training and tasks that measure cognitive flexibility. The present study aims at measuring the executive functioning of instrumentalists and non-instrumentalists.

Instrumentalists include people who have received formal training in playing the guitar, and who have been practicing the same for at least 24 months. Non-instrumentalists include people who have not received formal training in any musical instrument and have not practiced playing any musical instrument in recent times. The executive functions that are being measured in the current study are inhibitory control, working memory, cognitive flexibility and planning.

Method

The current study followed a quantitative framework.

Hypotheses

- Ho1: There is no significant difference in the cognitive flexibility among guitarists and non-guitarists.
- Ho2: There is no significant difference in the working memory among guitarists and non-guitarists.
- Ho3: There is no significant difference in the planning ability among guitarists and non-guitarists.
- Ho4: There is no significant difference in the inhibitory control among guitarists and non-guitarists.

In this study participants included were two groups of adults who are guitarists and non-guitarists. Guitarists are a group of people who received formal musical training in playing guitar. 48 guitarists under the age range of 18-25 years, playing the musical instrument for at least for duration of continuous 24 months were included. Participants who played more than one musical instrument were also included in the study. The non-guitarist group included people who have no formal musical training and have no experience playing guitar for more than a month. This group included 48 people. They fall under the age range of 18-25 years. The current study adopted a snowball sampling method. All the participants were selected from India based on the referral.

The consent form was taken from all the participants prior to their participation. No risk or harm was caused to the participants. The participants were debriefed after taking all the tests. Assurance that confidentiality will be maintained was given to the participants. Demographic details and capability in playing guitar was used to screen participants to meet the inclusion and excursion criteria.

Psychology Experiment Building Language (PEBL)

PEBL is an open-source software program that allows researchers to design and run psychological experiments. There is now access to a sizable library of well-known tests from the cognitive psychology and behavioural neurology domains that have been computerized.

Tower of London

The Tower of London is a well-known test used in applied clinical neuropsychology for the assessment of executive functioning. It is intensively used to test the planning ability of the participants.

Stroop Test

Troop test evaluates the inhibitory control of the subject. It assesses the subject's ability to inhibit an automatic behavior (reading a word) and perform a controlled behavior (saying the color the word is printed in). It included three categories: congruent words, incongruent words, and neutral words. It is a widely used test to measure inhibitory control [19].

Berg's Card Sorting Test

It is a shortened standardized form of Wisconsin card sorting test. It is a neuropsychological test of "set-shifting", i.e. the ability to display flexibility in the face of changing schedules of reinforcement. It is used to evaluate the mental or cognitive flexibility of the subject. It is widely used to measure the cognitive flexibility [19].

Corsi Blocks

The Corsi block-tapping task is a widely used test to assess visuospatial working memory. The participants for all the groups were screened based on their demographic details and music background considering the inclusion and exclusion criteria. Once the participants were identified, a consent form was provided for them to ensure their voluntary participation in the research. The executive functions were assessed on all the participants of all groups using PEBL software. The mode of conducting the experiments on the participants was hybrid; both offline and online. Participants who were assessed online were asked to download the software on their devices and instructions were given on the Google meet platform to participants individually. Participants who were assessed in an offline mode were seated comfortably in a calm, noise-free environment. The raw scores obtained for each of the domains of executive functions were statistically analysed by using independent sample t-test since the study aimed to find the difference between the 2 groups.

Results

Table 1 and shows the distribution of the groups in accordance with the gender. The study included a total of 96 participants which were divided into two groups; 48 guitarists and 48 non-guitarists. There were a total of 50 males and 46 females. The gender distribution for guitarists was 37 males (38.5%) and 11 females (11.5%). Among non-guitarists, 13 males (13.5%) and 35 females (36.5%) participated in the study.

Distribution	Guitarists (48)		Non-guitarists (48)	
	Male	Female	Male	Female
Frequency	37	11	13	35
Percentage	38.5	11.5	13.5	36.5

Table 1: Shows the distribution of the groups and gender.

As shown in Table 2, the mean age of the entire sample is 22.10. The mean age of guitarists is M=22.42 with a SD of 1.955. The mean age of non-guitarists is M=21.79 with a SD of 1.352.

Variable	Guitarists (48)		Non-guitarists (48)		Total (96)	
	M	SD	M	SD	M	SD
Age	22.42	1.955	21.79	1.352	22.1	1.701

Table 2: Shows the mean and SD of the age of the sample.

Table 3 shows the difference in cognitive flexibility between guitarists and non-guitarists assessed by BCST. The parameters that were included to calculate the cognitive flexibility are correct responses, total errors, perseverative responses, perseverative errors and non-perseverative errors for guitarists and non-guitarists. The mean and SD of all data points are shown in the table. As, p>0.05, the results are not significant at 0.05 level. No significant differences were seen in the total correct responses (t=0.462) and perseverative errors (t=0.393) between both the groups.

Variable	Guitarists(48)		Non-guitarists(48)		t	p
	M	SD	M	SD		
Correct responses	94.56	12.83	93.29	14.07	0.462	0.645NS
Perseverative responses	39.88	11.5	39.65	13.83	0.088	0.930NS
Perseverative errors	16.31	6.8	16.96	9.11	0.393	0.695NS
Non-perseverative errors	15.4	14.52	14.88	15.85	0.168	0.867NS

Table 3: Difference in cognitive flexibility of guitarists and non-guitarists assessed by Berg's Card Sorting Test (BCST).
Note: NS=not significant

Table 4 shows the difference in planning between guitarists and non-guitarists assessed by Tower of London. As indicated by p value (p<0.05), there is a significant difference in the planning ability between guitarists (M=44.63) and non-guitarists (M=38.56).

Variable	Guitarists(48)		Non-guitarists (48)		t	p
	M	SD	M	SD		
Total score	44.63	14.44	38.56	14.34	2.06	0.042*

Table 4: Difference in planning of guitarists and non-guitarists assessed by Tower of London.
Note: *p<0.05, significant at 0.05 level

Table 5 shows the difference in inhibitory control between guitarists and non-guitarists assessed by Stroop test. The table shows the mean reactions times and mean accuracy for both the groups on congruent, incongruent and neutral trials. The mean of total errors, incongruent errors and random errors were calculated as well. There is no significant difference in the response time between both the groups on congruent, incongruent and neutral words. However, there is a significant difference in the mean accuracy in incongruent trials (t=2.33) with guitarists (M=0.95) performing better than non-guitarists (M=0.92). No significant differences were observed in total errors made by both the groups.

Category	Variable	Guitarists(48)		Non-guitarists(48)		t	p
		M	SD	M	SD		
Congruent words	Mean response time	805.41	146.25	873.27	204.71	1.86	0.65NS
	Mean accuracy	0.97	0.29	0.96	146.25	0.99	0.32NS
Incongruent words	Mean response time	970.91	245.28	1064.12	301.63	1.73	0.86NS
	Mean accuracy	0.95	0.38	0.92	0.07	2.33	0.02*
Incongruent errors		1.35	1.37	2.23	3.005	1.83	0.07NS
Neutral words	Mean response time	839.72	167.61	916.46	231.58	1.86	0.66NS
	Mean accuracy	0.96	0.03	0.95	0.04	0.81	0.41NS
Total errors		5.25	4.09	7.27	5.87	1.95	0.054NS
Random errors		3.46	3.33	4	3.38	0.79	0.43NS

Table 5: Diference in inhibitory control of guitarists and non-guitarists assessed by Stroop test.
Note: *p<0.05, significant at 0.05 level, NS=not significant

Table 6 shows the difference in visuospatial working memory of guitarists and non-guitarists by Corsi Blocks. The parameter on which working memory is measured is the memory span of the participants. As p<0.01 (p=0.005), the hypothesis is rejected at 0.01 level meaning that there is a significant difference in the memory span of guitarists and non-guitarists with a mean of 5.77 and 5.20 respectively.

Variable	Guitarists(48)		Non-guitarists (48)		T	p
	M	SD	M	SD		
Memory span	5.77	1.19	5.2	0.65	2.87	0.005**

Table 6: Difference in visuospatial working memory of guitarists and non-guitarists by Corsi Blocks.
Note: **p<0.01, significant at 0.01 level

Discussion

The study aimed to investigate the executive functioning among guitarists and non-guitarists. The executive functions that were considered in the study were cognitive flexibility, inhibitory control, working memory and planning. Previous literature emphasize that executive functioning is better in musicians than non-musicians. The results conclude that sustained musical training does indeed give aid to the promotion and development of executive functions. A significant difference was seen in the tests of Tower of London and Corsi Blocks measuring planning and visuospatial working memory respectively. Guitarists showed a better performance in both the tests than non-guitarists. On the tests Berg's Card Sorting Test (BCST) and Stroop test measuring cognitive flexibility and inhibitory control respectively, no significant difference was observed between guitarists and non-guitarists. However, in the Stroop test, a significant difference was found in the mean accuracy on incongruent trials between both the groups, with guitarists performing better than non-guitarists.

The results reveal that there is no significant difference in cognitive flexibility (measured by BCST) between guitarists and non-guitarists. The hypothesis stating that there is no significant difference in the cognitive flexibility of guitarists, and non-guitarists is accepted. the results of the current study are incongruent with a few other previous studies done. A study suggests that musical training can increase the efficiency of people in cognitive flexibility as seen by task switching and dual-task performance [18]. Another study observed that neurologic music therapy (NMP) showed promising effects on the cognitive functioning in the form of cognitive flexibility. One possible explanation for the incongruence in the results could be the role of other factors that influence cognitive flexibility of an individual. Factors can include sleep [20], diet, exercise, meditation, dancing, martial arts, IQ, etc. A study that focused on the impairment of performance in cognitive flexibility as a cause of sleep deprivation found that dynamic attention control is fundamentally impacted by lack of sleep [20]. Previous literature also supports the intake of specific nutrients associated with improved cognitive flexibility. In addition to that, studies have also found that exercise and sports activity has a positive effect on cognitive flexibility [21].

The current study found that there is no significant difference in inhibitory control between guitarists and non-guitarists. So, the hypothesis stating that there is no significant difference in the inhibitory control of guitarists, and non-guitarists is accepted. Stroop test was used to assess this executive function. The results were measured based on the mean response time, and mean accuracy in three categories: congruent words, incongruent words and neutral words. The total errors made were also considered as a parameter. No significant difference observed in the mean response time in the three categories. However, there is a significant difference in the mean accuracy of incongruent trials with guitarists performing better than non-guitarists. The findings of the current study are not congruent with the previous studies. A study that assessed the effect of 4-month piano lessons on executive functions of older adults found a significant improvement on the Stroop test which measures inhibitory control [22]. Music training can improve the executive functions, namely working memory, inhibitory control, and cognitive flexibility [16]. Supporting this study, another research revealed that instrumentalists who played one or more instruments performed better on visuospatial span and on multiple aspects of inhibitory control [11].

There are various factors that can affect the inhibitory control of an individual. The maturity of the frontal lobe's functional capacity is necessary for the growth of inhibitory control. Many studies point prefrontal cortex as the brain region responsible for inhibitory control. Activities that influence this region can also contribute to the enhancement of the executive function (inhibitory control). Activities include sleep quality, physical activity, playing musical instruments [23], and video games. It is not just the activity but the duration for which the individual was engaged in it, along with the quality. For example, a study found that regular and adequate sleep schedule is beneficial for the improvement of inhibitory control [24].

The hypothesis stating that there is no significant difference in the planning ability of guitarists, and non-guitarists is rejected. The guitarists performed significantly better in Tower of London than non- guitarists. There have not been enough studies to investigate planning and music training. A study that investigated if 6 months of individualized piano lessons in older healthy adults can enhance cognitive performance found that the performance was improved in attention, cognitive flexibility as well as planning [25]. The lack of research in this executive function of planning with regard to music training gives rise to further scope and exploration of the topic. On the last test, measured by Corsi blocks, the study found that there is a significant difference in the visuospatial working memory between guitarists and non-guitarists. The hypothesis stating that there is no significant difference in the working memory of guitarists, and non-guitarists is rejected. The findings of the current study are congruent with the previous studies. A recent study revealed that musicians performed better on the task that measured working memory than non-musicians [13]. Another study that focused on the behavioural and neural aspects of working memory in musicians and non-musicians in college supports the idea that long-term musical training is associated with improved functioning of working memory [26]. The duration of musical practice also played a role in better performance on working [15].

The sample size of the current study is small. The tests were conducted in online mode which might have neglected factors like a suitable environment, noise or any other kind of discomfort to the participants [27-29]. Any malfunction in the system, the keyboard or the mouse could not be minimized [30-32]. The IQ of the participants was not considered as that could also be a factor in performing well in the tests [33-35]. The gender distribution was almost equal in total but it was disproportionate in both the groups [36,37]. The scope of this study is limited to only the young adulthood population and cannot be generalized to other age groups. The current study did not take into account the other activities that could have an influence on the executive functioning. Factors like sleep, physical activity, video games, lifestyle, etc. should be questioned and assessed in order to narrow down the cause behind the level of performance in the tests measuring executive functioning of the participants [38]. A few participants in the group of guitarists were trained for more than one musical instrument which could also be contributing to their better performance than others [39]. This also makes it difficult to attribute the better performance to playing guitar only [40].

Conclusion

The study's goal was to look into the differences in executive function between guitarists and non-guitarists. Cognitive flexibility, inhibitory control, working memory, and planning were the executive functions that were taken into consideration in the study. The Tower of London and Corsi Blocks tests, which measure planning and visuospatial working memory, respectively, revealed a significant difference with guitarists performing better. There was no significant difference between guitarists and non-guitarists on the Berg's Card Sorting Test (BCST) and Stroop tests, which assess cognitive flexibility and inhibitory control, respectively. Guitarists performed better than non-guitarists in the Stroop test, which revealed a significant difference in the mean accuracy on incongruent trials between the two groups.

The current study promotes the inclusion of music classes and musical training in schools, high schools and colleges

in India. Music training will also help in the long term as it also helps to slow down cognitive decline. Since papers on executive functions and musical training are limited in Indian context, this paper contributes to that field. This study highlights the limitations and precautions that can be taken into consideration for future studies. Current study results are varied in nature from the existing review of literature. Therefore, this research can contribute to forming the basis of new findings and interventions for developing executive functions. Future studies can make a deeper analysis by assessing the IQ of the participants and considering other activities that can have an effect on the executive functioning. Another aspect to consider in future studies is the holistic assessment of executive functions. The current study focuses only on a few aspects of executive functioning.

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