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The effect of playing different musical instruments on arm asymmetry

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Between the two hemispheres of the brain, structural and functional differences are called cerebral lateralization that can affect the skill performance of both arms in a different way, which is called handedness. Approximately 90% of people is right-handed and they use the right hand for most skillful activities. Interestingly, recent studies especially on musicians show that this difference is less in musicians than in non-musicians and musicians have better skillful performance compared to non-musicians in hand skill task. However, there is no study with the arms performance stated if this also depends on the type of playing instruments. Thus, the purpose of this study was to search if playing different kind of musical instrument, string and piano, can alter the arm asymmetry. Besides, it was also questioned whether string and piano players overall have less asymmetry compared to non-musicians. 30 right-handed participants from three groups (10 from each group) took part and were asked to reach one of three targets in front of them with either right or left arms. Their movements accuracy and linearity were analyzed by electromagnetic movement tracker system (please see method section). As a result, similar results were obtained with previous studies. A significant difference was not seen in the use of arms of musicians who play piano and string instruments. On the other hand, it was found that musicians make use of their arms better compared to non-musicians with their both arms. Thus, playing musical instrument can decrease the arm asymmetry regardless of the type of the instrument.

Key words: Interlimb difference, lateralization, arm asymmetry, musicians.

INTRODUCTION

The human brain is composed of two parts, namely the right and left hemispheres. Structural and functional difference between the two hemispheres of the brain is called cerebral lateralization. A hemisphere is heavier than the other anatomical cerebral lateralization, while handedness is considered as a functional cerebral lateralization (Yıldırım and Dane, 2007). These two hemispheres are specialized to control different aspects of activities. Left hemisphere tasks are controlling of the right side of the body, using right hand, verbal thinking, mathematic, speaking etc., while right hemisphere tasks are using left hand, singing, visuospatial movements, creativity, emotional reactions and dancing (Tarman, 2007). Although, two hemispheres with different tasks, a single brain that is doing completely accurate all of works. Corpus callosum provides this. Corpus callosum is a wide

neural fibers consisting of neural networks that connect information between the two hemispheres of the brain. It connects the left and right cerebral hemispheres and provides inter-hemispheric communication.

The corpus callosum supports information transfer between the two cerebral hemispheres while the planum temporal is crucial to language and music processing (Wilson, 2013). Many studies (Schlaug et al., 1995; Ozturk et al., 2002; Schmithorst and Wilke, 2002; Lee et al., 2003; Norton et al., 2005; Hyde et al., 2009; Schlaug et al., 2009) have shown the structural differences of corpus callosum of musicians. Moreover, numerous studies (Elbert et al., 1995; Zatorre et al., 1998; Evers et al., 1999; Schlaug, 2001; Gaser and Schlaug, 2003; Norton et al., 2005; Hyde et al., 2009; Gentner et al., 2010) have pointed those structural and/or functional differences on the musician's brain. Overall, these studies find out connections between specialized skills and specific brain structures on musicians.

According to Norton et al. (2005), musical performance demands complex cognitive and motor operations. Musicians must translate music notation (visual–spatial–temporal information) into precisely timed sequential finger movements involving coordination of both hands, recall long passages, bring meaning to music through the use of dynamics and articulation, transpose pieces to new keys, and improvise melodies and harmonies based on existing musical pieces. Besides, playing a musical instrument typically requires the simultaneous integration of multimodal sensory and motor information with multimodal sensory feedback mechanisms to monitor performance (Gaser and Schlaug, 2003). Feedback interactions are particularly relevant in playing an instrument such as a violin, or in singing, where pitch is variable and must be continuously controlled (Zatorre et al., 2007).

Every musical instrument playing requires some particular movements. For example, when you play piano both of your arms move horizontally. However, when you play string instruments, one arm moves horizontally, other arm moves vertically. Hyde et al. (2009) found effects of piano training on the primary motor hand area and on the corpus callosum, which were related to performance on a motor sequencing task, thereby again demonstrating the behavioral relevance of the observed cortical changes (Herholz and Zatorre, 2012). On the other hand, playing string instruments implies motor skills including asymmetrical interlimb coordination. Moreover, a recent study has been also showed that participating long-term sport training can also improve interlimb coordination and decrease asymmetry between arms (Akpinar et al., 2015).

Especially for a few decades, it can be seen an increase in the studies on musicians' brain. Important parts of this works are carried out upon the skills of musicians. Of course, hand and arm skills such as motor skills have been first examined elements. In recent years, the impact

on the motor skills of the musicians of the human brain has proven with various experiments. For instance, Jäncke et al. (1997) stated that keyboard instrument players displayed an increased tapping performance for both hands compared to string instrument players. However, string and keyboard instrument players displayed the similar performance of hand performance asymmetry (writing and drawing speed) and both groups performed better than non-musicians. Regarding Jäncke et al. (1997)'s study, they found a significant difference between string and keyboard instrument players in a specific task (tapping task) but not in a daily life task (writing and drawing speed) and they just tested the hand performance. In this current study, the aim of the study was to test the arm asymmetry between string and keyboard instrument players in a basic reaching task and also compare it with the non-musicians. Based on the previous study by Jäncke et al. (1997), it was hypothesized that there should not be a significant arm asymmetry differences between string and keyboard instrument players, but both musician groups should demonstrate less arm asymmetry compared to non-musicians.

METHOD

Participants

In the study 30 subjects who participated were divided into three groups: 10 string instrument players (SP-Group A) (5 female-5 male, M_{age} = 22.3 SD = 1.7 years), 10 piano players (PP-Group B) (5 female-5 male, M_{age} = 23.7 SD = 1.9 years), and 10 non-musicians (Group C) (5 female-5 male, M_{age}=19.5 years, SD: 1.4) voluntarily participated in this study. All participants across all groups reported right-handedness and scored above 70% on the widely known Edinburgh Handedness Inventory (Oldfield, 1971). All participants were recruited from Nevşehir Hacı Bektaş Veli University. Musicians were recruited from Department of Music; non-musicians were recruited from Faculty of Education.

Musicians in the two groups (SP and PP) were individually matched at least 5 years of musical experience and formal training. The exact nature of the experiment aim was explained to each voluntary participant.

Experimental Setup and Design

The participants were seated at the table with sensors of the electromagnetic movement tracker (TrackSTAR, Ascension Technology, USA) which is attached to their right and left forearm depending on the measured arm (Figure 1). This system has been used in many studies (Yong et al., 2015; Korshoj et al., 2014; Przybyla et al., 2012) and has an accuracy rate of 1.4 mm root mean square (RMS) and 0.5 degrees RMS (TrakSTAR, Ascension Technology, USA). Thus, this system is valid and reliable to measure the human movements in both 2D and 3D. This seating arrangement make it possible to participant's reaching in the 2D horizontal space. A mirror covered participants' arms in the start position for each hand and targets were sent from 55" flat screen TV, which is ensured by PC software.

The cursor movements of participants' index finger and positions were updated on the screen in the real time with the update speed

Figure1. The Experimental setup.

Figure 2. The experimental design.

of 100 Hz on the TV screen. At the same time, data of arm movements were saved at 100 Hz frequency.

The participants were asked to reach one of the three targets with three different directions which are 30°, 60°, and 90° (Figure 2). Although there were 3 targets, just one of them was displayed to the participant for each trial. The start position was shown as 2 cm diameter circle and placed 20 cm away from the mid of the body from the left or right side for each arm. Each target was shown as 3.5 cm diameter circle. The cursor was indicated as 1.6 cm diameter circle with cross hair simultaneously moving with the tip of index finger. For participants' reaching easily to the target, the distance between start and target point was limited to 30 cm. After participants positioned the cursor in the start circle for 300 ms, the audio-visual "go" signal was triggered and then the participants moved the cursor to the target. Each target was displayed earlier, after completing the previous trial, to allow participant to self-pace trial preparation by ensuring unlimited time for planning the movement. Participants had the chance to take a break during the experiment so that they could avoid from the exhaustion. This break was the same for all participants and was one minute in duration. Participants were asked to reach the targets with one arm in a session and then they were asked to carry out the movement by coming to the lab again to test the other arm in the other session. There was at least a week between the first and second sessions. The aim of this break between sessions was preventing the interlimb transfer.

Experimental task

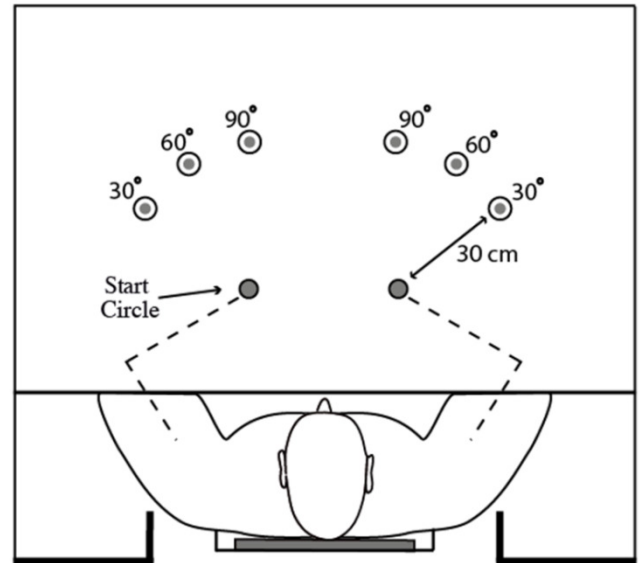Participants were asked to perform 60 reaching arm movements.

They had 20 movements for each target from the start circle (2 cm in diameter) that represented starting position to target (3.5 cm in diameter), which were projected in randomized way. It was very important for participants to reach to the target rapidly while maintaining accuracy and stop on the target without any corrections. Trials were 1 s in duration and at the end of each trial there was a beep signal after the cursor (1.25 cm in diameter cross hair) was hold in the start circle for 0.3 s in duration. For increasing the motivation of the participants' accuracy was awarded with 10, 3 and 1 points for landing within 3.5, 4.5 and 5.5 cm diameter from the center of the target respectively.

Data analysis

In order to find out the quality of arm skill asymmetry across three groups, it was determined two dependent measures: 1-Movement accuracy (Final Position Error = FPE) and 2- Movement quality (Hand Path Deviation from Linearity = HPDL). The FPE was specified as the Euclidian distance between the center of the target and the 2D final position of the tip of the index finger. The HPDL was specified as the ratio between the minor and the major axis of the movement path of the index finger (arm path). The longest distance between any of two points on the arm path was specified as the major axis and the shortest distance perpendicular to major axis was specified as the minor axis. Matlab software was used to analyze the acquired data and then the accuracy and linearity of the each reaching movement were calculated.

In order to define whether the musicians have less arm skill asymmetry difference at one of three different targets compared to non-musicians or not, three-way mixed model ANOVA was used. For reporting the ANOVA, F test result was used with the partial eta squared (η^2). η^2 is the value to show the effect size of the analysis (Levine and Hullett, 2002). An inferential test may be statistically significant (i.e., unlikely to have occurred by chance), but this doesn't necessarily indicate how large the effect is. Thus, reporting the η^2 makes the results even stronger. Post-hoc analysis was carried by using Bonferroni adjustment. Statistically significant level was determined as $p < .05$. If this value is above .05, it means that there is no significant difference between the variables but if the p value is below the .05 then there is a significant difference.
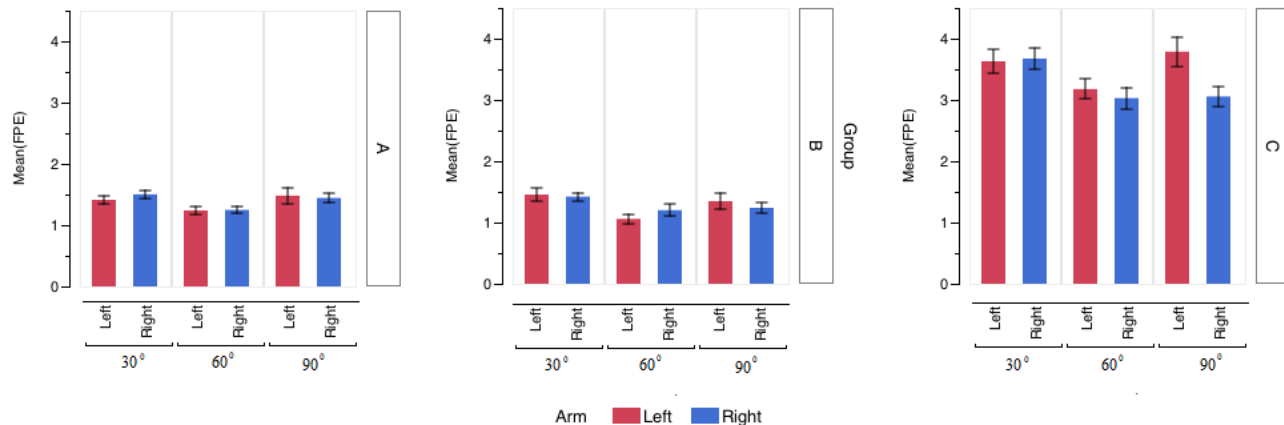
Figure 3. FPE between musicians (SP and PP) and non-musicians across three different targets.
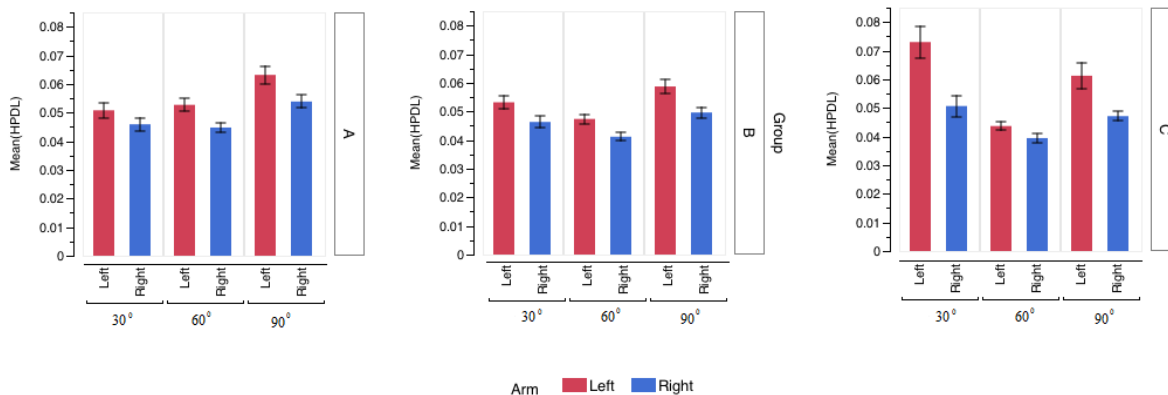

Figure 4. HPDL between musicians (SP and PP) and non-musicians across three different targets.

RESULTS

In this section, quantitative results according to their applied rank are presented. Firstly, both groups, musicians (SP and PP) and non-musicians, made reaches to the three different targets located across horizontal space in front of the body with the right and the left arm. Figure 3 shows the average magnitude of the FPE for each target for the right and the left arm across musicians (SP and PP) and non-musicians. The result of the statistical analysis for the FPE displayed a significant three-way interaction, Group x Arm x Target Region, $F_{(2, 27)} = 3.28$, $p = .04$, $\eta^2 = .22$. Post-hoc analysis displayed that left arm of musicians (SP and PP) had better accuracy for targets located in 30° , 60° and 90° compared to same arm of the non-musicians ($p < .05$). The same pattern was also observed for the right arm ($p < .05$). Whereas there was no significant accuracy difference between SP and PP for all targets on the left and right arm. However right arm displayed better accuracy performance than left arm for 90° target among non-musicians was significant difference.

Secondly, Figure 4 shows the HPDL across musicians (SP and PP) and non-musicians. The result of the statistical analysis for the HPDL displayed a significant two-way interaction, group x arm, $F_{(2, 27)} = 3.04$, $p = .05$, $\eta^2 = .15$ and a significant Arm main effect, $F_{(1, 27)} = 16.23$, $p = .0004$, $\eta^2 = .65$. The main effect of arm showed that right arm overall had straighter reaches compared to left arm. Post-hoc analysis for Group x Arm interaction displayed that there was only a significant difference in non-musicians between their right and left arm ($p < .05$). As expected, right arm of non-musicians had less linearity than that of left arm. All the other comparisons did not show any significant differences.

DISCUSSION AND CONCLUSION

The main finding of this research is that musicians'

accuracy data exhibited a reduced degree of arm skill asymmetry in comparison to non-musicians. On the other hand, there is no significant difference in linearity data between musicians and non-musicians. Moreover, when compared to string players (SP) and piano players (PP) there was no significant difference for all targets on the left and right arm both in accuracy and linearity. That is, SP and PP displayed the similar performance in the reaching task. Whereas both SP and PP displayed similar performance in the hand path deviation linearity with non-musicians, they had better accuracy than non-musicians.

It is uncertain which instrument more affects arm skill asymmetry. However, it can be said that playing a musical instrument performs secondary tasks better than non-musicians of both arms. In addition to that, there is a widespread view that playing a musical instrument should develop some skills (Rodrigues et al., 2010; Brochard et al., 2004, Norton et al., 2005). In the current study, the similar results were found. That is, both musician groups displayed better accuracy compared to non-musicians. This could be explained by some neurophysiological findings. It has been stated that musicians started to train music at young ages have been shown to have enlarged brain areas (Elbert et al., 1995; Pantev et al., 1998; Schlaug, 2001).

Moreover, degree of structural and/or functional brain differences between musicians and non-musicians related with density of musical training (Schneider et al., 2002; Gaser and Schlaug, 2003; Hutchinson et al., 2003).

It is currently still not clear if music training may improve cognition with the consequence of the attention, motivation, concentration, and discipline. On the other hand, music training could possibly have some specific effects which other forms of training do not have. As stated earlier, cognitive improvement through music training might be because of the particular kind of skills required by music study; for example, memorizing prolonged passages of music, learning music structures and rules, learning to make fine auditory spectral and temporal discriminations, and learning to perform skilled bimanual finger movements (Norton et al., 2005).

Otherwise according to Jäncke et al. (1997) it is ambiguous whether the altered hand skill asymmetry in musicians influences hand preference as measured by standard preference tests. Right handed musicians might exhibit a tendency to perform "secondary tasks," such as unscrewing a lid or dealing cards, more often with the non-dominant hand due to their increased left-hand skills. Jäncke et al. (1997) had two main findings; keyboard instrument players displayed better performance in tapping task compared to string instrument players, which was not surprising as this task was more familiar for them, and no differences between those two groups in writing and drawing task. In this current study, there was no significant difference between SP and PP for accuracy and linearity during the reaching task. The task used in this study is similar to a daily reaching task, like reaching

a glass or reaching to pick a pen. Thus, it is not specific for any group of musicians. As Jäncke et al. (1997) found no difference in daily life task (writing or drawing) between those groups of musicians; the finding of this current study is in agreement with those researchers findings.

Consequently, musicians who play an instrument at least 5 years use both arms better compared to non-musicians according to movements accuracy but not linearity.

Thus, it can be stated that playing both string and piano can decrease arm asymmetry and improve both arm performance, especially accuracy.

Conflict of Interests

The author has not declared any conflicts of interest.

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