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Motor Lateralization May Be Influenced by Long-Term Piano Playing Practice

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Abstract

Motor lateralization is viewed as anatomical or functional asymmetry of the two sides of the body. Functional motor asymmetry can be influenced by musical practice. This study explored whether piano playing experience modulates motor asymmetry and leads to an altered pattern of hand selection, reflecting an altered handedness. We asked two groups of right-handed participants—piano players and non-piano players—to reach targets in their frontal space with both arms, and we tested the motor performance of each arm on this task and then on an arm preference test. As musical practice can decrease motor asymmetry between arms, we hypothesized that participants with piano playing experience would display less interlimb asymmetry and that this, in turn, would change their arm preference pattern, compared with participants without piano playing experience. We found support for both hypotheses, and we conclude that arm selection (preference) is not biologically fixed, but, rather, can be modulated through long-term piano playing.

Keywords

interlimb difference, motor preference, motor accuracy, motor coordination, piano players

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Introduction

Lateralization, as a human characteristic, refers to having any anatomical structure or functional state of the body that is expressed more on either the right or the left side of the body (Leong, 1980). In this context, lateralization represents contralateral structural and functional differences between the brain's two cortical hemispheres. In humans, one of the cortical hemispheres is generally more developed than the other, with associated implications for brain areas associated with motor control functioning (Mutha, Haaland, & Sainburg, 2012). The more developed hemisphere has been called the dominant hemisphere, and the contralateral hand controlled by the dominant hemisphere, when compared with the other hand, generally exhibits superior motor skills. Przybyla, Coelho, Akpinar, Kirazci, and Sainburg (2013) hypothesized that the individual selection of which hand to use for a particular task may result from the interaction between the task conditions and these underlying neurobehavioral asymmetries. Based on this hypothesis, Przybyla et al. (2013) showed that abolishing visual feedback improved the relative performance of the nondominant arm and increased the individual's inclination to use the nondominant arm during a reaching task. Thus, there are connective links between this dynamic dominance hypothesis and hemispheric asymmetry and hand preference. From this point of view, it is important to study and better understand a preference for using either the right or left hand in various activities such as writing, playing musical instruments, painting, and sports activities. According to Uzun and Alkan (2002), there is a direct relationship between hand dominance and hemispheric dominance. Moreover, cross-dominance is supported by certain environmental factors, as, for example, when it provides important advantages to peak performers such as basketball players (Stockel & Weigelt, 2012), rowers (Akpinar, 2015), and musicians playing musical instruments (Kaya, 2015; Zatorre, Chen, & Penhune, 2007).

Playing musical instruments is an activity for which hand and arm skills are of great importance. In this field, controlling motor movements greatly influences the musician's musical performance.

> Musical performance requires 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 harmonics based on existing musical pieces. (Norton et al., 2005, p. 125)

It is vital for musicians to use both hands in an effective and coordinated manner during a musical performance. For example, when playing a stringed instrument, one of the musician's arms moves horizontally, while the other arm moves vertically; but, when playing a piano, the musician uses both arms horizontally.

Much past experimental research in this area has focused on musicians' brain processing, their hand-arm skills, and brain and motor asymmetries (Amunts et al., 1997; Brochard, Dufour, & Després, 2004; Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995; Gaser & Schlaug, 2003; Gentner et al., 2010; Kaya, 2015; Rodrigues, Loureiro, & Caramelli, 2010). More specifically, playing musical pieces in a technically appropriate fashion on the piano requires a high level of performance involving moving both the right and left hands in a precisely controlled way. Over time and with extensive repetitive practice, pianists are able to move both hands faster with greater automaticity.

According to Furuya and Altenmüller (2013), piano performance includes a large repertoire of highly skilled movements. An impressive music performance may require sensorimotor skills that make it possible for pianists to manipulate various musical elements (e.g., loudness, tempo, tone, and rhythm). This also includes the rearrangement of the motion by the motor system. Fast, precise, skillful, and efficient movements depend on exceptional cognitive, cognitive and motor skills such as the production of rich repertoires of complex movements, the rapid correction of erroneous actions, sensory-motor coordination, and large musical stored memory. Due to changes in piano players' cerebral motor representation, Meister et al. (2004) found that professional piano players showed less cerebral activation in their motor and premotor brain regions when performing the same movement, compared with nonmusicians. Hyde et al. (2009) examined the behavioral and auditory relationship of cortical changes related to piano education and observed more corpus callosum involvement in processing basic hand motor skills in the experimental pianist versus non-pianist control group. Krings et al. (1999) suggested that long-term motor practice might cause different cortical activation patterns among pianists such that pianists engaged fewer nerve cells when engaged in identical motor movements compared with control group.

As can be seen from this literature, lateralization and motor asymmetry are important to understanding musicians' motor control structures. Thus, the aim of the current study was to investigate whether long-term piano practice influences motor lateralization and hand preference. Due to active use of both hands in playing a keyboard instrument like the piano, we predicted that motor asymmetry among these musicians would be less strong than that of non-piano players. We expected that if piano players would also show less lateralization on a hand preference task compared with non-piano players. To test our predictions, we asked piano players and non-piano players to reach targets located on the left, right, and middle areas of their workspace so that we might judge the relative strength of their hand preference; right handers normally display an asymmetric distribution of dominant and nondominant reaches across the workspace, preferring dominant reaches to targets located in the right and middle areas of the workspace and also to targets just left of the body midline (Bryden, Pryde, & Roy, 2000; Gabbard & Rabb, 2000; Stins, Kadar, & Costall, 2001).

Method

Participants

We recruited 80 participants of 18-28 years of age. Forty participants comprised the piano playing group (20 female; $M_{\text{age}} = 22.42$, $SD = 2.82$ years), and they had 3-15 years of piano playing experience ($M_{\text{piano experience}} = 6$, $SD = 1.35$ years). Forty participants were in the control group (20 female; $M_{\text{age}} = 20.65$, $SD = 1.77$ years), and they had no musical instrument experience. Non-piano players (control group) also self-reported that they had no experience in any sports or regular participation in any sport activity. All participants signed an informed consent form approved by Nevsehir Haci Bektas Veli University Ethical Committee in accordance with the Declaration of Helsinki as amended by the World Medical Association Declaration of Helsinki. All participants were right handed and scored above 70% on the 10-item Edinburgh Handedness Inventory (Oldfield, 1971).

Experimental Design

Each participant was involved in three experimental sessions, separated from each other by at least 2-week intervals in order to avoid any potential interlimb transfer effect. The first and second sessions were nonchoice conditions in which participants were asked to perform reaches with either their dominant or nondominant hands. These sessions were designed to investigate the interlimb asymmetry. The last session was a choice condition designed to test arm selection preferences. The order of all sessions was counterbalanced across all participants.

Within the sessions, participants sat in an adjustable chair in front of a table with a sensor from the electromagnetic tracker (TrackSTAR ascension Technology, Shelburne, VT) attached to the index finger of either their dominant or nondominant hands. This system allowed testing of the reaches in the two-dimensional horizontal space in front of the participants. Participants could not see their arms, as their arms were covered by a mirror; instead, they could see a cursor or two cursors associated with the tip of each index finger. There was one start position for each hand, and for each trial, one target was projected onto a 55″ flat TV screen that displayed a custom-made virtual reality interface. The participants were seated 20 cm away from the bottom of the TV. The cursor position on the screen was updated in real time, limited only by the TV screen's update speed of 100 Hz. Finger displacements were recorded at 100 Hz frequency

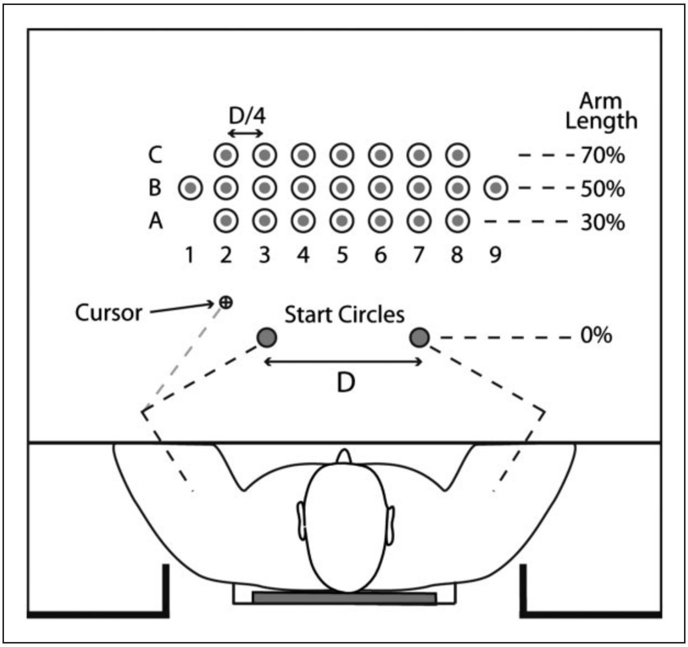

Figure 1. The distribution of the matrix of 23 targets.

during the participants' reaches. The matrix of 23 targets located horizontally in front of the participants was displayed as the reaching aim (Figure 1). These targets were placed in consideration of each participant's arms size. The targets' lines in the transverse plane were arranged with respect to 30%, 50%, and 70% of the arm extension. The targets' lines in parasagittal planes were placed symmetrically from the midsagittal plane into the participant's left and right hemispace by a quarter of the distance between the two starting positions.

Experimental Task

Participants performed 115 reaches (five per each target) from the start circles (two cm in diameter) representing the starting positions to the targets (3.5 cm in diameter), each presented in a pseudo-randomized order. The sizes of the start circles and targets were obtained from previous studies (Akpinar, 2015; Akpinar, Sainburg, Kirazci, & Przybyla, 2015) for which there was testing of optimal-sized starting circles and targets. To avoid fatigue, we gave participants two breaks of 30-second duration each, following their 40th and 80th trials. The task for the participants was to reach the shown target rapidly while maintaining accuracy and to finalize the movement on the target with no additional corrections. Each trial was one second in duration and was started with a beep signal after both cursors (1.25 cm in diameter with cross hair) were put in the start circles for a duration of 0.3 s. Each target was shown prior to the trial initiation; thus, all trials were self-paced, and participants had enough time for movement planning in all experimental sessions. To motivate the participants during the experiment, we rewarded each accurate reach with 10-, 3-, and 1-point rewards for landing within 3.5, 4.5, and 5.5 cm diameter from the center of the target, respectively. As noted earlier, there was no hand choice in the forced right- and left-hand conditions. In the choice conditions, participants were asked to choose one hand with which to reach the displayed target, and in these conditions, we placed two sensors (for the dominant and nondominant hand) onto the hands.

Data Analysis

Interlimb differences in reaching performance were determined by using two dependent measures—movement accuracy (final position error [FPE]) and movement quality (hand path deviation from linearity [HPDL]). FPE was defined as the Euclidian distance between the center of the target and the two dimensional final position of the tip of the index finger represented by the cursor. HPDL was defined as the ratio between the minor and the major axis of the movement path of the index finger (hand path). The major axis was defined as the farthest distance between any two points given on the hand path, and the minor axis was defined as the furthest distance perpendicular to the major axis from any given point on the hand path. For the hand selection pattern of the two groups, the frequency of the hand chosen for reaching to each target was calculated and separately averaged across the groups of participants in the experimental and control conditions. Data processing for all dependent variables was performed using MATLAB software.

For statistical analyses, the target workspace was divided into three distinct regions: left (Columns 1–4), middle (Column 5), and right (Columns 6–9). Means of the dependent variables (FPE, HPDL, and reaching frequency) were analyzed using a three-way mixed model analysis of variance (ANOVA), with arm (dominant or nondominant) and regions of space (right, middle, and left) as the within-subject factors and group (piano players or non-piano players) as the between-subject factor. For all analyses, the participants were treated as a random factor, and statistical significance was tested using an alpha value of .05; post hoc analyses, when needed, were conducted using Bonferroni adjustment. Please note that first two sessions were nonchoice conditions and we used the data from these two sessions to compare the motor asymmetry between the dominant and nondominant arms. As we know from previous literature that speed can affect movement accuracy (Fitts, 1954), we controlled speed by permitting one second of time for a single reaching movement. Thus, movement speed was matched between both groups and across conditions, eliminating any speed effect on the dependent measures. Statistical analyses were conducted using JMP 10 software.

Results

Lateralization—Motor Performance Measurements—Nonchoice Condition

As noted, we relied upon two dependent measures to depict and contrast participant group performance with regard to their reaching movements: (a) FPE and (b) HPDL. As shown in Figure 2, FPE values reflected a dominant arm advantage in the middle and right region for both participant groups in the no-choice condition. The three-way mixed model ANOVA revealed a significant two-way interaction between group and arms, $F(1, 78) = 16.08$, $p < .05$, $\eta^2 = .54$, meaning that group and arms differences accounted for 54% of this interaction plus associated error variance. Post hoc analysis revealed a higher FPE for non-piano players' nondominant arm ($M = 2.16$, $SD = 0.06$ cm) compared with their dominant arm ($M = 1.70$, $SD = 0.06$ cm) and to both the nondominant arm ($M = 1.54$, $SD = 0.06$ cm) and dominant arm ($M = 1.31$, $SD = 0.06$ cm) of piano players. FPE values were lower for piano players' dominant arm FPE

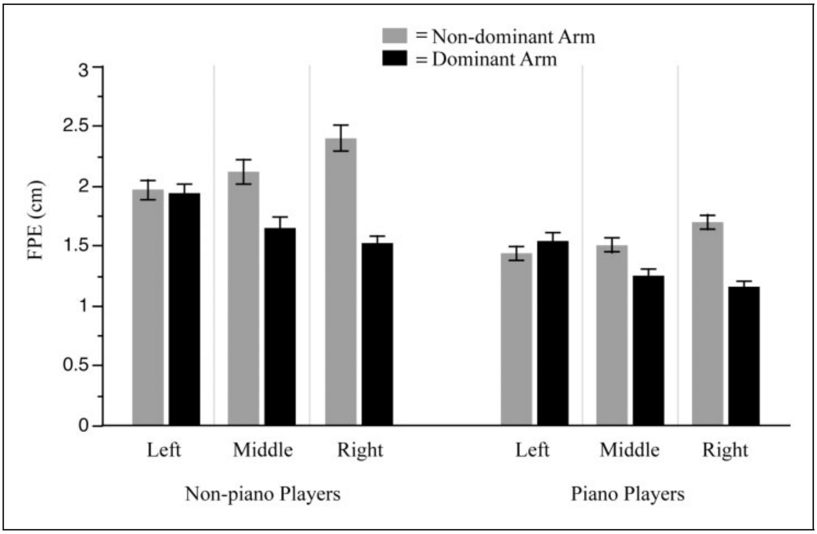

Figure 2. The magnitude of the FPE between non-piano players and piano players averaged across target regions (left, middle, and right) and arms.
FPE = final position error.

than for their nondominant arm, and for both arms of non-piano players. Overall, the dominant arm in both groups performed reaching movements with better accuracy; however, the nondominant arm of piano players was similarly accurate with the dominant arm of non-piano players.

Regarding test lateralization, Figure 3 displays HPDL, averaged for each region, for each arm of members in both participant groups. Figure 3 shows that each arm displayed superior performance on HPDL when reaching into the region most proximal to the arm, but piano players made straighter movements with both arms, compared with non-piano players. The three-way mixed model ANOVA showed a significant three-way interaction (Groups $\times$ Arms $\times$ Regions), $F(2, 77) = 3.13$, $p < .04$, $\eta^2 = .23$, indicating that Group $\times$ Arms $\times$ Regions differences accounted for 23% of this interaction plus associated error variance. Post hoc analysis revealed that HPDL was significantly higher for non-piano players' nondominant arm in the right region ($M = 0.08$, $SD = 0.01$ au) compared with their dominant arm in that region ($M = 0.03$, $SD = 0.01$ au). A similar right region pattern was also observed among piano players ($M = 0.02$, $SD = 0.01$ au for dominant arm and $M = 0.05$, $SD = 0.01$ for nondominant arm). An interesting result was observed in the middle region where there was no significant difference between the piano players dominant and nondominant arms ($M = 0.04$, $SD = 0.01$ au and $M = 0.04$, $SD = 0.01$, respectively), but, among non-piano players, HPDL was significantly lower

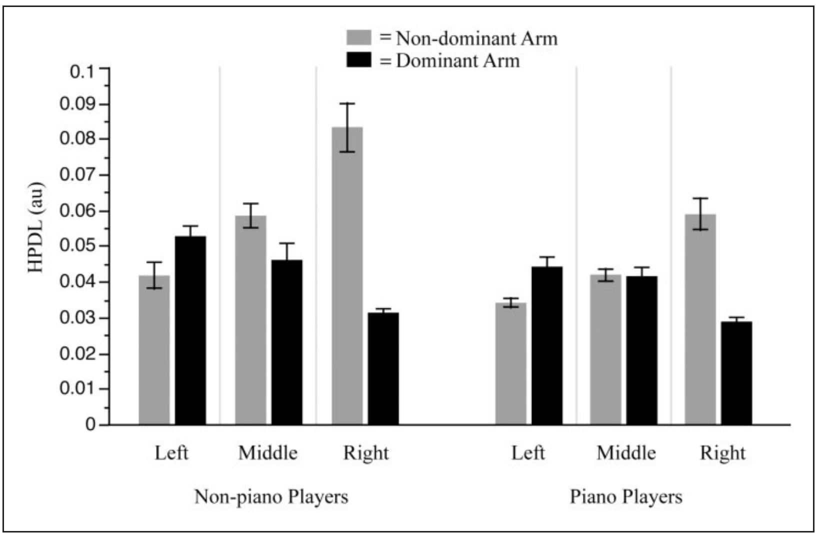

Figure 3. The magnitude of the HPDL between non-piano players and piano players averaged across target regions (left, middle, and right) and arms.
HPDL = hand path deviation from linearity.

for the dominant than nondominant arm ($M = 0.04$, $SD = 0.003$ au and $M = 0.05$ $SD = 0.003$, respectively). In the between-group comparisons in regions and arms, piano players had significantly straighter reaches (fewer HPDL) with their nondominant arm in the middle region ($M = 0.04$, $SD = 0.003$ au) and in the right region ($M = 0.05$, $SD = 0.003$ au), compared with the same arm of non-piano players in both regions ($M = 0.06$, $SD = 0.003$ and $M = 0.09$, $SD = 0.003$, respectively). There was no significant difference between both groups' dominant arm in three regions.

Arm Preference Between Piano Players and Non-Piano Players—Choice Condition

Figure 4 shows the distribution of reaching frequency averaged across regions, between arms and groups. Each arm was used more in its own region in both groups. However, piano players preferred to use their nondominant arm in the left and middle regions considerably more often, compared with non-piano players. The statistical analysis for arm preference revealed a significant three-way interaction (Groups $\times$ Arms $\times$ Regions), $F(2, 77) = 12.19$, $p < .05$, $\eta^2 = .42$, and post hoc analysis showed that the dominant arm was preferred significantly more often in middle and right regions for both groups ($M = 99.62$, $SD = 1.73$ vs. $M = 0.38$, $SD = 0.24\%$ in right region and $M = 80.52$, $SD = 2.9$ vs.

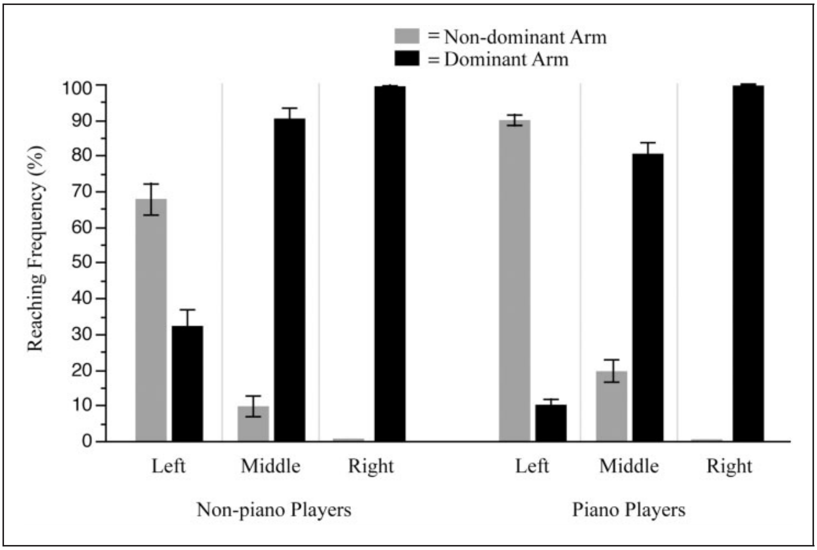

Figure 4. The percentage of the reaching frequency between non-piano players and piano players averaged across target regions (left, middle, and right) and arms.

$M = 19.48$, $SD = 2.92\%$ in middle region for piano players, $M = 96.92$, $SD = 1.75$ vs. $M = 3.08$, $SD = 3.25\%$ in right region, and $M = 90.31$, $SD = 2.9$ vs. $M = 9.69$, $SD = 2.97\%$ in middle region for non-piano players). In the left region, the nondominant arm was used significantly more often compared with the dominant arm among both groups ($M = 89.94$, $SD = 3.21$ vs. $M = 10.06$, $SD = 3.24\%$ for piano players, $M = 67.68$, $SD = 3.28$ vs. $M = 32.22$, $SD = 3.25\%$ for non-piano players). In the group comparison, piano players used their nondominant arm significantly more often in the left region ($M = 89.94$, $SD = 3.21\%$) compared with the same arm of non-piano players ($M = 67.68$, $SD = 3.28\%$). These results show that each arm was used significantly more often in the region proximal to it, but piano players used their left nondominant arm more often in the left region compared with the non-piano players' use of the left nondominant arm in the left region.

Overall, as the piano players performed similarly with respect to HPDL for both arms in the middle region, this group showed a relatively higher preference for the use of their nondominant arm.

Discussion

In this study, we conducted three different experimental tests of hand or arm use among 40 piano players and 40 non-piano players. In the first and second experimental tasks, participants were asked to make reaching movements with only their right (dominant) hands and only their left (nondominant) hands toward targets located in the right, left, and middle regions of their personal space. In the third task, participants were asked to make reaching movements toward targets in these regions with whatever hand they preferred. In the first two reaching tasks, we found that piano players were more accurate with the use of their nondominant hand than were the non-piano players when using their nondominant hand. There was no difference between the nondominant hand of the piano playing group and the dominant hand of the non-piano playing group. As for HPDL, piano players performed straighter movements with the nondominant arm in the ipsilateral region compared with the dominant arm and showed a similar HPDL in the middle region, while non-piano players showed better nondominant arm performance only when reaching into left region. In parallel with these results, piano players preferred to use their nondominant arm more often, compared with the non-piano players' preference for using the nondominant arm.

Past researchers observed similar patterns of motor lateralization and hand selection in sports, like fencing (Akpinar et al., 2015), rowing (Akpinar, 2015), basketball (Akpinar, 2016), judo (Mikheev, Mohrb, Afanasiev, Landis, & Thut, 2002), and kung Fu (Maeda, Souza, & Teixeira, 2014). Kaya (2015) found less motor lateralization among musicians (string and piano players) compared with a control group, but he did not study hand preference or control for target placement effects. Structural changes that have been observed in musicians' corpus callosum (Schlaug, Jäncke, Huang, Staiger, & Steinmetz, 1995) and motor cortex (Amunts et al., 1997) demonstrate an apparent neurofunctional correlate for our musicians' better nondominant hand performance and reduced motor lateralization compared with our nonmusician control group. This is consistent with Amunts et al. (1997), who found that left-right hemisphere asymmetry in the motor cortex in musicians was less than that of a control group, potentially improving the performance of both arms on different tasks. In fact, in other research, children who received musical training demonstrated improvements in nonmusical cognitive abilities (Piro & Ortiz, 2009; Schellenberg, 2004), and musicians have been shown to display shorter reaction times compared with controls (Brochard et al., 2004). Moreover, musicians showed improved visual ability, relative to nonmusicians, as a result of long-term musical training (Rodrigues, Guerra, & Loureiro, 2007; Rodrigues, Loureiro, & Caramelli, 2013). many studies have shown various cognitive and perceptual improvements for musicians versus nonmusicians (Kopiez, Galley, & Lee, 2006). Most of those studies were not connected with hand or arm preference. Pençe (2000) defined cerebral lateralization as the anatomical and functional differentiation between the right and left hemispheres of the brain. In addition, Wilson (2013) noted that while the corpus callosum supports information transfer between the two cerebral hemispheres, the planar temporal is very important for language and music processing. Jäncke, Schlaug, and Steinmetz (1997) also mentioned that right-handed musicians may be more successful in achieving certain secondary tasks with their nondominant left hands since their left-hand skills increase. Increased nondominant left-hand skills in musicians can modulate the lateralization, which was also found in the current study.

It has been previously stated that musicians have superior cognitive and perceptual performances on different tasks (D'Anselmo, Giuliani, Marzoli, Tommasi, & Brancucci, 2015; Landry & Champoux, 2017; Norton et al., 2005). These superior cognitive and perceptual processing in musicians may be associated with an improved motor performance pattern, especially for the left nondominant hand, and with a modified hand preference, resulting in a greater tendency to select the left nondominant hand, compared, in this case, to non-piano players. Regarding the arm preference pattern, prior researchers asserted that right handers prefer to use their dominant arm mostly in the right and middle regions and have a tendency to use their dominant arm for reaching to targets just left of the body midline (Bryden et al., 2000; Gabbard & Rabb, 2000; Stins et al., 2001). Our results with non-piano players are consistent with this previous literature, as they also preferred to use their right arm in the left region of space (see Figure 4). Interestingly, piano players displayed a different pattern compared with non-piano players. The percentage of piano player reaches in the left and middle regions was substantially higher for the left arm, a finding that was associated with superior (in the left region) or equal (in the middle region) performance of the left arm in those regions. Thus, increased performance of the left arm may lead to its being preferred more for piano players, compared with non-piano players.

In conclusion, our data suggest a link between reduced lateralization and hand preference in piano players versus non-piano players. Structural changes in the brain throughout music education (Amunts et al., 1997; Schlaug et al., 1995) and improved cognitive and perceptual functioning in musicians (Kopiez, Jabusch, Galley, Homann, Lehmann, & Altenmüller, 2011; Piro & Ortiz, 2009; Schellenberg, 2004) may lead piano players to perform superior reaching movements with their left nondominant arm and to alter their hand preference when compared with non-piano players. Our study participants included only right-handed piano players. Further research is needed to determine whether these findings would also be evident for left-handed piano players or other types of musicians.

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Declaration of Conflicting Interests

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