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Transfer of Motor Skills: A Comparative Study of College-Level Musicians and Athletes

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A R T I C L E I N F O

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ABSTRACT

Background: The transfer of motor skills is one of the central topics in motor behavior and speaks to the effects of learned motor skills on learning or performing other skills.

The purpose of this investigation was to examine the transfer of skillful fine or moderately-fine movements to novel tasks requiring similar movements.

Methods: The study involved 43 undergraduate university students in three groups: university musicians, athletes and a control cohort. Two novel motor tasks were performed that required either fine hand movements (pursuit rotor task), or moderately-fine arm movements (underhand dart throw task).

Results: For the fine motor task, musicians performed better than the athletes and the control ($p<0.05$), but did not demonstrate less movement asymmetry than the other groups, as hypothesized ($p>0.05$). For the moderately-fine task, the athletes performed better than the other two groups ($p<0.05$), and in particular, with the dominant arm ($p<0.05$), as hypothesized.

Conclusion: A lack of shared elements between musical instrument playing skills and the novel fine motor task likely contributed to the relatively low levels of performance with the musicians. Conversely, the presence of more shared elements between sports throwing skills and the novel moderately-fine task likely contributed to greater levels of performance by the athletes.

1. Introduction

Transfer of learning is defined as the influence of previous experiences on performing a skill in a new setting, or on learning a new skill. There are three main forms of transfer: positive, negative and zero. In situations with positive transfer, previous experience enhances the performance or learning of a new skill beyond the rate of learning or performance that would typically be seen without the benefits of the previous experience. Negative transfer is just the opposite, when previous experience hinders new learning or performance. In cases when previous experience has no impact on new learning or performance, there is zero (or neutral) transfer (Fischman, Christina, & Vercruyssen, 1981).

The study of transfer dates from at least the early 1900s with identical elements theory, by Thorndike and Woodworth (1901), one of the best-known early ideas about the process of transfer. The theory suggested that the main factor that determines the extent and form of transfer among different tasks are the number of specific elements the tasks share. Succeeding investigators have offered newer ideas, building on Thorndike and Woodworth's work, such as Taylor and Heilman (1980), who developed the callosal access model to explain the process of the transfer of skills between dominant hand to non-dominant hand. According to the model, a single memory is stored in the dominant brain hemisphere during initial training regardless of the limb used. When the other limb is initially trained on the same movement task, the motor system can access the memory of the movement via the corpus callosum connections between the motor areas of the brain. A comparable idea, referred to as the cross-activation model (Parlow & Kinsbourne, 1989), proposed that a similar, but weaker memory, is stored in the non-dominant hemisphere during training with the dominant limb, and that memory is used by the non-dominant limb when performing the movement. Taking a somewhat different approach, Logan's (1988) theory suggested that during an initial encounter with a novel task, the motor system needs to use adaptive strategies to transfer previous experience to the unknown task because no prior memories exist of the novel task. Lastly, Schendan and Kutas (2007), described the transfer-appropriate processing theory, which suggested that the same basic neural processes are applied to different tasks that are similar to one another irrespective of the limb that is trained initially.

The process of shared control of learned movements is commonly referred to as bimanual (or bilateral) transfer (Lee & Genovese, 1989). Previous research on bimanual transfer has reported on tasks such as tapping with the dominant hand, which was found to transfer to the non-dominant hand (Laszlo, Baguley, & Bairstow, 1970). Similar findings have also been reported for keyboard tasks (Taylor & Heilman, 1980), for a reverse writing task (Latash, 1999; Parlow & Kinsbourne, 1989), when reaching during coriolis force perturbations (Dizio & Lackner, 1995) and for movement tasks performed during visuomotor displacements (Elliott & Roy, 1981; Imamizu & Shimojo, 1995), among other findings.

Investigations into neuroplastic adaptations in regions of the brain associated with hand movements have contributed to the understanding of bimanual transfer. For example, neuroplastic changes have been found in the non-dominant hand hemisphere of the brain that are similar to changes seen in the dominant hand hemisphere in musicians (Amunts et al., 1997; Schlaug, 2001). Similarly, Gaser and Schlaug

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(2003) reported finding structural adaptations in areas of the motor cortex associated with hand movements in accomplished keyboard musicians when compared to amateur musicians and a matched control group. The effect of neuroplastic adaptations in both hemispheres in accomplished musicians may explain the findings in the study by Erdem, (2015), where musicians exhibited less movement asymmetry between the non-dominant and dominant arms in a novel reaching task than non-musicians.

Skillful musicians, such as those playing keyboards, woodwinds and string instruments, need to learn fine bimanual finger and hand control because both hands are used to make very accurate and quick movements to relatively small targets to play sequences of specific notes and chords (Watson, 2006). In contrast, in some sports players learn moderately-fine unilateral motor movements, such as throwing skills in baseball and softball, which is one of the most important skills of those sports. (French, Spurgeon, & Nevett, 1995; Yanagisawa, Futatsubashi, & Taniguchi, 2018).

The premise of the present investigation is based on identical elements theory: when different tasks share various elements, transfer from one task to another should be positive. In contrast, when tasks do not share many elements, transfer should be closer to zero. Two novel movements tasks were used in the study that were, presumably, either better suited for transfer by musicians, or better suited for athletes due to the differences in the training and experiences the two types of performers experience. Based on this principle, it was hypothesized that the musicians would perform better on the task that required fine movements of the fingers and hands, and also would show less movement asymmetry between the dominant and non-dominant hands, due to the bimanual nature of playing music. Further, it was hypothesized that athletes would perform better on a moderately-fine unilateral novel task due to their experience playing baseball or softball.

2. Materials and Methods

2.1. Subjects

The study employed a quasi-experimental design and involved 43 participants including 13 musicians (11 keyboard, 1 guitar, and 1 woodwind), 16 athletes (11 baseball and 5 softball), and 14 individuals in a control group. The participants were college undergraduate students and included 23 males and 20 females. Most of the musicians were recruited from the university School of Music, with a few participants recruited from other university departments. The athletes were recruited from the university baseball and softball teams (all athletes were position players, no pitchers participated), and the control participants were recruited from the general student-body. The university institutional review board gave approval for the study based on the informed consent procedures and the assessment of possible risks and harm to the participants.

Right hand dominance was required for all participants, and to screen for this, the online Edinburgh Scale was used. It consists of 15 questions that are designed to assess the strength of hand preference on a percentile rank scale ranging from -100 for full left-handedness to +100 for full right-handedness. According to the Edinburgh scale, a score of +48 or greater indicates strong right handedness. All participants were found to be right hand dominant because they met or exceeded the +48 score criteria (musicians M = 83.5, SD = 12.1, athletes M = 85.0, SD = 14.3, control M = 83.6, SD = 17.9).

Participants from the musician and athlete groups were also required to have at least eight years of organized playing experience respectively, while the control group participants needed to have less than one-year experience for both music and baseball or softball. All of the music students (M = 12.2 years), and athletes (M = 13.9 years), met the minimum inclusion criteria while all of the control group students met the exclusion criteria for music (M = 0.1 years), and organized baseball or softball experience (M = 0.0 years).

2.2. Apparatus and task

Two novel movement activities were used in this study. The PEBL pursuit rotor time-on-target task was used to assess fine movements in the hands and fingers (Mueller, 2012). A test-retest reliability of r = .86 for time-on-target scores was reported by Piper et al. (2015). An underhand dart throw task was used to assess moderately-fine arm movements from the shoulder joint. No studies have reported on the reliability of this task. However, it has been used as a novel motor task previously in studies like the one by Radlo, Steinburg, Singer, Barbra and Melnikov (2002).

2.3. Procedures

2.3.1. Fine motor skill task

The PEBL pursuit rotor application was used to assess fine motor skills in movements of the hands and fingers. Using a computer trackpad, the goal of the task was to accurately mirror a moving target, tracing a circular path on the computer screen, using finger movements. During each trial, the moving target traced two laps, and the measured score was time-on-target tracing, with values ranging from 0 to 15 seconds per trial (greater time-on-target scores indicated better mirroring). Five blocks of trials were conducted with each hand, with four trials per block. A 30 second rest break separated each practice block. Participants were seated 46 cm above the floor in front of a 76 cm tall table and facing a 13-inch Macbook Pro notebook computer. The arms of the participants were positioned on the table parallel with two white lines, with a specific orientation to the computer, so that all trackpad movements were produced with only the index finger and wrist. Based on pilot testing, the computer trackpad speed was set at fast-tracking for all participants. Starting hand order was counterbalanced between the dominant and non-dominant hand across participants. Four practice trials were completed with each hand just prior to starting the testing trials.

2.3.2. Moderately-fine motor skill task

The underhand dart throw task was used to assess moderately fine limb performance using shoulder joint movements (finger movements were used just to hold and release the darts, the wrist and elbow joints were held in a fixed straight-arm position during the throwing motion). The goal of the task was to throw the darts as close as possible to the bull's-eye (center of the board) as many times as possible. The participants threw steel-tips darts (12 cm long and 23 grams) from a seated position 46 cm above the floor and 335 cm from the dartboard. A 30 cm plastic ruler was positioned between the participant's upper-back and the seat backrest, and they were instructed to lean moderately backwards, holding the ruler in position, to prevent using trunk movements during the throws. A standard dartboard with a diameter of 45 cm was mounted on a wall, and positioned at the center of a form white-board (122 x 122 cm), with the center of the dart board 183 cm above the ground. The dartboard was custom painted with eight concentric black circular strips on a white background. The black strips were spaced 5 cm apart extending outward from the bull's eye and were numbered from 1 (inner) to 8 (outer), along with horizontal (± X) and vertical lines (± Y), used to designate the landing coordinates for each dart throw. SRE scores were calculated as measure of distance from the bull's-eye to the dart landing position for each trial (Radlo, Steinburg, Singer, Barbra & Melnikov, 2002), according to the formula:

$$\mathbf{SRE = (X2 + Y2)\ ½}$$

where:
X = position of dart on horizontal axis,
Y = position of the dart in vertical axis.

Dart throws hitting the bull's eye were given a score of 0, 0, while throws that missed the dartboard, but did hit the foam mounting board, were given a score of 8, 8. Throws missing the foam board entirely were given a score of 9, 9. Thus, lower SRE scores indicated better performance.

The same as the pursuit rotor task, five blocks of trials were conducted with each arm, with four trials per block, along with the same 30 second rest breaks between blocks. The starting arm for the trials was also counterbalanced, as there were for the pursuit-rotor task, across the participants.

2.4. *Rewards*

Participants were able to earn 5-dollar rewards for achieving specific performance goals on both the pursuit rotor and the dart throw tasks. For the pursuit rotor task, the performance goal was a time-on-target score of 13 seconds or more on any given trial. For the dart throw task, the performance goal was hitting the dartboard bull's-eye. The maximum reward was 20-dollars for each of the two tasks respectively. The purpose of the reward was to help motivate the participants to give their best effort during the trials.

2.5. *Data analysis*

Means and standard deviations were calculated for the laterality index scores, levels of music and baseball or softball experience, pursuit rotor time-on-target scores, pursuit-rotor asymmetry values between hands, dart throw SRE scores and the number dart throws hitting the board. To express the performance differences among the groups as a percentage, the percentage transfer formula (Schmidt & Young, 1987) was used for the pursuit rotor time-on-target mean scores with the musicians compared with the athletes and control group respectively, and dart thrown SRE mean scores for the athletes compared with the musicians and the control group, also respectively (percentage of transfer = (mean-A – mean-B) / (mean-A + mean-B) x 100).

Two separate 3 (group) x 2 (handedness) mixed ANOVAs, with repeated measures on handedness, were conducted on the pursuit rotor time-on-target scores, and the dart throw SRE scores. Three sets of planned complex comparisons on the group variable were anticipated depending on the ANOVA outcomes: For the pursuit rotor task, musicians would be compared to the combined values for the athletes and the musicians on the time-on target scores for each hand, and for the hand asymmetry scores. For the dart throw SRE scores, athletes would be compared to combined values for the musicians and the athletes, also for each arm. In addition, one-way ANOVAs were conducted on time-on-target hand asymmetry scores, and on the number of throws hitting the dart board, respectively. Partial eta-squared effect size values were found for the mixed ANOVAs and eta-squared effect size for the one-way ANOVAs. Effect size criteria were 0.01 (small), 0.09 (medium) and 0.25 (large) for all measures. An alpha = 0.05 was set for all ANOVAs and planned comparisons.

3. Results

3.1. *Pursuit rotor task*

A 3 x 2 mixed ANOVA was conducted with the pursuit rotor time-on-target scores to test the research hypothesis that musicians would demonstrate greater time-on-target performance than control and athlete groups**.** The main effect of the group ($F_{(2, 40)} = 4.71$, $p = 0.02$, $\eta^2P = 0.19$), and handedness ($F_{(1, 40)} = 212.67$, $p < 0.05$, $\eta^2P = 0.84$), were significant. The group * handedness interaction was not significant ($F_{(2, 40)} = 0.67$, $p = .52$, $\eta^2P = 0.03$). The effect size values were medium for group and large for handedness, and small for the interaction. The planned complex comparison between the musicians and the combined pursuits time-on-target scores for the athletes and the control group with the dominant hand was not significant ($t = 1.50$, $p = 0.14$), while the outcome for the non-dominant hand was significant ($t = 2.10$, $p = 0.04$). When expressed as percentage transfer, the musicians performed about 1% and 5% better with the dominant hand, and about 3% and 10% better with the non-dominant hand than the athletes and the control group respectively. Figure 1 shows the mean dominant and non-dominant hand time-on-target scores for the three groups.

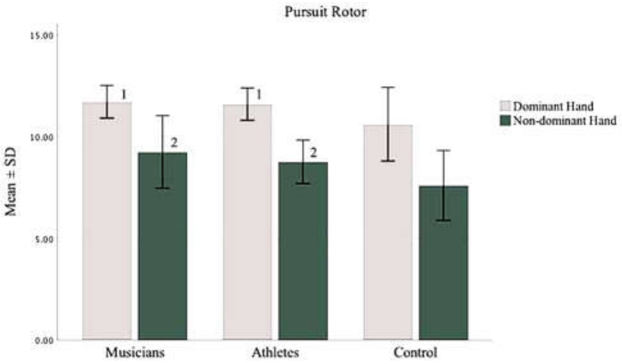

Figure 1. Mean ± SD time-on-target scores for the dominant and non-dominant hand ($p < .01$) on the pursuit rotor task for the three groups ($p = .02$). Higher scores indicate better performance. (Means that share numerical notations are not different, $p > .05$).

3.2. *Pursuit rotor hand asymmetry*

The one-way ANOVA for the groups on the pursuit rotor time-on-target hand asymmetry values, showed no significant time-on-target asymmetry differences ($F_{(2, 40)} = 0.67$, $p = 0.52$, $\eta^2P = 0.003$) with a small effect size. Because the ANOVA was not significant, a planned complex comparison between the musicians and the combined scores for the athletes and control group was not conducted.

Even though the mean values of difference scores followed the expected trend, the large amount of score variability within the groups may have negated any potentially significant findings among the groups. The variance ratio (musician variance / athlete variance) was $V = 5.8$ (musicians had the greatest variance and athletes had the least variance, among the three groups). A variance ratio greater than 2.0 is generally considered as indicative of heterogeneous scores between groups.

3.3. *Underhand dart throw task*

The hypothesis for the moderately-fine motor skill task was that athletes would demonstrate better SRE scores than the musicians and control group. The findings from 3 x 2 mixed ANOVA for the SRE scores showed significant main effect of group ($F_{(2, 40)} = 15.24$, $p < 0.05$, $\eta^2P = 0.43$), and handedness ($F_{(1, 40)} = 37.20$, $p < 0.05$, $n_p2 = 0.48$). The interaction effect for the group* handedness was not significant ($F_{(2, 40)} = 1.15$, $p = .33$, $\eta^2P = 0.05$). The effect size for both group and handedness were large, and small for the interaction. The planned complex comparison between the athletes and the combined SRE scores for the musicians and the control group with the dominant arm was significant ($t = 4.47$, $p < 0.05$), and the outcome for the non-dominant arm was also significant ($t = 4.65$, $p < 0.05$). Better performance by the athletes was also reflected in the mean number of throws overall actually hitting the dartboard (athletes: $M = 25.19$, $SD = 4.72$; musicians: $M = 15.15$, $SD = 5.26$; control $M = 15.86$, $SD = 7.47$) out of 40 trials ($F_{(2, 40)} = 13.54$, $p < 0.05$, $\eta^2P = 0.40$). In terms of percentage transfer, the athletes performed close to 14% and 11% better with the dominant arm, and about 12% and 6% better with the non-dominant arm compared to the musicians and the control group respectively. Overall, the hypothesis that athletes would show better performance on the underhand dart throw task was supported. Figure 2 shows the mean dominant and non-dominant arm SRE scores for the three groups.

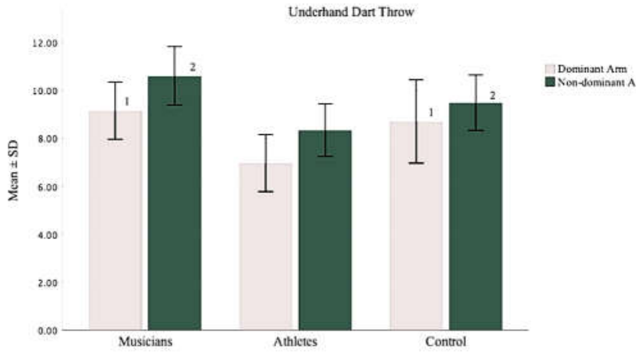

Figure 2. Mean ± SD subject centroid radial error scores for the dominant and non-dominant hand ($p < 0.05$) for the three groups ($p < .05$) on the underhand dart throw task. Lower scores indicate better performance. (Means that share numerical notations are not different, $p > 0.05$).

4. Discussion and Conclusion

The purpose of the study was to investigate how well previous experience with fine bimanual motor skills (musicians) and moderately-fine unilateral motor skills (athletes) would transfer to novel motor tasks based on identical elements theory. For the novel fine motor task, the musicians were hypothesized to perform better than the athletes and the control group, and musicians were also hypothesized to have lower levels of movement asymmetry between the dominant and non-dominant hands than the other two groups because of their fine motor skills used playing music. For the novel moderately-fine motor task, the athletes were hypothesized to perform better than the other two groups because of their throwing skills.

The PEBL pursuit rotor fine movement task used in the present study involved continuous hand and finger movements, with constant pressure on the computer trackpad, performed one hand at a time. In contrast, the movement skills that certain types of musicians, such as keyboard and woodwinds, make involve combinations of simultaneous finger pressing movements to specific targets. Based on (Thorndike & Woodworth, 1901) theory of identical elements, limited shared elements between the music skills of the musicians, and the pursuit rotor task, likely limited the amount of transfer by the musicians to the pursuit rotor task observed in the study. Other studies investigating musicians and movement transfer have used novel tasks involving movements similar to instruments. For example, Kincaid, Duncan and Scott (2002), and Franek, Mated, Radil, Beck and Poppel (1991), used novel key-pressing tasks, and found that musicians performed better and less hand asymmetry than non-musicians, as they hypothesized. A different approach was used by Erdem (2015), whereby participants perform discrete reaching tasks with the goal to move a cursor seen on a screen to target location as quickly and as accurately as possible. As hypothesized, musicians (both string and piano players) were found to perform those movements more accurately and with less asymmetry when compared to non-musicians.

Conversely, the athletes performed better than the musicians and the control group on the underhand dart throw task, as hypothesized. The underhand dart throw shared a number of elements used with normal overhand throwing used in baseball and softball including the goal of projecting an object toward a target, primarily using movements from the shoulder joint. Supporting this conclusion about the differences in the shared elements between the pursuit rotor task and playing an instrument, and the underhand dart throw and throwing in baseball or softball was the musicians only performing about 1% and 5% better with the dominant hand, and about 3% and 10% better with the non-dominant hand than the athletes and the control group respectively. Conversely, the athletes performed close to 14% and 11% better with the dominant arm, and about 12% and 6% better with the non-dominant arm compared to the musicians and the control, indicating the dart throw and baseball or softball throwing shared more elements than the pursuit rotor task and playing certain musical instrument.

In addition, the musicians did not show less movement asymmetry than the other two groups, as hypothesized, further suggesting that musical experience did not transfer well to the pursuit rotor task. One possible issue influencing the less than hypothesized movement asymmetry for the musicians may have been the proficiency levels of the participants in that group. The initial inclusion criteria for the music group were 10 years of experience. However, due to the difficulty of recruiting participants that met the criteria, it was lowered to 8 years, and the recruitment pool was expanded from the School of Music students to individuals from other majors that met the 8-year criteria. Because of this, the participants may not have experienced similar levels and types of brain adaptations as seen in musicians with greater and more specific levels of experience. For example, Gaser and Schlaug (2003) found a direct relationship between levels of experience and brain adaptations in professional keyboard musicians when compared to amateurs and non-musicians. Participants in the present study may have been closer to the amateur-level musicians in the Gasser and Schlaug study than the professionals observed in their study, although it is not possible to quantify the differences, if they exist.

In conclusion, while the present findings were mixed with respect to the hypotheses under investigation, and were constrained by a number of limitations, further study into the topic appears to be warranted. Future studies on these questions should involve musicians with more specific training and more advanced levels of experience than the musicians involved with this investigation. In addition, different tasks that involve fine bimanual movements might prove to be a better measure of the effects of bimanual skills training on fine movement transfer and on movement asymmetry between hands compared to other populations.

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Conflicts of Interests

The authors affirm that there are no conflicts of interest.

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