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Hand Skill Asymmetry in Professional Musicians

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Hand skill asymmetry on two handedness tasks was examined in consistent right-handed musicians and nonmusicians as well as mixed-handed and consistent left-handed nonmusicians. Musicians, although demonstrating right-hand superiority, revealed a lesser degree of hand skill asymmetry than consistent right-handed non-musicians. Increased left-hand skill in musicians accounted for their reduced asymmetry. Musicians predominantly playing keyboard instruments demonstrated superior tapping performance than musicians playing predominantly string instruments, although they did not differ with respect to hand skill asymmetry. Since the diminished tapping asymmetry in musicians was related to early commencement but not duration of musical training, results are interpreted as an adaptation process due to performance requirements interacting with cerebral maturation during childhood.

The prevalence of right, left, and mixed handedness in musicians was repeatedly examined in order to elucidate assumed differences in cerebral dominance of musicians (Oldfield, 1969; Byrne, 1974; Gates & Bradshaw, 1977; Fry, 1990; Hassler & Birbaumer, 1988; Götestam, 1990; Hassler, Gupta, & Wollmann, 1992; Hassler & Gupta, 1993; Christman, 1993; Aggleton, Kentridge, & Good, 1994). Most of these studies used hand preference tests while hand skill measurements have only been performed by Peters (1985a, b). Peters found reduced hand asymmetry on a bimanual tapping task in two of five piano players.

Hand *skill* as a measure of handedness has the advantage of quantifying

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TABLE 1
Gender and Age for the Groups of Subjects Studied (Standard Deviation in Parentheses)

	Women (*n*)	Men (*n*)	Age range (years)	Mean age (years)
CRH musicians	8	23	21–38	27 (5)
CRH controls	8	23	21–38	26 (4)
CLH controls	8	23	21–39	25 (4)
MH controls	8	23	20–37	27 (4)

the asymmetry on a continuous scale (Peters & Durding, 1977, 1979; Annett, 1992a, b). It is thought that this asymmetry remains stable even after extensive practice, although both hands may show improvement after training (Annett, Hudson, & Turner, 1974; Annett, 1970; Peters, 1981).

We hypothesized that musicians due to intensive hand skill training might differ from nonmusicians and that the more skillful use of the nondominant hand might interfere with hand preference for certain tasks. In order to investigate this hypothesis we examined hand skill asymmetry in professional musicians addressing the following questions: (i) Is the degree of hand skill asymmetry reduced in right-handed musicians compared to right-handed control subjects? (ii) Does the degree of hand skill asymmetry depend on age of commencement of musical training? (iii) Do string and keyboard instrument players differ with respect to hand skill asymmetry? (iv) How does hand skill asymmetry of right-handed musicians compare with a group of mixed- and left-handed nonmusicians?

METHODS

Subjects

We examined 31 professional classical musicians (keyboard or string instrument players, or both) who described themselves as strong right-handers according to writing hand. All musicians were students or had just finished training at a Music School. Seventeen musicians were keyboard instrument players while the remaining 14 were playing string instruments predominantly. Mean age at commencement of musical training was 5.7 years (range 3 to 10 years). Musicians were compared to three control groups of nonmusicians: (1) 31 consistent right-handers (CRH), (2) 31 consistent left-handers (CLH), and (3) 31 mixed-handers (MH) (with handedness defined according to Annett (1970)). The three groups were carefully matched for sex, age, and socioeconomic status. All subjects were paid for their participation. Gender and age distributions are given in Table 1.

Handedness Measurement

Hand preference was assessed with the Annett handedness questionnaire (Annett, 1970). This 12-task inventory defines ‘‘handedness’’ according to the hand preferred for each task. CRH or CLH corresponds to the consistent performance of all of the six ‘‘primary’’ tasks (writing, throwing, racket, match, hammer, and toothbrush) with the right or left hand. Subjects who do not fit into one of these preference patterns are defined as MH. According to these criteria all musicians were CRH. Hand skill performance was assessed using two tests. The ''hand-dominance test'' (HDT; (Steingrüber, 1971; Jäncke, 1996)) comprises three dexterity tasks, each to be performed with maximal speed and precision over 15 sec, separately for the right (R) and left (L) hand (tracing lines, dotting circles, and dotting squares). Performance was scored for each hand. According to previous experiments, HDT scores of the dominant hand were strongly correlated with writing and drawing speed (writing: $r = .65$, $n = 120$, $p < .001$; drawing: $r = .70$, $n = 120$, $p < .001$; L. Jäncke, unpublished data). Therefore, an index finger tapping task (TAP) was adopted to study skills independent of writing practice. Here the subjects were asked to tap with their index finger as fast as possible and separately for each hand onto a space bar of a computer keyboard (Apple Macintosh) for 20 sec while the arm rested on a table. For each hand, the number of taps was counted. In previous experiments we did not find a correlation between TAP scores of the dominant hand and writing or drawing speed (writing: $r = .20$, $n = 120$, $p = >.05$; drawing: $r = .11$, $n = 120$, $p > .05$; L. Jäncke, unpublished data). For both hand skill tasks a widely used asymmetry score ($[R - L]/[R + L]$) was calculated, in order to obtain hand skill asymmetry scores independent of overall performance.

Statistical Analysis

The basic design was two factorial with one between-subjects factor (CRH musicians, CRH nonmusicians, CLH nonmusicians, and MH nonmusicians) and one within-subjects factor (right vs. left hand). Dependent variables were hand skill for the right and left hand as well as the asymmetry scores. Since the data did not fulfill the prerequisites for conventional ANOVA analysis (normal distribution, homogeneity of variances), distribution-free statistical models were applied. Within-group differences (right vs. left hand skill) were analyzed with Wilcoxon matched pairs signed rank tests (Bortz, Lienert, & Boehnke, 1990). Between-group differences were analyzed with the Mann–Whitney *U* test. In order to adjust the α-level to compensate for the increased probability of finding significant results a modified Bonferroni procedure was applied (Holm, 1979). For each dependent variable an α-level of $p = .05$ was chosen associated with a two-sided test problem. The *p* values of the 18 statistical tests[1] were ranked from the smallest to the largest value. The smallest *p* value was then compared to $\alpha_1^* = \alpha/k$ ($\alpha_1^* = 0.05/18 = 0,0028$). If this *p* value were to exceed α_1^*, none of the *k* comparisons would be significant. However, because this *p* value was smaller than the reference value, this particular comparison yielded a significant difference. The *p* value next in rank was then compared to a different reference probability ($\alpha_2^* = \alpha/(k - 1)$, $\alpha_2^* = 0.05/17 = 0,0029$). This procedure was continued, as described by Holm (1979) until a nonsignificant value was obtained or until the final comparison was made. Where it was useful the effect size according to Cohen (1969) was calculated. Here, the *d* coefficient was used which is the difference between two means divided by the largest standard deviation of both means. Effect sizes $>$ .5 are considered as moderate while those $>$ .8 are considered as large (Cohen, 1969).

No separate analyses of gender effects were performed, since prior analyses as well as descriptive data inspection revealed that the means for men and women were fairly similar.

[1] Four within-groups tests comparing right vs. left hand skill for each group independently; 2 within-groups tests comparing right vs. left hand skill for musicians playing string or keyboard instruments; 9 between-groups tests comparing musicians with the four control groups; 3 between-groups tests comparing musicians playing string or keyboard instruments.

TABLE 2
Mean Hand Performance and Laterality Measures (Standard Deviation in Parentheses) for the Groups Studied

	R	*L*	$(R - L)/(R + L)$
Tapping			
(1) CRH musicians	126 (13)[a]	116 (13)[b]	.04 (.03)[c,d]
(2) CRH nonmusicians	110 (10)	96 (07)	.07 (.03)[c]
(3) CLH nonmusicians	100 (15)	121 (18)	−.09 (.04)[c]
(4) MH nonmusicians	114 (17)	114 (23)	0 (.07)
HDT			
(1) CRH musicians	149 (26)[e]	126 (22)[f,g]	.09 (.05)[h,i]
(2) CRH nonmusicians	154 (17)	115 (14)	.14 (.05)[h]
(3) CLH nonmusicians	129 (18)	159 (21)	−.10 (.01)[h]
(4) MH nonmusicians	157 (21)	155 (24)	.01 (.06)

Note. Values for absolute performance are rounded to integer values.
Tapping.
[a] CRH musicians > nonmusicians, all p values $< .001$; [b]CRH musicians > CRH nonmusicians with $p < .001$; [c]right–left hand difference with $p < .001$; [d]CRH musicians < CRH nonmusicians with $p < .001$.
HDT.
[e] CRH musicians > CLH nonmusicians; [f]CRH musicians < CLH nonmusicians and MH nonmusicians, all p values $< .001$; [g]CRH musicians > CRH nonmusicians with $p = .04$ (nonsignificant after alpha-adjustment although the effect size is reasonable large $d = [126\text{-}115]/22 = 0.5$; [h]right–left hand difference with $p < .001$; [i]CRH musicians < CRH nonmusicians with $p < .001$.

In addition, multiple regression analyses were computed where they were useful to describe between-variable relations.

RESULTS

Overall Analysis of Performance Scores

Table 2 gives the group means of the hand skill measures. Analysis of the tapping task revealed a significant right-hand skill superiority for CRH musicians and CRH nonmusicians and a significant left-hand superiority for CLH nonmusicians (all p values $< .001$). It is noteworthy that right-hand superiority (in terms of hand skill asymmetry) was significantly less for the musicians than for the CRH nonmusicians ($p < .001$). For the right hand, it was found that musicians outperformed nonmusicians of all handedness types (all p values $< .001$). For the left hand, musicians outperformed the CRH nonmusicians but not the MH and the CLH nonmusicians.

For the HDT task, CRH musicians and CRH nonmusicians revealed significant right hand superiority while CLH nonmusicians revealed significant left-hand superiority (all p values $< .001$). Although CRH musicians and CRH nonmusicians demonstrated clear right-hand superiority (in terms of

TABLE 3
Mean Hand Skill Measures (Standard Deviation in Parentheses) for the Musicians Playing Keyboard or String Instruments

	R	*L*	$(R - L)/(R + L)$
TAP			
Musicians playing keyboard instruments	130 (12)[a]	120 (12)[b]	.038 (.03)
Musicians playing string instruments	121 (13)	110 (11)	.046 (.03)
HDT			
Musicians playing keyboards instruments	150 (30)	126 (24)	.08 (.05)
Musicians playing strings instruments	148 (20)	125 (19)	.08 (.05)

Note Values for absolute performance are rounded to integer values.
[a] Between-groups difference with $p = .04$; [b]Between-groups difference with $p = .03$; both comparisons are nonsignificant after alpha-adjustment although the effect sizes are reasonably large ($d_r = .75$, $d_l = .83$).

hand skill asymmetry score), this asymmetry was significantly reduced in CRH musicians ($p < .001$). Musicians scored higher than CLH nonmusicians for the right hand ($p < .001$), but lower than CLH and MH nonmusicians for the left hand ($p < .001$).

Difference between String and Keyboard Instrument Players

In Table 3 the hand skill measures for keyboard and string instrument players are depicted. Between-group comparisons revealed no significant difference (after alpha-adjustment) although it was worth to note that there is a tendency for keyboard instrument players to outperform string players in the tapping task (right hand: $p = .04$, $d = .7$; left hand: $p = .03$, $d = .8$).

Relation between Age Commencement of Musical Training and Performance Measures

In order to examine whether age of commencement of musical training had an influence, hand skill asymmetry scores were regressed on age of commencement of musical training and duration of musical training. By calculating a stepwise regression, the statistical influence of duration of musical training was partialized out in order to obtain a measure reflecting the relation between age of commencement of musical training unrelated to duration of musical training. This analysis revealed that hand skill asymmetry on the tapping task (but not HDT) was related to age of commencement of musical training ($r = .45$, $r^2 = .21$, $p = .01$) while duration of musical training had no effect ($r = .09$). The relation between tapping asymmetry and age of

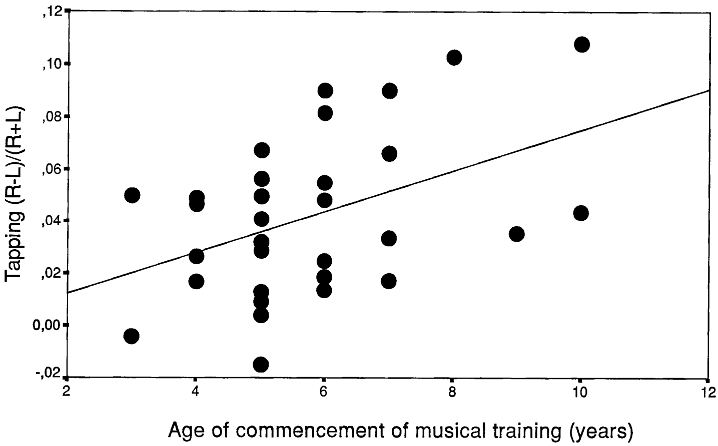

FIG. 1. Relation between tapping asymmetry scores ($[R - L]/[R + L]$) and age at commencement of musical training in 31 musicians (dots are coincident in some cases).

commencement of musical training is depicted in Fig. 1, demonstrating that early commencement was associated with smaller tapping asymmetry.

DISCUSSION

The main finding of our study is that CRH musicians exhibited a reduced degree of hand skill asymmetry in comparison to CRH nonmusicians. Despite the difference in hand skill asymmetry, musicians still revealed a right-hand skill superiority distinguishing them from CLH and MH nonmusicians. The reduced degree of right-hand superiority was mainly due to a left-hand gain and not to a right-hand loss of skill. These results concur with the finding of Annett (1992a) that increasing hand skill symmetry in children is explained by a skill increase of the nondominant hand.

Although the absolute numbers of index finger taps differed between musicians and CRH nonmusicians, performance in the HDT did not show a similar trend. The strong association between HDT performance and writing speed might explain this. Thus, HDT performance is probably more strongly influenced by writing experience than fine distal hand/finger motor skills which are trained and acquired during musical practising. Both writing and performance in the HDT involve finger, hand, wrist, upper arm, and shoulder movements which are controlled differently compared to fine distal finger movements in the finger tapping test (Mai & Marquardt, 1995).

The comparison of hand performance between those musicians predominantly playing keyboard instruments and musicians playing string instruments revealed an increased tapping performance for both hands in keyboard instrument players. This may well be a long term effect of their extensive training of fast distal tapping movements. This pattern was, however, unrelated to hand performance asymmetry which was similar in both musician groups. Our results are in contrast to those reported by Christman (1993) who demonstrated that musicians playing string or woodwind instruments exhibited a lesser degree of hand preference (composite hand preference score) than musicians playing keyboard instruments. However, Christman's sample of musicians was more heterogenous than ours with respect to the prevalence of right, left, or mixed handedness, and we have demonstrated a discrepancy between hand preference and performance in musicians in the present study.

We found a moderate negative correlation between age of commencement of musical training and hand performance asymmetry as measured with the index finger tapping task. Musicians with early commencement of musical training exhibited the smallest tapping asymmetry. Since duration of musical training was unrelated to hand performance asymmetry, it is likely that early commencement of musical training is the main factor influencing this asymmetry. Because movement control and motor coordination improve gradually from ages 4 to 11 years, it can be speculated that early hand skill training interacts with the cortical organization of hand motor dominance leading to improved performance of the nondominant hand (Kerr, 1975; Müller & Hömberg, 1992; Schlaug, Jäncke, Huang, & Steinmetz, 1995; Schlaug, Jäncke, Huang, Staiger, & Steinmetz, 1995; Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995).

It is unclear 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 nondominant hand due to their increased left-hand skills. This may well influence prevalence figures obtained with questionnaires. However, it should be noted that the prevalence of left or mixed handedness in musicians is only slightly (4–6%) higher than those in nonmusicians (Aggleton, et al., 1994, Gilbert & Wysocki, 1992; Perelle & Ehrman, 1994). Our data suggest that the higher prevalence of left or mixed hand preference reported in previous studies may be due to increased skill of the nondominant hand as a result of early and intensive training.

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