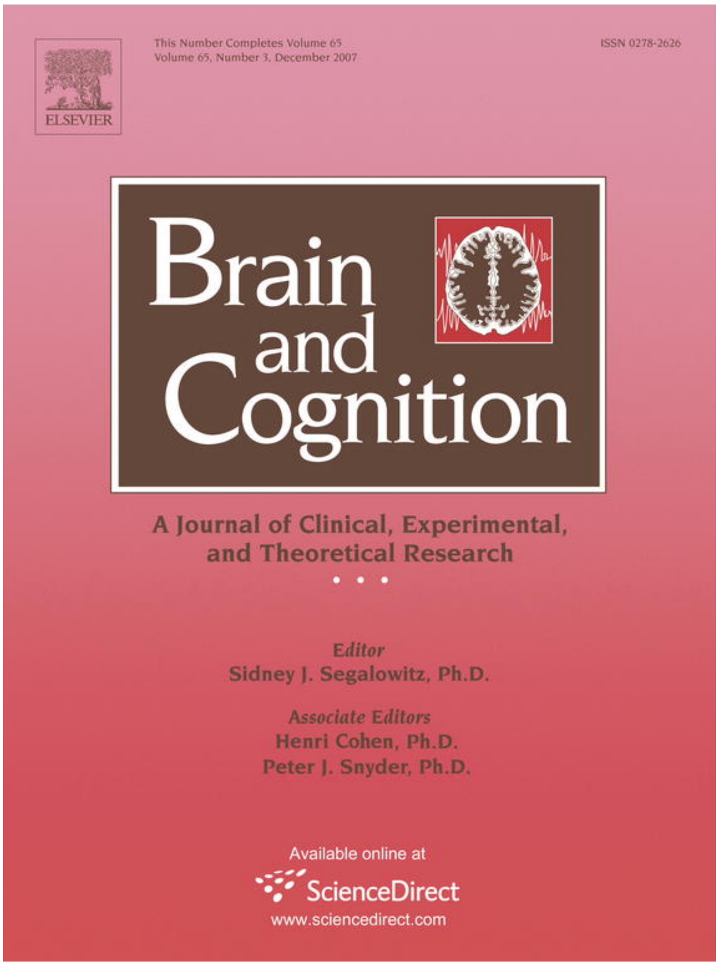
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Shift of manual preference in right-handers following unimanual practice

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Abstract

The effect of unimanual practice of the non-preferred hand on manual asymmetry and manual preference for sequential finger movements was evaluated in right-handers before, immediately after, and 30 days following practice. The results demonstrate that unimanual practice induced a persistent shift of manual preference for the experimental task in most participants, but no significant correlation between manual asymmetry and manual preference was detected. These findings are explained by proposing that manual preference is influenced by a task-specific confidence developed from the recent history of differential use of the limbs, in interaction with a generalized confidence on a single hand for performance of motor skills.

Keywords: Handedness; Manual preference; Performance asymmetry; Manual asymmetry; Sequential finger movements; Motor learning

1. Introduction

Manual preference has been proposed to have as one of its main causes the history of relative experience of each hand (Provins, 1997). This proposition has received some support by findings from studies on humans and animals, suggesting an effect of unimanual experience in the modification of the original manual preference. Mikheev, Mohrb, Afanasiev, Landis, and Thut (2002), for example, compared lateral preferences between judo sportsmen and controls in a number of daily living motor tasks. Their results indicate that those athletes prefer to perform certain motor tasks more frequently with the left hand than non-athletes, although overall right-handed. This characteristic was especially evident in the most proficient participants. This finding suggests that shift of manual preference for a motor task is mediated by cumulated lateralized experiences during extensive practice, overriding intrinsic lateral tendencies.

More direct experimental evidence for the effect of regular use of a single limb on the establishment of lateral preference comes from studies conducted on animals. Warren (1958) assessed the preferred limb of cats and monkeys to bring food to the mouth after different periods of unilateral experience at that task. The results showed a progressive increment of preference for the used limb as a function of cumulated unilateral experiences. At the first evaluation, individual scores of lateral preference at the experimental task ranged from 30% to 53% for the targeted limb; following unilateral use, scores of lateral preference increased to values between 61% and 89%; and after a longer period of unilateral use a well defined lateral preference at the experimental task was observed, with scores ranging between 71% and 100%. McGonigle and Flook (1978), in addition, evaluated the extent to which manual preference is shifted by unilateral training in monkeys. Manual preference was initially assessed for reaching and, in the sequence, the animals practiced the task using only their non-preferred hand. The results showed a marked shift of manual preference following unimanual practice, with reaching being performed at that moment predominantly by the originally non-preferred hand. This behavioral modification was still

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observable several weeks following the end of practice (see also Collins, 1975; Deuel & Dunlop, 1980).

An intuitive hypothesis to explain the effect of differential practice between homologous limbs on manual preference is that, as one cumulates practice using predominantly a single limb neural adaptations take place (cf. Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995; Grafton, Hazeltine, & Ivry, 2002; Pascual-Leone & Torres, 1993), leading to modification of previous manual asymmetries (difference of performance) between the hands (cf. Hoffmann, Chang, & Yim, 1997; Peters & Ivanoff, 1999). These changes induced by learning would lead then to increased preference for that limb capable to produce superior performance. In this case, manual preference would be modulated by modification of the relative dexterity between homologous body segments, with strengthening of lateral preference when the original manual asymmetry is amplified, attenuation of the magnitude of lateral preference when the original manual asymmetry is reduced, and shift of lateral preference when performance of the originally disadvantaged limb surpasses that achieved with the contralateral limb. This hypothesis was tested by providing right-handers with unimanual practice of the non-preferred hand on sequential finger movements, and assessing its effect on manual asymmetry and preference for the experimental task.

Previous research has shown that performance on tasks requiring sequential finger movements is predominantly symmetric (Haaland, Elsinger, Mayer, Durgerian, & Rao, 2004; Hausmann, Kirk, & Corballis, 2004; Teixeira, in press). Furthermore, Verstynen, Diedrichsen, Albert, Aparicio, and Ivry (2005) have shown that sequential finger movements are featured mainly by ipsilateral hemispheric activation, which is especially pronounced in the left hemisphere during left-hand movements (cf. Haaland et al., 2004; Hlustık, Solodkin, Gullapalli, Noll, & Small, 2002; Mattay et al., 1998; Solodkin, Hlustik, Noll, & Small, 2001). These characteristics of sequential finger movements, i.e. initial low manual asymmetry and bilateral cerebral organization, might provide appropriate grounds for emergence of different magnitudes of manual asymmetries across subjects favoring the non-preferred hand following unimanual practice (cf. Karni et al., 1995). If manual preference is determined by difference of performance between the hands, magnitude of manual preference should be correlated with magnitude of manual asymmetry.

2. Methods

2.1. Participants

Twelve male and five female university students, age ranging between 17 and 31 years ($M = 20.89$ years; $SD = 3.32$ years), participated in the study.[1] All participants were right-handers, as indicated by the Edinburgh manual dominance inventory (Oldfield, 1971): scores varied between 4 and 4.9 ($Med = 4.5$) on a 5-point scale. Participants signed an informed consent form to take part in the study, and experimental procedures were approved by the local Ethics Committee.

2.2. Equipment and task

The motor task consisted of sequentially touching the thumb with the other four fingers, beginning with the index finger touching the thumb, in the following order: ring, middle, little, and index finger. One trial consisted of performing this sequence (cycle) of finger movements for five times without interruption. The aim of the task was to complete a trial in the shortest period of time. Participants performed this task while sitting on a chair, having the elbow of the active hand upheld on a table. The forearm was kept stable by the participants without physical constraints in a predominant vertical orientation, slightly bent forward, with the active hand pronated. Movements were filmed with a digital camera (SONY, DV-500), and images were analyzed at 60 Hz using the Ariel Performance Analysis System.[2]

2.3. Experimental design and procedures

Experimental procedures were initiated by assessing handedness and then specific manual preference for the experimental task. Overall manual preference was assessed using the Edinburgh inventory. Specific manual preference was assessed by asking participants about their manual preference for the experimental task. Handedness and manual preference were assessed on a five-point continuous rating scale, ranging from $1 = \text{left}$ always to $5 = \text{right}$ always. In the sequence, participants were provided with instruction about the task and with familiarization trials. Familiarization consisted of three trials performed slowly, followed by another set of three trials performed in a fast rate. This procedure was employed for both hands immediately before initial evaluation of manual asymmetry.

Participants were pseudorandomly assigned to one of two groups: experimental ($n = 10$; 8 males, 2 females), or control ($n = 7$; 5 males, 2 females). Experiment was divided into four phases: pre-test, practice (or rest), post-test, and retention. In the pre-test performance of both hands was assessed on the experimental task. Participants performed three trials using each hand, having order of hands alternated across participants. There were regular intervals of approximately 30 s between trials, and the interval between assessment of one hand and the other was 2 min approximately. Trials were accepted only if the correct sequence of finger movements was performed, with erroneous trials

[1] The study was initiated with 18 participants, but one participant of the control group failed to complete the whole experiment.

[2] This is a commercial computational system for kinematic analysis with automatic tracking of passive markers. It was used here to measure movement time between the selected landmarks of finger movements.

repeated immediately. Following pre-test, the experimental group were provided with practice of the left hand on the task, while the control group had no activities other than those usually performed in their daily living duties. Practice trials were divided into 10 sessions completed within a period of two weeks. On each session, the experimental group performed two blocks of 10 trials (one trial = five cycles of finger movements), with rest intervals self determined by the participants. Thus, at the end of this phase participants had performed 200 trials, corresponding to 1000 cycles of finger movements. In order to increase motivation to improve performance, participants trained the task in couples. During each session of practice, while one participant performed the task the other in a couple registered the time spent to complete each trial with a stopwatch. They were shown these times as feedback and asked to reduce their movement time across training sessions. Practice trials were performed under supervision of the laboratory staff. One (post-test) and 30 (retention) days following the end of practice, procedures employed in the pre-test were repeated.

3. Results

Analysis of movement time was conducted on the third (intermediate) cycle of each trial. Movement times achieved on the three trials for each hand were averaged for analysis. Total movement time, finger touching time, and time between touches were analyzed through three-way 2 (group) × 2 (hand) × 3 (phase: pre-test, post-test, and retention) analyses of variance with repeated measures on the last two factors. Analysis of total movement time indicated significant main effects for hand, $F(1, 15) = 7.31$, $p < .05$, and phase, $F(2, 30) = 54.63$, $p < .0001$. Significant interactions were also found for group by hand, $F(1, 15) = 9.45$, $p < .01$, and for hand by phase, $F(2, 30) = 6.15$, $p < .01$. The main effect of hand is due to overall better performance when using the right hand. Post hoc contrasts through Newman-Keuls procedures indicated that the main effect of phase is due to better performance in the post-test and retention in comparison with the pre-test. The group by hand interaction is due to a right-hand advantage for the control group, while no significant between hand difference has been detected for the experimental group. Decomposition of the hand by phase interaction indicated a right-hand advantage in the pre-test, but absence of significant between hand differences in the post-test and retention (Fig. 1).

Analysis of finger touching time showed a significant hand by phase interaction, $F(2, 30) = 5.30$, $p < .05$, an effect due to similar performance between hands in the post-test and retention in contrast to a right-hand advantage in the pre-test. Analysis of time between touches showed a significant group by phase interaction, $F(2, 30) = 4.37$, $p < .05$, an effect which post hoc contrasts revealed to be due to similar performance between groups in the pre-test, while in the post-test and retention phases the experimental group presented significantly shorter times in comparison with the control group.

Handedness scores were similar between the control ($Med = 4.6$) and the experimental ($Med = 4.5$) group, which were not significantly different from each other as indicated by the Mann–Whitney U test, $Z = 1.09$, $p > .2$. Analysis of manual preference for the experimental task was made by comparing the scores across experimental phases separately for each group. This analysis was initially conducted through the Friedman's rank test, followed by the Wilcoxon's matched pairs signed-ranks test to make follow-up contrasts. The results indicated a significant phase effect for the experimental, $\chi^2_F = 12.48$, $p < .005$, but not for the control, $\chi^2_F = 0.67$, $p > .7$, group. Paired comparisons between phases for the results of the experimental group showed a significant reduction of the score of manual preference from the pre- ($Med = 5$) to the

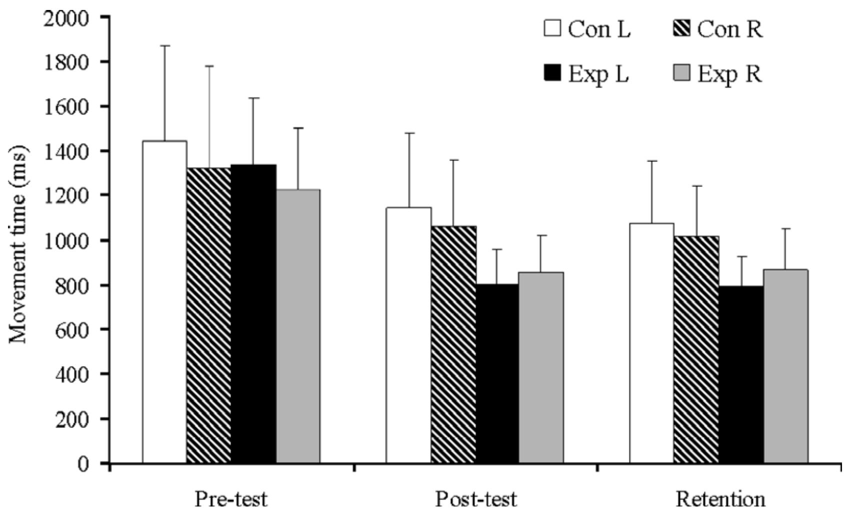

Fig. 1. Total time to complete one cycle of finger movements for the control and experimental groups when using the right (R) or the left (L) hand across phases.

post-test ($Med = 2$), $Z = 2.37$, $p < .02$, and retention ($Med = 2.5$), $Z = 2.52$, $p < .02$, with no significant difference between the latter two phases. For the control group the median score was 5 in all phases. Thus, a significant shift of manual preference was found for the experimental group only, with transition from a predominant consistent preference for the right hand to a predominant preference for the left hand after unimanual practice.

Of central importance for this study is the extent to which the observed shift of manual preference after unimanual practice is related to individual variation of manual asymmetry. In order to address this issue, we plotted manual asymmetry scores against manual preference scores separately for pre-test, post-test, and retention. As depicted in Fig. 2A, the pre-test was featured by overall congruence between manual preference and manual asymmetry, with a single exception in the control group. In the post-test (Fig. 2B) most participants in the experimental group showed a coherent relationship between the new manual preference and manual asymmetry, but there were important exceptions. Some participants of the experimental group shifted their preference to the left hand although performance either favored the right hand, or was virtually equivalent between the hands. In addition, one of the three participants of the experimental group who maintained right hand preference after practice showed one of the highest scores of manual asymmetry favoring the left hand. In the retention phase (Fig. 2C), although a left-hand advantage was still observable for most participants in the experimental group, there was a migration from consistent to inconsistent left hand preference or to undefined preference in a number of cases. Yet, in this last experimental phase we detected (a) absence of manual preference in spite of manual asymmetry favoring either the right or the left hand; (b) consistent manual preference associated with symmetric performance for the control group; and also (c) cases of incongruent relationship between manual preference and manual asymmetry, which was manifest in the preference for the disadvantaged hand. These cases are surrounded by dotted markers in the figure, and identified with the same letters as presented here. Spearman rank order correlation analysis applied separately for each phase showed non-significant values either for the control (rs ranging from -0.43 to zero, ps $> .3$) or the experimental (rs ranging from -0.27 to 0.18, ps $> .4$) group.

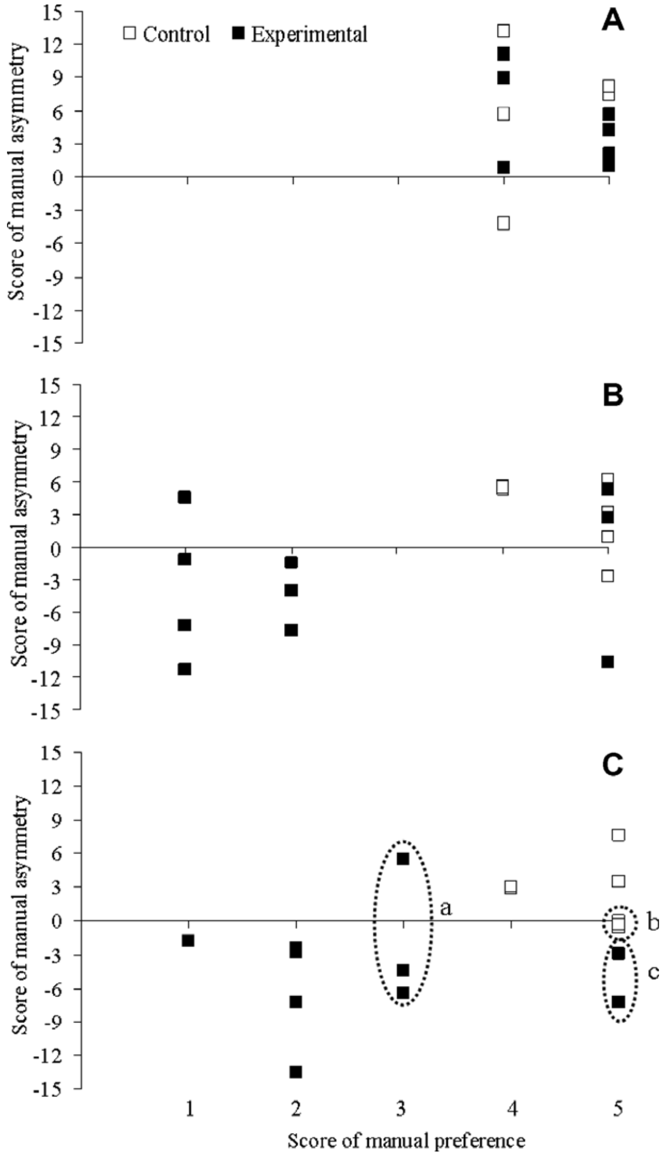

Fig. 2. Relationship between scores of manual asymmetry and scores of manual preference for the control and experimental groups in the pre-test (A), post-test (B), and retention (C). Cases of incongruence between manual asymmetry and manual preference in retention are surrounded by dotted markers: (a) absence of manual preference associated with manual asymmetry, (b) consistent manual preference associated with symmetric performance, and (c) preference for the disadvantaged hand.

4. Discussion

The results showed that unimanual practice of sequential finger movements led to a noticeable shift of manual preference in contrast to a less evident change of manual asymmetry between the hands. Absence of significant lateral asymmetry following unimanual practice may be due to the pattern of cerebral activation observed in the performance of this task. Results from previous studies have shown that performance of sequential finger movements, by either hand, is characterized by bihemispheric cerebral activation (Kawashima et al., 1998; Solodkin et al., 2001) with preponderance of the left hemisphere (Haaland et al., 2004; Hlustık et al., 2002; Verstynen et al., 2005). Grafton et al. (2002) studied asymmetries in cerebral activation and in motor performance during practice of a sequential movement by the non-preferred left hand with posterior transfer to the contralateral hand. Their results showed that, as learning progressed, increases in brain activity were observed in the left lateral premotor cortex and supplementary motor area. A more salient increment of activation of these cortical areas in the left hemisphere as a result of practice was similar to one previously identified with right-hand learning (Grafton, Hazeltine, & Ivry, 1998), suggesting that those areas are critical for representing a sequence of manual movements for either body side. Consistent with this pattern of cerebral activation, analysis of their respective behavioral results showed a significant transfer of learning to the preferred right hand. From these results, it seems that the left hemisphere dominance for sequential movements minimizes the proportional gain of the left over the right hand after unimanual practice, preventing a greater advantage of the practiced over the resting hand.

The effect of unimanual practice on manual preference was clearly shown in the group analysis. Consistent with previous findings suggesting shift of manual preference in humans (Mikheev et al., 2002) and animals (McGonigle & Flook, 1978) induced by unimanual practice of the non-preferred limb, the present results show that manual preference for the experimental task was shifted following a period of unimanual training. This finding reveals the dynamic character of manual preference by demonstrating that the initial preference for the right hand in lateralized individuals is overcome by repetitive experiences of the initially non-preferred hand. Additionally, the relative persistence of this effect in the retention phase indicates that unimanual practice produced an enduring effect on manual preference (cf. McGonigle & Flook, 1978). Observation of individual results added relevant information for this analysis. Particularly in the post-test, a noticeable effect of unimanual practice on hand preference was found, with most participants declaring left hand preference for the sequential finger movement task in contrast to not a single case of left hand preference in the pre-test. Moreover, four participants in the post-test not only declared left hand preference but also indicated that they had become consistent left-handed for the experimental task at that time. After 30 days of rest the experimental group maintained the overall preference for the left hand, although at that moment only one participant declared to be consistent left-handed and three participants declared to have no manual preference for the task. These results indicate that, although persistent over time, shift of manual preference is somewhat unstable and tends to weaken following several days of rest.

Results from the correlational analysis showed that magnitude of manual asymmetries is not significantly associated with magnitude of manual preference (cf. Teixeira & Gasparetto, 2002). This finding suggests that manual asymmetry is not the main factor determining shift of manual preference. Analysis of individual results shed further light on this point. Although manual preference shifted predominantly in agreement with manual asymmetry from the pretest to the following phases in the experimental group, there were several exceptions to this trend. This aspect is particularly evident in retention, a phase in which incongruence between manual preference and manual asymmetry was most evident, with half the participants of the experimental group presenting manual preference incongruent with manual asymmetry. Such incongruence was observed either by an undefined manual preference associated with manual asymmetry favoring the right or the left hand, or by a manual preference for the disadvantaged hand. Overall, the results from group and individual analyses indicate that variation of manual preference between experimental phases is not dictated by modification of manual asymmetry between the hands.

From the results reported here, we propose a two-component model of manual preference. One component is conceived to be task-specific, consisting of the effect of the recent history of differential use of the limbs for a particular motor task. The second component is proposed to be general, and reflects a higher confidence on a single hand for motor performance in tasks of different natures. For most participants of the experimental group the specific component of manual preference was shown to be stronger in the post-test, prevailing over the generalized preference for the right hand. Although manual asymmetry can not be disregarded as a potential factor contributing to definition of manual preference, we propose that the specific component arises mainly from an increased confidence on a single limb resulting from previous lateralized experiences. On the basis of this conceptualization, an individual becomes more confident on that hand used most in previous opportunities to perform a motor task, and this increased confidence would influence the choice of the hand to perform that task in future situations.

In daily living occasions both specific and general components usually act in the same direction, reinforcing manual preference for the same body side. In our experimental setup, conversely, the two components had a competitive relationship. This dispute between the specific and the general component is hypothesized to be responsible for the fact that fewer participants declaring consistent left hand preference were found in the retention phase in comparison with the number observed in the post-test. In other words, immediately after practice participants would rely more strongly on the practiced left hand; following several days of rest confidence on the left hand would weaken, giving place to the effect of the general component. For those participants of the experimental group who did not shift manual preference after practice, it is apparent that the specific factor affecting manual preference was unable to overcome the generalized preference for the right hand. It is worth noting, in addition, that in retention the only two participants of the experimental group declaring right hand preference presented asymmetric performance favoring the left-hand. This finding provides further support for the proposition of a general component of manual preference, independent either of task-specific experiences or manual asymmetry, which seems to predominate in some individuals.

As concluding remarks, the results of shift of specific manual preference by unimanual practice without relationship with manual asymmetry offer preliminary insights into the different factors related to the history of use of the hands which might affect manual preference for performing motor skills. More specifically, the proposition of lateral preference established by increased confidence rather than manual asymmetry leads to the conception that manual preference might be the precursor of manual asymmetries in a number of motor tasks and not the opposite.

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