

Asymmetrical Transfer of Braille Acquisition between Hands

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Two experiments are presented which demonstrate asymmetrical transfer for tactual recognition of individual braille letters in sighted subjects, a task usually associated with right hemisphere specialization. Right-handers were studied in Experiment 1, left- and right-handers in Experiment 2. Poor transfer of training from the right hand to the left hand was observed for right-handed subjects in both experiments. The same was true for one group of left-handers (who wrote with the "inverted" position). For another group (who wrote with the "non-inverted" position), no disadvantage was associated with opposite-hand training for either hand. The role of hemispheric specialization of function in determining the direction of greater transfer is discussed, and it is argued that handwriting posture may be an index of the degree of functional "connectedness" of the two hemispheres in left-handers. © 1990 Academic Press, Inc.

Attempts to explain asymmetries in the transfer of training between hands in normal subjects (e.g., Hicks, 1974; Taylor & Heilman, 1980) have focused on the special role of the left hemisphere in the performance of manual skills. For example, Taylor and Heilman argued that the right hand benefited more than the left from opposite-hand training in a sequential tapping task because "the right hand [has] direct access to skills learned by the left hand (and stored in the left hemisphere) whereas the left hand [has] only indirect access, across the callosum, to skills learned by the right hand (and also stored in the left hemisphere)" (p. 558).

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Parlow and Kinsbourne (1989) also studied a "left hemisphere" skill—*inverted-reversed printing*—but concluded that the nonpreferred hand typically benefits more than the preferred hand from *opposite-hand training*. Furthermore, they found that the direction of greater transfer (right to left vs. left to right) was opposite for right-handers and left-handers who wrote with a "noninverted" (LN) posture (cf. Levy & Reid, 1976, 1978). They argued that proficiency differences between left and right hemispheres accounted better for their data than the currently popular *callosal access model*; transfer was typically greater from the more proficient hand to the less proficient one than vice versa (cf. Ammons, 1958; Laszlo, Baguley, & Bairstow, 1970). Alternatively, *coactivation* of the ipsilateral hemisphere by the specialized hemisphere (the left for right-handers and the right for LNs) might have established an independent internal representation in that hemisphere and thereby facilitated the transfer of skill between hands. Thus, these models also assume that one hemisphere (usually the left) is "dominant" for manual skills.

It can be argued, however, that the direction of greater transfer should be reversible (as we showed between right-handers and LNs for the printing task) given a "right hemisphere" skill. We present here findings from a second and very different kind of skill which involves the tactile recognition of individual braille letters (cf. Rudel, Denckla, & Spalten, 1974; Rudel, Denckla, & Hirsch, 1977). This task putatively engages the right hemisphere in sighted subjects (Harris, 1980; Harris & Carr, 1981). Furthermore, although *alexia for braille* in previously fluent braille readers has been (predictably) associated with *aphasia* and damage to the left hemisphere (e.g., Carmon & Benton, 1969; Fontenot & Benton, 1971; Birchmeier, 1985), cases have also been reported with damage restricted to the right hemisphere and with otherwise normal language skills (Perrier, Belin, & Larmande, 1988; Jacquy, Piraux, Josquet, Loas, & Noel, 1977). *Hand order effects* in "learning how to learn" have been reported for sighted subjects learning different lists of braille-like stimuli with left and right hands (e.g., Wagner, 1977, cited in Harris, 1980). However, transfer of training across hands has not been systematically examined for a previously practiced list (i.e., declarative knowledge).

A *between-subjects design* was used, which permitted us to compare *same-hand* and *opposite-hand training* separately for left and right hands. The same list of letters was used for practice and test trials. We predicted that the right hand of right-handed subjects would benefit more than the left from *opposite-hand training*, reversing the asymmetry previously observed for *inverted-reversed printing*. As this and similar skills appear to be mediated by the right hemisphere in left- and right-handers (Hecaen, de Agostini, & Monzon-Montes, 1981), we predicted that the direction of greater transfer would be the same in both populations. Finally, because left-handers who wrote with an "inverted" (LI) posture showed

little transfer between the hands in our previous investigation, we predicted that LNs would demonstrate greater transfer of training than LIs.

Right-handed subjects were studied in Experiment 1. Right- and left-handers were then compared in Experiment 2.

EXPERIMENT 1

Subjects

Forty right-handed undergraduates participated, 20 male and 20 female. Hand preference was verified by questionnaire. The right hand was preferred for an average of 13.4 ($SD = 2.2$) of 15 common unimanual tasks (which included handwriting, using scissors, and other tools). Seventeen of the subjects (43%) reported having one or more left-handers among their first and second degree relatives.

Materials

Braille stimuli (see Appendix) were produced using a standard Braille slate and stylus and heavy paper which was then run through a Thermoform Brailon Duplicator (American Thermoform Corp.) to obtain a durable, waterproof surface. A backing of heavy paper was applied and the surface cut into 5×7 -cm cards. Each card contained one letter positioned 2.5 cm from top and side edges. Stimuli for the same/different discrimination task were positioned centrally in vertical strips, 6 stimuli (3 pairs) to a strip. A distance of 3 cm separated the members of each pair; 4.5 cm separated successive pairs. Half of the 10 test and 2 practice pairs contained identical items and half contained different items.

Procedure

Subjects were pseudo-randomly assigned to four groups so that there was an equal number of males and females in each. Subjects in each group were trained to identify four braille characters by touch (A, K, S, and T) with either the left or the right hand and completed a same-different tactual discrimination task before the test trials. Half of the subjects were tested with the same hand used during the practice trials, and half, the opposite hand. The groups were designated L-L, L-R, R-L, and R-R, with the first letter indicating the practice hand and the second letter the test hand.

Stimuli were presented behind a small hinged screen covered by a cloth. The subject passed one hand through a curtain in the screen, using the middle finger to palpate the stimulus. Because we wanted to ensure adequate time to explore the stimuli, the subjects were allowed to self-pace this process. Each stimulus was presented and named by the experimenter prior to beginning the practice trials. The stimuli were then presented in random orders in blocks of four. The subject's task was to identify each by name. Feedback was provided, and the correct name given after incorrect responses. The practice trials were discontinued when each letter had been presented six times. The procedure was the same for practice and test trials. However, the stimuli were not identified again prior to beginning the test trials. Errors were recorded for later analysis.

For the same-different tactual discrimination task, subjects were asked whether the second of two braille stimuli, presented one at a time, was the same or different. Each member of the pair was presented for 5 sec. If subjects did not respond after 15 sec, they were encouraged to guess.

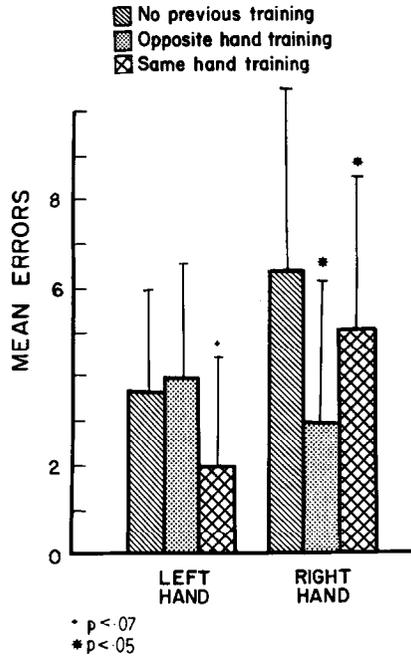


FIG. 1. Mean errors made by right-handers in Experiment 1, as a function of hand and type of training. Means for left (averaged across groups L-L and L-R) and right (averaged across groups R-R and R-L) hands during practice trials have been included to indicate expected performance in the absence of training. Vertical bars represent standard deviations.

RESULTS

An analysis of variance based on hand, type of training, and gender revealed that females ($M = 2.7$, $SD = 3.0$) tended to be more accurate than males ($M = 4.3$, $SD = 3.0$), $F(1, 32) = 3.17$, $p < .09$, but there were no significant interactions involving gender. The interaction of Hand \times Type of Training was significant, $F(1, 32) = 5.37$, $p < .05$, and probing the simple effects revealed the left hand to be more accurate than the right after same-hand training, but not after opposite-hand training. Planned comparisons also revealed that subjects in group R-L tended to be less accurate than subjects in group L-L, $t = 1.53$, $df = 18$, $p < .07$, while those in group L-R were more accurate than those in group R-R, $t = 1.75$, $df = 18$, $p < .05$ (see Fig. 1).

The scores for groups L-R and R-L were then compared with scores obtained during the practice trials, in order to contrast opposite-hand training and performance without prior training. Subjects in group R-L at test performed at the same level as subjects in groups L-L and L-R during practice, $t < 1$. In contrast, subjects in group L-R were more

accurate at test than novices in groups R-R and R-L, $t(28) = 2.34$, $p < .05$.

Same-Different Discrimination

No differences between males ($M = 3.7$ errors, $SD = 1.9$) and females ($M = 3.0$, $SD = 1.8$) nor between left ($M = 3.5$, $SD = 1.9$) and right ($M = 3.2$, $SD = 1.8$) hands were observed in the ability to make simple same-different discriminations between successive braille stimuli.

DISCUSSION

Transfer of training within hands favored the left hand. Transfer of training between hands was asymmetrical for the braille task. This had the effect of minimizing hand differences after opposite-hand training. As predicted, there was greater transfer to the right than to the left hand. Performance by the right hand was improved by opposite-hand training (compared to no training and same-hand training conditions) while performance by the left hand tended to worsen after opposite-hand training (relative to same-hand training) and was, in fact, not better than expected had there been no prior training.

A second experiment was then conducted which compared right- and left-handed subjects (and within the latter, LI and LN subjects). In this experiment, practice trials were discontinued upon reaching a predetermined performance criterion. This was done better to equate the experiences of the two hands during training. The distractor task was also made somewhat more difficult (and more similar to the experimental task).

EXPERIMENT 2

Subjects

Ninety-six male undergraduates participated, including 48 left-handers and 48 right-handers. They completed the handedness questionnaire and handwriting posture was assessed as they wrote a brief sentence. Those left-handers who wrote with the pen nib facing the body and the wrist inverted above the line of writing were classified as left-inverters (LI). Those who wrote with the wrist held straight and the hand below the line of writing so that the pen faced away from the body (or in a vertical position) were classified as left-noninverters (LN). Half of the left-handers used the LI posture and half the LN posture. All right-handers used the noninverted posture. LI and LN subjects did not differ significantly in the extent of the left-hand preference (LI, $M = 11.0$; LN, $M = 11.1$) nor in reported familial sinistrality ($t = 1.16$). A total of 67% of LI subjects and 50% of LN subjects reported having one or more left-

handed relatives. A left-hand preference was rarely endorsed by right-handers ($M < 1$), 19% of whom reported left-handed relatives.

Materials

Cards containing the braille letters for A, K, S, and T were made using a braille typewriter (in standard size) and heavy paper and preserved by coating the undersurface with glue. This method produced a slightly sharper tactual stimulus than the thermoform procedure. Two sets of distractor stimuli were similarly prepared. List A consisted of the braille letters for C, I, O, U, V, G, R, and N. List B consisted of the braille letters for B, E, M, L, P, X, W, and Z.

Procedure

Subjects in each of the three handedness groups were assigned to groups L-L, L-R, R-L, or R-R, as in the first experiment. Within each group, half of the subjects received List A and half List B as a distractor between training and test trials.

The same procedure was used as before, but practice was discontinued if subjects successfully identified the four list items twice in succession (to a maximum of six passes through the list). Two dependent measures were obtained: (1) errors and (2) trials to criterion (TTC, ranging from 2 to 8, the latter indicating failure to reach criterion after six attempts).

A distractor task followed the practice trials, and consisted of three trials in which a new list (A or B) containing eight stimuli was presented. The letters were identified by the experimenter before each trial was begun. No feedback was given during this task. Item order was randomized at each presentation of the list. Identification errors were summed across the three trials and recorded. The distractor task was followed by a 2-min unfilled rest interval and the test trials.

RESULTS

Mean TTC and error scores as a function of training are presented in Fig. 2. For comparison, practice scores for left and right hands (averaged across groups L-L and L-R, and across groups R-R and R-L, respectively) have also been included in the figure to illustrate expected performance without training.

Familial sinistrality and hand preference scores were investigated as potential covariates. These factors were not found to be substantially associated with either dependent measure and were dropped from subsequent analyses. A $3 \times 2 \times 2 \times 2$ MANOVA was then conducted to examine the effects of handedness, distractor list, hand, and type of training. The three-way interaction of Handedness \times Hand \times Type of Training was significant, $F(4, 142) = 2.54, p < .05$. Probing simple interactions and simple main effects subsequently revealed that left hand scores varied as a function of handedness and type of training. Among right-handed and LI subjects, opposite-hand training was inferior to same-hand training of the left hand. In contrast, opposite- and same-hand training were equivalent for the left hand in LN subjects, as they were for the right hand across the sample.

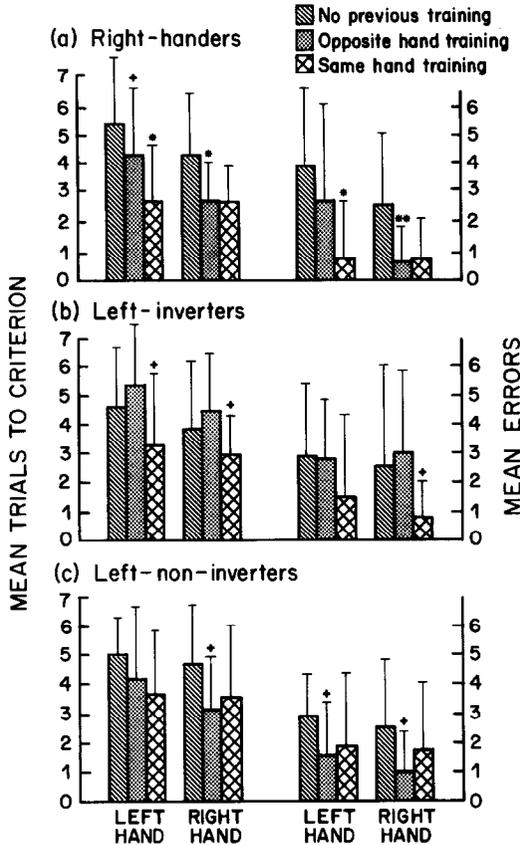


FIG. 2. Mean trials to criterion and errors made in Experiment 2, as a function of hand and type of training for (a) right-handers, (b) left-inverters, and (c) left-noninverters.

Planned comparisons were then performed to compare scores after opposite-hand training with no training. This analysis confirmed that right-handers in group L-R required fewer trials to reach criterion and made fewer errors at test than did novices in groups R-R and R-L during the practice trials, Hotelling's $T^2 = 6.60$, $p < .05$. Right-handers in group R-L performed similarly to novices in groups L-L and L-R (Hotelling's $T^2 = 2.23$, n.s.).

Although mean scores for both hands of LN subjects were lower after opposite-hand training than in the no-training conditions, the differences were not statistically significant. In fact, neither LI nor LN subjects appeared to have profited from opposite-hand training when compared to novices (LI subjects: right hand, $T^2 = 0.50$, left hand, $T^2 = 2.20$; LN subjects: right hand, $T^2 = 2.25$, left hand, $T^2 = 2.47$).

Distractor Task Scores

Analysis of scores for the distractor task revealed an interaction of Handedness \times List, $F(2, 84) = 3.19, p < .05$. The simple effects were examined first, followed by Newman-Keuls Multiple Comparisons ($\alpha = .05$) which showed LI subjects ($M = 8.4$ errors) to be more accurate than LN subjects ($M = 12.7$) on List B, while right-handers ($M = 10.7$) did not differ from either LI or LN subjects. Handedness was not a factor for List A (LI = 17.4, LN = 16.4, right-handers = 15.6), the more difficult of the two lists. The latter observation was confirmed by a significant main effect for list, $F(1, 84) = 48.66, p < .001$. No other factors were significant.

DISCUSSION

As in Experiment 1, the right hand of right-handed subjects benefited more than the left did from opposite-hand training. Opposite-hand training was inferior to same-hand training for the left hand, and not significantly better than no training.

The same pattern was observed for LI but not for LN subjects. For these subjects, same- and opposite-hand training were equivalent for both hands. However, neither LI nor LN subjects performed significantly better after opposite-hand training than in the absence of training.

GENERAL DISCUSSION

Two experiments were presented which demonstrated asymmetrical transfer of training for tactual recognition of individual braille letters in sighted subjects. In both experiments, the right hand of right-handed subjects benefited more than the left from opposite-hand training, reversing the asymmetry observed in a previous experiment for inverted-reversed printing. Taken together, these findings support our hypothesis that the direction of greater transfer (at least in right-handed subjects) is related to relative hemisphere specialization of function and does not reflect the properties of one hemisphere (the left) alone.

Comparison of left- and right-handers in the second experiment revealed the same pattern of transfer for one group of left-handers, those who wrote with the inverted (LI) posture. Those who wrote with the noninverted (LN) posture showed no hand differences, however, and performed as well after opposite-hand as same-hand training, regardless of hand. In the previous study, LI subjects had shown little transfer in either direction. These data support the claim that hemispheric representation for spatial skills is not reversed for left- as compared to right-handers, and also the hypothesis that skill is more readily transferred between the hands in LN than in LI subjects. The data remain equivocal, however, as neither group of left-handers performed significantly better after opposite-hand training than after no training.

Although these findings are compatible with both the *proficiency* and *cross-activation* models, the experiments were not designed to permit comparison between them. Transfer was greater in Experiment 1 from the more proficient (left) hand to the less proficient (right) hand than vice versa. It is noteworthy, however, that introducing a criterion into the training phase successfully reduced hand differences in Experiment 2 without altering the direction of greater transfer. Proficiency differences between the hands are not sufficient, therefore, to account for the asymmetry. Alternatively, one could argue that practice with the left hand but not with the right hand resulted in cross-activation of the ipsilateral hemisphere in right-handers and perhaps also in LIs, facilitating transfer of training between the hands. Neither model adequately accounts for the different performances of LI vs LN subjects, however.

Alternative interpretations should also be considered. The importance of the distractor task used in the present investigation is not clear. In the Parlow and Kinsbourne (1989) study, an unfilled 2-min interval separated practice and test trials. The reversal of the directional effect seen here might reflect greater vulnerability of the right hemisphere to distraction rather than a reversal in information flow from one side of the brain to the other. The tasks studied in the two investigations differ in other ways, as well. For example, the braille task was less familiar to our subjects than the inverted-reversed printing task, which relies heavily on routinized skills. The direction of greater transfer may favor the right or preferred hand during early stages of skill acquisition and the other hand later on if the right hemisphere has a special role in processing unfamiliar stimuli (cf. Gordon & Carmon, 1972; Goldberg & Costa, 1981; Kinsbourne & Bruce, 1987). Varying the extent of practice prior to test trials and the presence/absence of a distractor test in future studies will address these issues.

The distinction between "learning to learn" and transfer of learning as it pertains to specific (i.e., declarative) material may also warrant further investigation. In the Wagner study cited by Harris (1980), children and adults learned two lists of braille-like stimuli, one list with each hand. Wagner observed that the left hand gained from following right-hand trials while the right hand did not gain from following left-hand trials (see also Rudel et al., 1974, 1977). Rudel et al. (1974) argued that girls and older children may apply verbal (i.e., left hemisphere) strategies to learning braille. Employing this strategy may benefit the second hand (and the untrained left hand, in particular) when the letters to be learned are different. If the adult subjects described in the present experiments were doing this, one would have to argue that this strategy benefited the right but *not* the left hand at test when the same letters were used.

To account for the performance of left-handed subjects both in the present study and in our previous study of inverted-reversed printing

(Parlow & Kinsbourne, 1989), we would like to suggest that the transfer paradigm may tap two dimensions of cerebral organization: (1) a structural one which reflects the topography of functional cerebral localization, and (2) a nonstructural one which reflects the functional interrelationships between the hemispheres. The two dimensions would be reflected in the direction and magnitude of transfer, respectively.

These dimensions may be orthogonal; handwriting posture may tap into the latter more than the former. If so, this would contradict McKeever's (1979) assertion that handwriting posture is not a unique source of information regarding cerebral organization. The present LI and LN samples were (fortuitously) well matched with respect to both familial sinistrality and the consistency of hand preference for a variety of tasks. These factors have been linked (rather imperfectly) with cerebral organization of function, that is, with the structural aspects of cerebral organization. Handwriting posture may be a unique behavioral index of the nonstructural dimension, that is, of hemisphere "connectedness" in left-handers.

According to this theory, the cerebral hemispheres are less connected in LI subjects than in LN subjects. This might also relate to previous reports of reduced hand differences in this population. For example, Parlow and Kinsbourne (1981) found that LN subjects displayed strong manual asymmetries on selected tasks reversing those seen for right-handers. In contrast, LI subjects were functionally ambidextrous on these tasks, despite reporting consistent left hand preferences (see also Parlow, 1978; Todor, 1980; and also Halsey, Blauenstein, Wilson, & Wells, 1980; Dabbs & Choo, 1980; Bashore, McCarthy, Heffley, Clapman, & Donchin, 1982). Conceivably, established hand differences in performance may reflect a longstanding flow of asymmetrical transcallosal inhibition, which is reduced in the LI population. The motor programs controlling the hands of LI subjects might then be more functionally autonomous than for right-handed and LN subjects. Note also that the inverted hand posture has been linked to reading disabilities (Allen & Wellman, 1980) and to reports of birth stress (Searleman, Coren, & Porac, 1982). The present findings are compatible with a functional interhemispheric information flow defect in this group, although such a defect need not be structurally based, as Levy and Reid (1978) originally proposed. This may explain some of the inconsistency that has characterized experiments designed to test Levy and Reid's original hypothesis (reviewed by Weber & Bradshaw, 1981).

APPENDIX

Test stimuli, Experiments 1 and 2:

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•	•	•	•	•	•
•	•	•	•	•	•
A	K	S	T		

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