Manual Performance on the GATB as a Screening Measure for Neurological Impairment

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Runninghead: Manual performance on the GATB

Abstract

This study investigates the effect of practice order and initial hand performance on laterality. Thirty-two right handed subjects, ages 19-42, performed 3 trials on a manual dexterity task (General Aptitude Test Battery - Turn) with each hand. Half of the subjects performed with their preferred hand first, using the nonpreferred hand on the subsequent 3 trials. The order of administration was reversed for the other subjects. Each subject also completed the Quick Neurological Screening Test. The degree of manual specialization (functional asymmetry between the hands) on the pegboard task was not correlated with performance on the Quick Neurological Screening Test (QNST). Level of manual dexterity (total number of pegs turned) was correlated with the QNST. Both hands showed improvement over practice, but the preferred hand superiority existed. Order of administration influenced laterality, with the left/right order of administration showing more manual specialization than the reversed order of administration. The results provide support for left hemisphere control of movement sequencing. The effect of practice order and hand performance on laterality is discussed.

Introduction

Although the two cerebral hemispheres are similar, they are not identical. J. Hughlings Jackson in the 1870's first suggested that the left hemisphere was dominant in the control of speech and the right hemisphere was dominant in the control of nonverbal functions. Research on the "split brain" individual, without a functional corpus callosum, established the principle of differential hemispheric function.

The establishment of lateral dominance is part of normal development and has been defined by Harris (1957 as cited in Rider et al. 1985) as "the preferred use and superior functioning of one side of the body over the other". Not all individuals are left hemisphere dominant for speech. A number of studies have attempted to identify the actual percentage of people who are right hemisphere dominant or who show a mixed dominance. Milner (1975 cited in Golden 1981) found that 96 percent of the right-handed population was left hemisphere dominant, while only 4 percent were right dominant. In left-handers, 70 percent were left dominant, 15 percent were mixed dominant, and 15 percent were right dominant.

Research investigating left-hemisphere function has revealed not only an asymmetry for speech production but an asymmetry of control for manual movement as well. Although the two hemispheres have contralateral control for distal musculature, the effects of right- and left-hemisphere damage is not symmetrical (Brinkman, Kuypers, 1972 cited in Edwards, Elliott 1987). Their results indicated that patients with right hemisphere damage suffered only left-hand performance deficits on a sequential motor task, whereas individuals with left hemisphere damage demonstrated a bilateral deficit. Evidence suggests that the development of skilful, rhythmic use of the arms and hands may be a direct reflection of the nature and degree of hemispheric lateralization of the brain.

Kimura and Archibald (1974) extended the work on motor asymmetries. In their study, right- and left-hemisphere damaged patients completed an abbreviated aphasia battery, visio-spatial tasks, and a series of motor tasks. Patients with left hemisphere damage were found to be impaired, relative to patients with right hemisphere damage, on a task in which they copied unfamiliar meaningless movements of the hand and arm.

The impairment was bilateral and equal in the two hands. These same patients showed no difficulty in isolated finger flexion or in copying a static hand posture. Correlational data indicated that finger flexion and the copying of movement sequences were unrelated tasks. There was also no significant correlation between verbal and motor impairment. Their results suggest that the impairment is a disorder of motor control, unrelated to representational content. They concluded that the bilateral deficit presented by the left-hemisphere damaged group was due to the disruption of that hemisphere's control for the production of a series of complex movements. In contrast, the right-hemisphere damaged group performed more poorly than the left hemisphere damaged group on visuospatial tasks. Their results lend support to the contention that the left hemisphere has important functions in motor control, not shared by the right hemisphere.

Evidence suggests that the left hemisphere may be specialized for sequential, rhythmic organization of fine motor control involving both the left and right sides of the body. (Williams, Wernier 1986). "Sequence of movements implies that the task does not consist merely in repetition of the same discrete movement over and over" (Lomus, Kimura as cited in Summers, Sharp 1978).

Left hemisphere specialization for sequential movement has also been studied using a transfer of training paradigm. The ability of a person to learn or to perform a particular skill with one hand which has been learned with the opposite hand is generally termed bilateral transfer (Ammons 1958 as cited in Byrd, Gibson, Gleason 1986). Hicks, Frank, and Kinsbourne (1982) suggest that when one limb is trained, and a second limb is subsequently trained in the same skill, the second training typically reaches criterion after fewer trials than were needed for the first initial training.

Attempts to explain asymmetries in the transfer of training between hands in normal subjects have focused on the special role of the left hemisphere in the performance of manual skills. Taylor and Heilman (1980 as cited in Edwards and Elliott 1987) tested subjects using a sequential tapping task and found that left-hand training resulted in greater transfer of training to the opposite right-hand than did the reverse situation. Hicks (1974 cited in Parlow and Kinsbourne 1989) using an inverted-reversed printing task found similar results. These authors attribute this to the right hand having direct access to skills learned by the left hand (and stored in the left hemisphere), whereas the left hand has only indirect access to skills learned by the right hand, via the corpus callosum (access model). In other words, "the transfer of training pattern exists because both hemispheres are involved during left hand performance whereas during the right-hand performance, only the left hemisphere is involved" (Elliott 1985 as cited in Edwards and Elliott 1987).

Other studies have found the left hand to benefit more than the right from opposite-hand training in mirror-drawing, rotor pursuit, and fast tapping tasks (Ewert, 1926; Ammons & Ammons, 1951; Laszlo, Baguley, & Bairstow, 1970, as cited in Parlow, Kinsbourne 1989). A greater proficiency model, in which the more proficient hand learns more elements during training and then is used to advantage by the untrained hand, was postulated to explain the results. Parlow and Kinsbourne (1989) studied a left hemisphere skill - inverted-reversed printing. They concluded that the nonpreferred hand typically benefits more than the preferred hand from opposite hand training. They found the direction of transfer (right to left vs. left to right) was opposite for right handers and left handers who wrote with a noninverted posture (wrote with the pen nib facing the body and the wrist inverted with the hand above the line of writing).

These results appear inconsistent with the results reported by Hicks (1974). However, review of the his data indicates that during early trials, his subjects demonstrated greater transfer to the left hand following right hand training. Parlow and Kinsbourne suggest that in the Hicks study, same-hand training obscured the effect of opposite-hand training during later trials.

Parlow and Kinsbourne (1990) suggest that Taylor and Heilman's omission of same-hand training leads to erroneous conclusions regarding transfer, specifically that the right hand benefited more from opposite-hand training simply because it improved at a faster rate. They also argued that the direction of greater transfer should be reversible for a right hemisphere skill - tactile recognition of braille letters. As predicted, the asymmetry previously observed for the inverted-reversed printing task, was reversed. The right hand of right handed subjects benefited more than the left from opposite-hand training. This supported their hypothesis that the direction of greater transfer is related to relative hemispheric specialization of function and does not reflect the properties of the left hemisphere alone.

Further investigations by Parlow and Kinsbourne (1989), found that their results could not be fully explained by the proficiency model. Differences in performance between left-inverted and left non-inverted subjects could not be explained on the basis of proficiency. Both groups performed better in the training phase with the preferred hand, however, the left-inverted subjects demonstrated little transfer to either hand. Also, examination of the between hand differences revealed that greater transfer between the hands was associated with lower correlations between the hands. In their study, the left hand of right handed subjects benefited more from opposite-training than did the right. The reversed pattern of transfer was found for one group of left-handers, those who wrote with the non-inverted posture. They speculated that the activation of the dominant hemisphere may lead to maintaining the opposing hemisphere in a state of readiness to respond. In this state, the nondominant hemisphere learns about the task in parallel fashion.

Rider et al. (1985) suggest that "handedness implies the trend toward the use of one hand over the other in the performance of manipulative skills".

Hand differences in the performance of various motor tasks are often attributed to the ability of the contralateral hemisphere to process certain types of information (Elliott, 1985). Investigators have attributed right-hand advantages in motor tasks such as finger-tapping and complex finger sequencing to left-hemisphere superiority. A left hand advantage for finger flexion and line detection has been related to a right hemisphere superiority. The search for the underlying mechanisms of handedness is complicated by the effects of practice. The preferred hand has greater experience in performing certain movements and this may be an important factor in performance asymmetries quite independent of the nature of motor and attentional systems which guide the two hands (Peters, 1981).

Investigators have examined whether the origins of between hand differences are a result of an inbuilt superiority of one hand or if they develop as a result of differential practice and experience. (McManus, Kemp, Grant 1986). They suggest that the critical question for distinguishing such theories is whether differential practice can reduce hand differences. In their study exploring the role of experience in altering dominance, Dwivedi, Tiwari, and Shukla found no significant interaction between hand and practice. Although both hands became practised as trials increased, the right hand remained quicker in picking up a weight placed on a table. (Maxwell, Niemann, Hendrik 1984). In contrast, Perelle, Ehrman, and Manowitz (1981) tested the hypothesis that practice or training tends to improve performance of both hands, but improves performance of the nonpreferred hand more than the preferred hand to the point where performance of both hands is approximately the same. They expected to find initial differences in hand dexterity, as measured by the speed at which subjects completed a fine non-verbal motor task (Crawford Small Parts Dexterity Test). They also expected that after a short training period, differences in dexterity would be eliminated. Results supported their theory. Training decreased the time required to complete the task with each hand, but decreased it more for the nonpreferred hand. The authors concluded that practice had a significant effect upon hand usage relative to this task as their subjects learned to use both hands equally skilfully.

Peters (1981) also studied the effects of practice on hand dexterity. In his study, subjects were asked to practice a finger-tapping task until both hands reached asymptote. Even with intensive practice, considerable differences in the rhythmic control of the two hands exists. For one of his subjects, hand performance was closely matched at the beginning of practice. This subject failed to equalize between hand performances. Peters indicates that this illustrates problems inherent in drawing conclusions about hemisphere equipotentiality on the basis of the magnitude of performance asymmetries. Subjects that demonstrated equal performance after a period of practice did not maintain matched hand performance on retesting. He concluded that the finger tapping task is a very basic motor task which, compared to more complex movements, is relatively resistant to change. It is possible that the limitations of the nonpreferred hand in finger tapping does not apply to more complex movements. "However, the variability for such movement, are such that practice leads to a greater degree of improvement and this potential for greater improvement may mask inherent limitations in the nonpreferred hand" (Peters, 1981). The findings support those of Sheridan (1973 as cited in Dwivedi 1977) who found that as task difficulty is increased, the difference between the hands becomes marked. Peter summarized his study by suggesting that finger tapping is not subject to many sources of variability and may reflect some basic aspects of the system which produces it.

In normal development, hemispheric specialization for both language and hand control is present as early as 3 to 5 years of age (Williams, Wernier 1986). A lack of lateral dominance has been associated with learning deficiencies, maturational deficits, behaviour problems, as well as problems in respect to motor functioning.

Preferred lateralization of manual behaviour, either in terms of lateralized usage of highly practised daily tasks (handedness) or in terms of novel unpractised and relatively complex tasks (manual specialization), is of interest not only because there are interesting implications for lateralization of brain function but also for clinical and practical reasons. The extent of laterality in using the hands might reflect the degree to which language is lateralized. Degree and type of manual preference then might influence cognitive performance. Other studies (Kimura, Archibald 1974) have found verbal and motor performance unrelated.

A major goal of clinical neuropsychology is to differentiate the brain-damaged patient from all other patients. Attempts have been made to develop a single test or a test battery that can make this distinction. In analyzing test results, clinicians often include a measure of overall level of performance, differential scores, and differences between the right and left side of the body. The use of normative data adds to the sensitivity of measure used (Golden 1981). Since the dominant hand is generally expected to do better than the nondominant hand, expected differences must be taken into account when analyzing results.

A complete neurological examination evaluates the full range of basic abilities represented in the brain. A measure or measures of manual motor control, speed, and dexterity in a neurological battery is common practice. Such tests have been useful in the detection of lateralized brain dysfunction (Berg, Franzen, Wedding 1987). These tests are timed tests that either have an apparatus with a counting device or require a countable response from the patient. In the presence of cerebral pathology lateralized to one cerebral hemisphere, one is likely to observe deficits on the contra-lateral body side. Since such deficits are often discernable in testing for fine as well as gross motor functioning, testing is most appropriate within the context of a complete neuropsychological assessment.

Although the dominant hand is expected to perform better than the non-dominant hand, differences of a large magnitude are excellent indicators of dysfunction of one or both cerebral hemispheres (Knights 1983). If the dominant hand performs more poorly or equal to the non-dominant hand on any motor task, this is possibly indicative of an injury to the contralateral hemisphere. However, impairment in the non-dominant hand must be significantly larger than the expected difference before involvement of the non-dominant hemisphere is hypothesized (Golden 1981).

The major measure of motor skill on the Halstead-Reitan is the Finger Tapping Test, which measures the speed of tapping by the index finger of both hands. In general, the left hand (non-dominant), is expected to be about 10 percent slower than the right hand. Consequently, any situation in which the dominant hand is not 5 percent or more effective than the non-dominant hand suggest the possibility of dominant hemisphere damage. If the dominant hand is slower than the non-dominant, this is strongly indicative of dominant hemisphere dysfunction. To hypothesize lateralized non-dominant hemisphere dysfunction, the performance of the left hand should be at least 20 percent below that of the right hand. (Reitan 1959 as cited in Golden 1981).

On the Luria Nebraska, the motor function scale is one of the longest and most complex of all scales. Items include a measure of left-right motor speed, motor coordination, and verbal control of movement.

The purpose of a screening is to identify clients who would most benefit from an extended neurological assessment. It is important not to see such an examination as an end in itself, for the conclusions that can be reached are strictly limited (Golden 1981). One can only conclude that the patient has some neuropsychological deficit consistent with a diagnosis of brain dysfunction.

The Purdue Pegboard has been extensively used as a screening measure for left/right performance differences. On this task, subjects are required to place pegs in a series of holes as quickly as they can using their right, left, and then both hands simultaneously. This dexterity test can be a highly efficient method of screening for cortical dysfunction and detecting a lateralized lesion (Berg, Franzen, Wedding, 1987). Costa et al. (1963 as cited in Golden 1981) found a 90 percent hit rate for the test in an initial study. In a second study, Costa's group achieved a 95 percent accuracy identifying a brain-damaged group and 73 percent accuracy in a control group. They found the Purdue to be an effective screening device in detecting the presence and laterality of cerebral lesions.

The Purdue Pegboard has also been studied as a screening device for identifying children with learning disabilities (Kane, Gill 1972). The impetus leading to the investigation is the need for an effective, practical, and economical means of screening children for accurate diagnosis and proper remediation. Results indicated that as a diagnostic measure the Purdue Pegboard had some potential, but the authors caution that further investigation is necessary to warrant its inclusion in a test battery or as a sole screening device. They also suggested that longitudinal studies should be undertaken to determine the efficiency of the instrument's predictive power.

Bielecki and Growick suggest that screening for brain damage has become an essential clinical tool to the rehabilitation practitioner. Vocational counsellors and evaluators must respond to the complexities of a brain-damaged population so that appropriate recommendations for further testing can be initiated (1984).

Knights, in an article prepared for the Canada Employment Centre, postulated that it was possible on the basis of performance on the General Aptitude Test Battery, to identify individuals who are at high risk for neurological difficulties. The pattern of sub-test performance could be examined in a variety of ways including overall performance, verbal-spatial differences, intertest differences, and left-right performance differences. The assumption is that some individuals would be identified for referral to a neurologist for detailed examination. The goal is not to accurately diagnose conditions, but to select out those who appear to have some basis for suspicion of neurological deficits so that they may be counselled to see their physician for preliminary neurological assessment. He suggests that Part 10-Turn of the General Aptitude Test Battery may be adapted to assess right left performance differences. This motor test is already given to the dominant hand. The procedure would require instruction modification so that the subject performs the same task a second time using the non-dominant hand.

The purpose of the present study was to investigate the effects of practice and hand order on Part 10 - Turn, of the General Aptitude Test Battery, by comparing right and left hand performance scores.

In a 1967 article, Reitan pointed out that clinical sensory tests may require modification when used in experimental research. He noted that this would hold true when sensory tests are applied to research questions regarding asymmetries of cerebral function (as cited in Maxwell and Niemann 1984).

For example, in the standardized clinical administration of the Finger-Tip Numberwriting test, the right hand is always tested first, and a left hand superiority is typically observed. Maxwell and Niemann (1984) found that when hand order is counterbalanced, the test shows no left-hand advantage but a significant practice effect. The authors suggest that the features of the Finger-tip Numberwriting test, favouring superior left-hand performance, might lead the clinician to predict left-hemisphere dysfunction too often. Experimentally, the results demonstrate the influence of counterbalancing starting-hand order and the importance of manipulating independent variables when applying standard clinical neuropsychological tests to the study of functional organization of the intact brain.

According to the access model, lateral transfer should favour the right hand. The proficiency model generates the converse prediction, that the left hand should benefit more than the right hand from opposite hand training.

Method

Subjects

Thirty-two right handed subjects between the ages of 18 and 42, (mean of 31), participated in the study. Each subject was referred to the Vocational Evaluation Unit of the Ontario March of Dimes. All subjects had full range of upper extremity motion. Subject handedness was determined by the hand used to write their name.

Apparatus

The apparatus used for Part 10 (Turn) of the General Aptitude Test Battery is a rectangular pegboard containing 48 holes. Each hole contains a cylindrical peg which is to be removed, turned over so that the opposite end is up, and returned to the hole from which it came. The Quick Neurological Screening Test assesses maturity in motor development, skill in controlling large and small muscles, motor planning and sequencing. Standardized instruction as outlined in the administration manual was provided to each subject.

Procedure

Subjects completed Part 10 - Turn of the General Aptitude Test Battery. One half of the subjects were instructed to start the sequence with their preferred hand (right), the other half with their non-preferred (left) hand. Each subject was tested individually. The actual testing time for the turning task was 180 seconds - three trials of 30 seconds for each hand. Including instruction and demonstration, the entire procedure required approximately 5 minutes. On each trial subjects were encouraged to attempt to beat their best score. The number of pegs turned was recorded for each condition. The same person administered the test to all subjects. The motor task was used to measure manual specialization (the lateralized use on a novel and complex task) and motor ability of both hands. (Smirni, Zappala 1989). Manual specialization was calculated as (R - L)/(R + L), where R is the number of pegs turned on all three trials with the right hand and L is the number turned for the left hand to yield a measure of hand differences relative to the level of performance. Manual dexterity was the total number of pegs placed with both hands.

A subjects score on the Quick Neurological Screening Test was obtained by tabulating the scores on the 15 subtests. A total score exceeding 50 placed a subject in a high score range, a score exceeding 25 in a suspicious range, and a score less than 25 in the normal score range. All testing was administered individually. Testing time was approximately 20 minutes.

Results

The preferred hand was significantly more skilful on the pegboard task (preferred Mean 26.56 SD 6.20; nonpreferred Mean 23.13 SD 4.06 $t=1.86$, p .05) than the nonpreferred hand. The order of administration on laterality was also significant. Laterality scores were higher when subjects completed the task in the left-right order ($t=1.960$, $p < .05 = 1.70$) than the reversed order. There was greater transfer of training to the left hand following right hand training ($t=2.08$ $p < .05=2.04$). Manual dexterity was significantly correlated with performance on the turning task ($r = -.79$). No significant correlation was found between manual specialization and performance on the Quick Neurological Screening Test.

Table one shows the effect of practice between the first and third trails when starting hand is reversed.

RIGHT/LEFT ORDER

	TRIAL 1	TRIAL 3	DIFFERENCE	% GAIN
RIGHT HAND	26.56	27.94	1.38	5.2
LEFT HAND	23.13	25.86	2.75	11.89

LEFT/RIGHT ORDER

	TRIAL 1	TRIAL 3	DIFFERENCE	% GAIN
LEFT HAND	24.75	28.19	3.44	13.88
RIGHT HAND	25.81	28.73	2.92	11.31

Discussion

The present study examined the effect of experimentally manipulating hand order on laterality and the direction of transfer of training on a motor sequencing task mediated by the left hemisphere. The degree of manual specialization, expressed as the functional asymmetry between the hands on the pegboard task, did not influence manual skill. In this study a positive correlation was found between motor ability of both hands and performance on the Quick Neurological Screening Test.

Transfer of training was asymmetrical for the turning task. The left hand benefited more from opposite training than the reverse order. This had the effect of minimizing, but not eliminating hand differences after opposite hand training. This supports the proficiency model which predicts greater transfer of training to the left hand following practice with the right hand. This has been attributed to the more proficient hemisphere (hand) learning more elements during training which is used to the advantage by the untrained hand. The access model was not supported. The experiment was not designed to permit comparison with the predictions made by the cross-activation model primarily because only a right handed sample was used in the study. Analysis confirmed that for right handers, hand differences are minimized when the left hand follows right hand performance.

This is consistent with the results reported by Parlow and Kinsbourne (1989) who suggest that practising a skill with the right hand is the most efficient strategy for promoting maximum skill in both hands. The handicap to the left hand is minimal. In contrast, when the left hand leads in practice, between hand differences are greater.

The design of the study did not permit an analysis of same hand training. Two additional groups (R -R and L - L) would have been necessary to draw same and opposite hand comparisons.

To maximize performance on Part 10 - Turn of the General Aptitude Test Battery, it is suggested that a right to left order of administration be followed. Results also found that the amount of variability between the hands was greater for the right hand than left hand. This is in contrast to the findings by Elliott (1985). He indicated that the asymmetry in variability between the hands (left being more variable) is the result of the superior ability of left hemisphere (right hand) to program and modulate force.

The small group size does not allow us to rule out using lateralization scores as a screening device for neurological impairment. The implications of the order of administration on laterality must be further investigated. Results of the present study support the effectiveness of manual dexterity in identifying individuals at risk for neurological impairment (Elliott 1985, Kimura, Archibald 1974). Manual dexterity of both hands was related to performance on the Quick Neurological Screening Test. Smirni and Zappala (1989) suggest that the developmental process implies not only the leading motor abilities of one hand, but also an increased performance with both hands.

Jamie:

- a glossary of terms would have helped
- I'm not sure about the role of the QNST in your study
- Were there any statistical tables re: the QNST?
- Including more ideas on future research would strengthen your study

D.H.

References

Berg, R., Franzen, M., Wedding D. (1987). Screening for Brain Impairment: A Manual for Mental Health Practice. Singer Publishing Company, New York.

Bielecki,R.A., Growick, B., (1984). Validation of the Valpar Independent Problem-Solving Work Sample as a Screening Tool for Brain Damage, Vocational Evaluation and Work Adjustment Bulletin, Summer, 59-61.

Studied the effectiveness of the Independent Problem Solving Work Sample as a screening measure for the presence of organicity in rehabilitation clients.

Dwivedi, K., Tiwari, Smt. M., Shukla, K.D., (1977). Reaction Time as the Function of Handedness, Practice and Set. Asian Journal of Psychology and Education, 2, 49-54.

Studies reaction time as a function of handedness, practice and set. The study provided support to the idea that the right hand is quicker than the left hand and that reaction time is reduced by practice.

Edwards, J.M., Elliott, D., (1987). Effect of Unimanual Training on Contralateral Motor Overflow in Children and Adults. _Developmental Neuropsychology, 3,_ 299-309.

Investigated active hand performance and ipsilateral and contralateral overflow in children and adults. A developmental trend was evidenced with children exhibiting more motor overflow than adults. There was also greater overflow evidenced when performing with the left hand than with the right hand. The children also evidenced a similar asymmetry in transfer of training.

Edwards, J.M., Elliott, D., (1989). Asymmetries in Intermanual Transfer of Training and Motor Overflow in Adults with Down's Syndrome and Nonhandicapped Children. _Journal of Clinical and Experimental Neuropsychology, 11,_ 959-966.

Elliott, Digby, (1985). Manual Asymmetries in the Performance of Sequential Movement by Adolescents and Adults with Down's Syndrome. _American Journal of Mental Deficiency_, _90_, 90-97.

Fields, Frances R.J., (1979). A Motor Reversal Phenomenon in Individuals with Medically Documented Cerebral Electrophysiological Disturbances, Clinical Neuropsychology, Second Quarter, 48-50.

Golden, Charles J., (1981). Diagnosis and Rehabilitation in Clinical Neuropsychology, 2nd Ed. Charles C. Thomas, Publisher, Springfield.

Chapter 4 deals with the research within clinical neuropsychology that has been directed toward the differentiation of the brain damaged patient from all other patients. Several methods of analyzing test results including the level of performance, the differential score and the differences between the right and left side of the body, are discussed.

Hartlage, L. C. (1990). Neuropsychological Evaluation of Head Injury. Professional Resource Exchange, Inc., Sarasota, Florida.

Hautala, R.M., (1988). Does Transfer of Training Help Children Learn Juggling? Perceptual and Motor Skills, 67, 563-567.

Kane, J., Gill R., (1972). Implications of the Purdue Pegboard As a Screening Device. Journal of Learning Disabilities 1, 36-40.

Studies the effectiveness of Purdue Pegboard test in discriminating children with learning disabilities. Results support previous research but data are insufficient to recommend the inclusion of this test in any test battery as a diagnostic instrument.

Kimura, D., Archibald, Y., (1974). Motor Functions of the Left Hemisphere, Brain, 97, 337-350.

A group of patients with left hemisphere damage was clearly impaired, relative to a group with right hemisphere damage, on a task requiring the copying of visually presented meaningless hand movements.

Knights, R.W., Stoddart, C. (1983). Automated Assessment of Vocational Aptitudes: A Feasibility Study. Minister of Supply and Services, Canada.

Maxwell James K., Niemann, H. (1984). The Finger-Tip Numberwriting Test: Practice Effects versus Lateral Asymmetry, Perceptual and Motor Skills, 59, 343-351.

Measured lateral asymmetry on the Finger-Tip Numberwriting Test when hand order was counterbalanced. When starting order was counterbalanced, the test showed no lateral asymmetry but a significant practice effect.

Parlow, S.E., Kinsbourne, M., (1989). Asymmetrical Transfer of Training between Hands: Implications for interhemispheric Communication in Normal Brain, Brain and Cognition, 11, 98-113.

An investigation of asymmetrical transfer of training between the hands/hemispheres. Results showed differential transfer on the basis of handedness. The authors postulate a cross-activation model to explain their results.

Parlow, S.E., Kinsbourne, M., (1990). Asymmetrical Transfer of Braille Acquisition between the hands. Brain and Language 39, 319-330.

Asymmetrical Transfer for tactile recognition of individual braille letters was studied. Poor transfer of training from the right hand to the left hand was observed for right-handed subjects. The same was true for left-inverted subjects. No advantage was associated with opposite hand training for either hand.

Perelle, I. B., Ehrman, L., Manowitz, J.W., (1981). Human Handedness: The Influence of Learning. Perceptual and Motor Skills, 53, 967-977.

Subjects were administered a manipulative skill at pretest and counterbalanced for starting hand.

Subjects in the experimental group were given 5 practice sessions and then were given a posttest. Both hands showed significant improvement as a result of practice, with the nonpreferred hand showing no significant difference from the preferred hand.

Peters, Michael (1981). Handedness: Effect of Prolonged Practice on Between Hand Performance Differences. Neuropsychologia, 19, 587-590.

Investigated the effect of practice on preferred hand superiority on a finger tapping task. Results showed no indication of a change in the magnitude of the between hand performance differences over practice.

Smirni, P., Zappala, (1989). Manual Behavioral Laterization of Manual Skills and Cognitive Performance of Preschool Children, Perceptual and Motor Skills, 68, 267-272.

Motor maturation is viewed as a process that implies a richer motor performance of both hands. Bilateral motor dexterity is offered as a more specific parameter than that of traditional handedness.

Williams, H., Werner, P. Purgavie, G., (1986). Relation Between Hemispheric Specialization and Gross Motor Control In Normal Right- Handed Children, Perceptual and Motor Skills, 63, 1227-1231.

Investigated nature of relationship between gross-motor, eye-hand coordination and hemispheric specialization. Analysis indicated that speed and accuracy of responses to verbal and spatial stimuli presented to left cerebral hemispheres were significantly related to proficiency of eye-hand coordination.