

LEFT-HANDEDNESS

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The aim of this article is, first, to summarize the literature of the subject, and second, to give in brief the results of certain experimental studies in the field. In part it is a condensed statement of data published in another connection (7).

I. LITERATURE ON LEFT-HANDEDNESS

Investigations of the general problem of left-handedness have confined themselves largely to four aspects: (1) the prevalence of left-handedness in normal and sub-normal human beings, and its variation with age, sex, race, etc.; (2) its hereditary nature; (3) its origin and cause, and (4) its relationship to "mirror-writing."

1. THE PREVALENCE OF LEFT-HANDEDNESS

According to Gould (10) 6 per cent of all normal human beings are left-handed. Smith (24) gives the percentage as 5; Lombroso (20) and Jones (12) give it as 4; Ballard (4) states the distribution as 2.7 per cent, while Hyrtl (11) and Baldwin (3) give it as 2 per cent.

It is affirmed by Weber (28), Ballard (4), and Smith (24) and denied by Lombroso (20) that left-handedness is more frequently found among males than females.

Lombroso (20), Audenino (1), Lattes (18) and Smith (24) find left-handedness more frequent among delinquents. Lattes (18) also finds the characteristic more frequent among negroes. Hrdlička (10a) found it in 4 per cent of Apache and 3.6 per cent of Pima Indian children and adolescents.

According to these investigations the distribution of left-handedness among the normal population ranges from 2 to 6 per cent, with 4 per cent as the median. The latter is the more reliable figure, in the writer's opinion, and is confirmed by his own investigations (7).

2. THE INHERITANCE OF LEFT-HANDEDNESS

Wilson (30), Merkel (21), Weber (28), Bardeleben (5), Jordan (14), and Ramaley (22) affirm the hereditary nature of left-handed-

ness, while Gould (10) and Kellogg (17) deny it. There are but two systematic investigations reported, however, which go into the matter with any degree of thoroughness.

Based upon a study of 700 university students, 1,394 colored public-school pupils, and 668 others, Jordan(14) concludes that left-handedness is hereditary to some extent, although he does not imply from the limited data accumulated that the phenomenon follows Mendelian principles.

Ramaley (22), after studying 1,740 cases, concludes that left-handedness is a Mendelian recessive and exists as such in about one-sixth of the population.

3. THE ORIGIN AND CAUSE OF HANDEDNESS

1. *Primitive Warfare*.—Gould (10) and others argue that since the heart is the most vital organ of the body and is located nearer the left side the shield was held with the left hand thus protecting the heart, while the right hand became the spear hand and has consequently acquired a dexterity which has been perpetuated through many ages.

2. *Accident*.—Some argue that a child's handedness is the result of imitating its parents, or that it arises from the mother's constant method of carrying it; the child's hand which is thus left free being exercised more and therefore stronger. The hereditary nature of handedness would invalidate this theory, as would also the observations of Baldwin (2) of his own child in which all such influences were removed and handedness was found to develop spontaneously about the seventh month. Baldwin's findings are confirmed by the observations of Mrs. Woolley (31).

3. *Gravity Theory*.—Struthers and Buchanan (cited by Wilson (30)) argue that since the viscera on the right side of the body (the liver and the lungs) are heavier than those on the left side, this condition places the center of gravity to the right of the anatomical center, thus rendering the use of the right limbs more likely.

This theory implies that left-handedness would be the result of a transposition of the viscera or what is known as *situs inversus*. Cases of transposition are on record which were not correlated with left-handedness. Furthermore left-handed people in general are not "viscerally transposed."

4. *Mechanical Theory*.—Buchanan (quoted by Wilson (30)), argues that full strength cannot be put forth without making deep inspira-

tion and maintaining the chest expanded. Since the viscera of the right side are heavier than those of the left, this so alters the mechanical relations of the two sides of the body that the muscles of the right side act with superior efficacy. To render this inequality greater the muscles of the left side act with a mechanical disadvantage. The evidence adduced to disprove the gravity theory applies equally well here.

5. *Origin of Subclavian Arteries*.—Hyrtl (11) claims that owing to the position of the arteries the blood is forced through the right subclavian artery under a greater pressure than through the left, and as a result the muscles of the right side are better nourished and stronger. Left-handedness is explained by the lower branching off of the left subclavian artery. The negative evidence of visceral transposition just referred to invalidates this theory also; *i.e.*, left-handedness is not necessarily correlated with *situs inversus*.

6. *Greater Blood Supply to one Cerebral Hemisphere*.—This theory is put forth by Leuddeckens (19), Lombroso (20), Judd (16), and others, the essence of which is quoted from Judd (16):

“The two sides of the brain receive their blood supply through arteries which are asymmetrical. Where the blood supply is larger to the left side of the brain, the right hand is naturally developed to a higher degree of dexterity; where the right side of the brain receives the greatest blood supply the person is naturally left-handed.”

This theory is invalidated by the presence of the anterior communicating artery, which connects the two cerebral arteries of the brain and forms part of the circle of Willys. As a result the cerebral blood supply is pooled, so to speak, thus making it impossible for one hemisphere to receive a greater blood supply than the other. Furthermore, Cunningham, (8) by measuring the size of twenty-four pairs of carotid arteries as they entered the brain, and comparing the total area of the left carotids with the total area of the right carotids, found no perceptible difference in size between the right and the left.

7. *Cerebral Asymmetry*.—This theory is advocated by Baldwin (3), Lombroso (20), Wilson (30), and is based upon such evidence as is put forth by Boyd (quoted by Wilson (30)). Boyd, for example, examined two hundred brains, weighed each hemisphere separately, and found that almost invariably the weight of the left exceeded that of the right. Lattes, quoted by Jordan (14), notes also that cerebral asymmetry is greater in delinquents, children, idiots, and

negroes than in normal adults. Broca (cited by Wilson (30)), found also that in forty brains the left frontal lobe was heavier than the right.

The objection to this as a theory explaining handedness is that cerebral asymmetry may be the result of handedness and not the cause.

8. *Continuous Variation*.—Bardeleben (5) was the earliest advocate of this theory and contends that the neurological evidence proves that right handedness was and is the primary condition, and that the superior organization of the cerebrum is the result. Handedness from this point of view becomes a continuous variation.

9. *Vision*.—Gould (10) holds that "in about 96 per cent of all infants the right eye is the better-seeing eye and thus compels the right hand to work with it." This, he maintains, is due to the fact that vision develops long before the muscles, in the embryo. His conclusion is, therefore, that handedness is determined primarily by ocular dominance "and only indirectly and partially by heredity."

Stevens (25) and Stevens & Ducasse (27) determined experimentally that in a majority of their subjects objects appearing in the right half of the field of vision of both eyes are uniformly enlarged over objects appearing in the left half of the field of vision. From this they conclude that "by reason of the fact of a marked difference in the space sense of the two halves of the retina, objects in the right half of the field of vision by appearing larger attract the visual attention which in turn leads to grasping movements of the right hand. The hand thus favored by earliest experience acquires a special skill which causes it to be used in all manual acts requiring the greatest precision."

Ballard (4) was the first to point out a fatal objection to this theory by adducing evidence to show that among the congenitally blind one finds about the same proportion of right- and left-handedness as among the sighted. Ballard further points out that Stevens' results were secured from experimentation with adults, and since space perception involves the higher mental processes the implication is, therefore, that a similar experiment upon children would yield totally different results.

10. *Education*.—Wilson (30) says "that the preferential use of the right hand is natural and instinctive with some persons; that with a small number an equally strong impulse is felt prompting to the use of the left hand, but that with the great majority right-handedness is largely the result of education." Kellogg (17) also holds this view.

4. LEFT-HANDEDNESS AND "MIRROR-WRITING"

"Mirror-writing" is a reversed form of conventional, right-hand writing, executed by the left hand backwards, which becomes intelligible when seen in a mirror.

Judd (16), Barr (6), and Sherlock (23) hold that "mirror-writing" is a correlate of mental deficiency. Fuller (9) studied the aberration by inducing it in normal and abnormal subjects. He concludes: "the more the psychological, or higher, parts of the nervous system are disorganized, the more confidently we may expect a left-handed reversed writing to result."

The writer studied "mirror-writing" as it occurred spontaneously in a normal school population of 106,356 children (7). Out of this number, 42 pure "mirror-writers" were found and studied. The results of his investigations, while not purporting to be absolute, prove that "mirror-writing" is not necessarily correlated with mental deficiency; the data rather prove that "mirror-writing" is a characteristic of extreme left-handedness.

II. EXPERIMENTAL METHODS AND RESULTS

The extreme right-handed nature of man's mechanical environment and the necessity of the sinistral's adjustment thereto, render the problem of left-handedness largely one of education. Furthermore, the necessity of working in "right-handed classrooms," and of acquiring facility in a right-handed system of handwriting make the left-handed child's school-tasks unusually difficult.

In its last analysis the educational problem in regard to left-handedness becomes one of accurately diagnosing a child's native handedness at an early age, *i.e.*, at least before he begins to acquire dexterity in the various school subjects. The facts regarding the prevalence of left-handedness and also its hereditary nature would imply that there are all degrees of handedness ranging from extreme right-handedness on the one hand to extreme left-handedness on the other. To force a strongly left-handed child, therefore, to become right-hand is just as wrong as to permit a slightly left-handed person to remain sinistral when he might easily be changed to right-handedness.

It was to this fundamental aspect of the problem, *viz.*, the derivation of a test for diagnosing the native handedness of young children, that the writer applied himself (7).

The field was canvassed for tests which have been used or suggested for the purpose indicated. The dynamometer and the ergograph were

ruled out because the former yields unreliable results and the latter because of its impracticability for school-room use. The Jones' (12) brachiometer tests which measure the ulna and humerus and infer native handedness by the superior bone measurements, were experimentally applied to 123 children in the kindergarten and the first grade. The results, however, gave a distribution of handedness which does not square with the known facts.

In the effort to perfect or devise a reliable test the writer proceeded upon the following assumptions:

1. That a test involving acts of dexterity would be superior to a test of skill or endurance, since such a test would ultimately be given to children between the ages of four and eight years.

2. The desired test, in order to be valid for the purpose in mind, must be relatively accurate when applied to individual cases.

3. The test must be simple, not alone of comprehension by the subject, but in its construction and application; it must be designed to meet the needs of school administrators, teachers and other educational officers.

4. The ability or dexterity tested must closely resemble the principal dexterities called forth in school work and in practical life; at the same time the two must not be identical.

With these basic considerations uppermost in mind the writer decided upon the general plan of trying out certain of the most suggestive tests, in order first, to eliminate the least promising, and second, either to perfect the remaining ones or to glean suggestions for the construction of a new test. The essence of the general method was "to apply certain tests to a large number of children of different school ages, whose handedness was already known quite accurately, and to determine the validity of the tests by the degree or extent to which its results corresponded or correlated with the known facts of the children's handedness.

"The method, while somewhat unique, is simple and resembles very closely the method evolved by society for measuring and indicating temperature. Before the advent of the thermometer the extremes of temperature were known in a general way; the need lay in devising an instrument which would always give, at least approximately, the same indication at the same temperature and at the same time accurately measure any change. In other words, a device was needed which would record a change in direct proportion to the change already known and felt empirically. Of the various

liquids tried out experimentally in the thermometer, that one was finally chosen, of course, which showed the greatest correspondence or correlation with the changes in temperature known empirically.

The method employed, stated in brief, is as follows. A tapping test, a steadiness test, a tracing test (A) were tried out simultaneously upon group 1, 114 boys and girls in the 3rd, 4th, 5th, and 6th grades. The results revealed the superiority of the tapping test. An arm-tapping test and a wrist-tapping test were then tried out simultaneously upon a second group of 116 boys and girls of the same age. These results revealed the superiority of the wrist-tapping test. Finally, a wrist-tapping test, a finger-tapping test and tracing test B were applied simultaneously to a third group of 112 boys and girls of similar ages, with the result that the tracing test B showed a superiority. This test, devised by the writer, was an attempt to embody in a single test the valid characteristics and merits of the tests used in the course of his investigation.

"The apparatus is designed for use with an electric counter or other electric recording devices. It is 20 inches long and 8 inches wide. At one end of the board or arm-rest is inlaid, flush with the surface, a brass plate 8 centimeters square and 4 millimeters thick. The entire surface of the plate is milled in both directions, with grooves 1 m. wide and 2 mm. deep, distance between grooves is also 1 m. The entire surface of the plate presents the appearance as shown in Fig. 1.

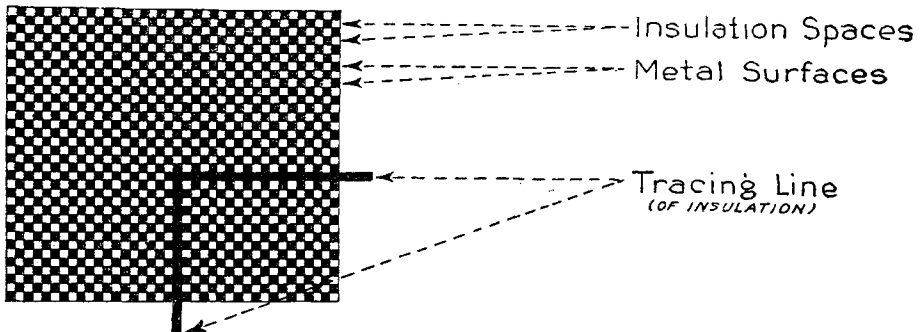


FIG. 1. Diagrammatic appearance of tracing plate in tracing test B.

"The grooves were filled with an insulating material composed of china clay and shellac, which hardens when dry. The entire surface, after sandpapering, presents a perfectly smooth appearance. In the center of the plate is a black line 1 m. wide, forming a rec-

tangle 6 cm. square. This line was made by adding carbon black to the original insulating compounds in order that it should stand out in bold relief from the white lines of insulation.

"The apparatus thus described makes it possible for a subject using a platinum stylus .75 m. in diameter to trace the black line of insulation forming a rectangle without touching any metal surface. This, of course, is the ideal record as far as errors are concerned. A deviation of .25 m. or more will record an error or errors in direct proportion to the number of metal surfaces encountered with the stylus. The entire surface of the tracing plate is perfectly smooth; this makes it possible for the stylus to travel unhindered and unchecked over the entire surface of the plate and in immediate response and direct proportion to the subject's control of movement or lack of it, as the case may be. Furthermore, the alternating metal and insulation surfaces of the plate in both directions make and break contact respectively, so that the number of errors recorded by an electric counter is in direct proportion to the amount of deviation in any direction from the black tracing line.

"Still another feature of the test is important, viz., the similarity between the movements involved in tracing the lines of the apparatus and those involved in handwriting; (1) arm movement, (2) wrist movement, and (3) finger movement."

The errors made by the subject were recorded by means of an electric counter, and the time consumed in making the excursion around the rectangle was kept by means of a stop-watch. The method tentatively adopted for stating the results quantitatively in terms of one coefficient, was to multiply the time-score by the error-score.

The following tables give in brief the results obtained by the author.¹ They justify the conclusion that the test just described reveals all the characteristics of a valid test for diagnosing handedness, since (1) its results correlate perfectly with the known facts and (2) it reveals an increasingly greater difference in the dexterity of the two hands in the lower grades. The writer makes no claim that the test can be used with absolute reliability in every case. All that is claimed is that its use will render the diagnosis of a doubtful case of handedness more accurate and scientific than is possible by any other existing test or method. Furthermore, before the test can be used extensively, norms of ability must be derived for the right hand and for the left hand, at various ages.

¹See also his "Experimental Study in Left-handedness," Univ. of Chicago Press, 1918.

RESULTS IN CONDENSED TABULAR FORM

TABLE I

COMPARISON IN PERCENTAGES OF DISTRIBUTION OF HANDEDNESS AMONG 100 FIRST-GRADE CHILDREN AND 23 KINDERGARTEN CHILDREN ACCORDING TO JONES BRACHIOMETER MEASUREMENTS

	Ulna			Humerus			Total Arm Length		
	R	L	Amb.	R	L	Amb.	R	L	Amb.
100 first-graders	46	40	14	44	34	22	46	40	14
23 kindergartners . . .	47.8	39.1	13.1	21.7	43.4	34.9	34.8	43.4	21.8

TABLE II

SHOWING THE RELATIVE DIAGNOSTIC VALUE OF THE TAPPING, STEADINESS, AND TRACING A TESTS WHEN APPLIED TO 100 RIGHT-HANDED CHILDREN (Group 1)

Grade	No. of Children Tested	Tapping Test			Steadiness Test			Tracing Test		
		R	L	Amb.	R	L	Amb.	R	L	Amb.
III	25	23	2	0	20	5	0	19	6	0
IV	27	22	4	1	18	8	1	19	7	1
V	26	24	1	1	21	4	1	24	2	0
VI	22	21	1	0	18	3	1	19	2	1
Total	100	90	8	2	77	20	3	81	17	2

TABLE III

COMPARISON OF THE HANDEDNESS OF 105 CHILDREN (GROUP 2) ACCORDING TO THE ARM TEST AND THE WRIST TEST WITH THEIR KNOWN HANDEDNESS

Grade	No. of Children Tested	Known Facts			Arm Test			Wrist Test		
		R	L	Amb.	R	L	Amb.	R	L	Amb.
III	26	26	0	0	23	2	1	26	0	0
IV	26	26	0	0	22	3	1	26	0	0
V	26	26	0	0	24	2	0	25	1	0
VI	27	27	0	0	25	2	0	26	1	0
Total	105	105	0	0	94	9	2	103	2	0

TABLE IV

SHOWING THE RELATIVE DIAGNOSTIC VALUE OF THE WRIST TEST, FINGER TEST·
AND TRACING TEST B WHEN APPLIED TO 103 RIGHT-HANDED CHILDREN
(GROUP 3)

Grade	Wrist Test			Finger Test			Tracing Test B		
	R	L	Amb.	R	L	Amb.	R	L	Amb.
III.....	26	0	0	26	0	0	26	0	0
IV.....	27	0	0	27	0	0	27	0	0
V.....	26	0	0	26	0	0	26	0	0
VI.....	22	2	0	24	0	0	24	0	0
Total.....	101	2	0	103	0	0	103	0	0

TABLE V

SUMMARY AND COMPARISON OF DIFFERENCES IN INDICES OF TWO HANDS REVEALED
BY TRACING TEST B

Grade	Right Hand (Average Index)	Left Hand (Average Index)	Difference
III.....	301.5	705.3	403.8
IV.....	354.8	902.3	547.5
V.....	322.2	790.7	468.5
VI.....	338.6	551.0	212.3
Average of Grades III and IV.....	328.7	805.6	476.9
Average of Grades V and VI.....	330.1	675.6	345.5
Total average.....	329.4	742.5	413.1

TABLE VI

SUMMARY AND COMPARISON OF THE AVERAGE TIME AND ERRORS PER TRIAL
REVEALED BY THE APPLICATION OF TRACING TEST B

Grade	Time (in seconds)			Errors		
	Right	Left	Diff.	Right	Left	Diff.
III.....	15.5	20.7	5.2	18.3	32.4	14.1
IV.....	18.6	26.3	7.7	17.7	32.2	14.5
V.....	17.0	26.7	9.7	18.5	29.7	11.2
VI.....	15.0	18.5	3.5	21.5	28.9	7.4
Average of Grades III and IV.....	17.0	23.5	6.5	18.0	32.3	14.3
Average of Grades V and VI.....	16.0	22.6	6.6	20.0	29.3	9.3
Total average.....	16.6	23.2	6.6	18.9	30.8	11.9

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