Journal of Genetic Psychology, 148(4), 469–478

Differences in Academic Performance at School Depending on Handedness: Matter for Neuropathology?

STEPHEN M. WILLIAMS
Department of Psychology
University of Ulster at Coleraine, Northern Ireland

ABSTRACT. Two studies found that left-handed children had significantly poorer academic records than did right-handed children, though the effect was small. Study 1 provided evidence that, for some academic disciplines, the important difference appeared to be between those children whose family history of handedness was concordant with their own handedness and those children whose family history of handedness was discordant with their own handedness. The inclusion of gender in asymmetry research was bolstered by Study 2. When predicting idiosyncrasies in left-handers' cognitive performance, it should be borne in mind that left-handers form a minority group as well as a neurologically distinct one.

DOES HANDEDNESS AFFECT childrens' academic performance at school? The main hypothesis examined in these two studies, based on neuropsychological evidence, was that right-handers would show superiority in some disciplines. Subsidiary hypotheses were that results might be influenced by family history of handedness and by sex.

Most individuals show a bias toward one hand, more frequently the right, but this behavioral phenomenon is far from being straightforward or simple. The complexity is brought out most acutely, perhaps, by the failure of much of the neuropsychological literature to handle the distinction between definitions of handedness in terms of preference and definitions in terms of skill. Hardyck and Petrinovich (1977), in their review of left-handedness, suggest that handedness is most appropriately regarded as a continuum (ranging from

Requests for reprints, and for detailed tables of the statistical analyses, should be sent to Stephen Williams, Department of Psychology, University of Ulster at Coleraine, Cromore Road, Coleraine, Co. Londonderry BT52 1SA, Northern Ireland.

right-handedness to left-handedness through mixed-handedness) and that the utility of handedness as a predictive variable improves when the handedness of a subject's family is taken into account.

Older studies, including Levy (1969a), have classified subjects simply by asking them whether they were left- or right-handed. In contrast, the method of assessment used in clinical neuropsychology is to question subjects about hand preference. Clinicians determining preference have used a great variety of functional traits (Subirana, 1969), some of them not directly connected with the hand at all, for instance, ocular dominance and footedness. Fortunately the problem posed by this variety has been given attention previously, resulting in the development of systematic questionnaires, which have been standardized on large samples and designed in the awareness of general factors influencing handedness research. The questionnaire used in these two studies was the Edinburgh Handedness Inventory (Oldfield, 1971), which asks respondents whether they have a strong or weak preference for either hand in the execution of ten everyday acts, such as writing, drawing, striking a match, and using a toothbrush. From the answers a laterality quotient can be calculated, ranging across the cardinals from + 100 (pure right-hander) to – 100 (pure left-hander). Nevertheless, the questionnaire is merely a sample or an abbreviated description of handedness rather than an authoritative statement of it, and the quotient is certainly not a genuine cardinal, but scarcely even an ordinal, for questionnaire items are given equal weight in the calculation of the quotient although there is no empirical evidence for their equivalence (Williams, 1986).

Psychological significance to handedness is suggested by neurological evidence. A natural way to accommodate modern neurological findings is to accept that language is, after all, bilaterally represented in the brain but with the relative importance of the two hemispheres not necessarily the same (cf. Searleman, 1977) and to accept that the relative importance of the right hemisphere is greater in some persons with sinistral tendencies. But, can a mutually beneficial bridge be built between neuropsychological data and psychological studies of normal subjects? Levy (1969a) argued that the tendency toward bilateral organization of language in left-handers interferes with and depresses the performance of nonverbal functions (but may give left-handers a slight advantage on verbal functions). She gave the Wechsler Adult Intelligence Scale (WAIS) to 10 self-styled left-handers and 15 self-styled right-handers (all graduate students) and found that the difference score (Verbal IQ minus Performance or Nonverbal IQ) derived from this test was significantly greater for the left-handers than for the right-handers. The separation was due mostly to left-handers' lower scores on the Performance tests of the Wechsler battery, which, contrary to their description, seem principally to measure cognitive-perceptual skills. These skills, largely of a visual-spatial character, should be mediated more by the right than by the left hemisphere (Blakemore, Iversen & Zangwill, 1972), and because in left-handers the right hemisphere is not freed for these skills, a deficit is predicted. If left-handers show a deficit for right-hemisphere skills, one would expect this to have wider implications for their cognitive functioning.

Study 1

Method

This study corrected two features of Levy's (1969a) design: It used a sample less highly selected than Levy's graduates, and it made the measurement of ability realistic by using the academic records of a secondary school. This was a medium-sized, urban boys' school, independent but receiving a direct grant, in Somerset, England. The records provided information on a substantial sample of up to 190 boys (in Forms 3 to 7, ages 13 to 18 years) for seven separate disciplines: geography, history, mathematics, science, French, English, and Latin. Developmental progress toward hemispheric asymmetry has long been assumed (but Kinsbourne [1975] has offered a critique of the relevant evidence), and the onset of that asymmetry is believed to come well before the age of this sample (and in Brown and Jaffe's [1975] theory, which postulates a life-long development toward asymmetry, there is not even a minimum age of "best" sampling). The information available was a mixture of 'O' level grades, form positions, and internal grades (these latter assessing performance over a complete school year).

For the purpose of pooling information, I placed all boys studying a particular discipline in a full rank order. The calculation of this ranking required certain assumptions to be made, mainly commonsense ones, though it had to be assumed that average ability in each form was constant. All boys who were first in their form were deemed equal first overall, and 'O' level results were transformed into a ranking (everyone on 1 higher than everyone on 2 and so on down to 9).

Each boy completed the Edinburgh Handedness Inventory (Oldfield, 1971) and an additional question about the handedness of relatives ("Please write down any relatives known to be left-handed or ambidextrous"). The questionnaires were handed out and collected in class. With children of this age, it is unlikely that poor reading ability was an influential factor in completing the Edinburgh inventory. Certainly, no respondent gave evidence of misunderstanding the instructions. On the basis of this questionnaire, four groups were distinguished according to whether their members were left- or right-handed and whether or not they had left-handed relatives. The presence or absence of familial sinistrality was decided according to the criterion of one left-handed relative at one remove or two at two removes.

Results

The data were inspected to see whether separating out mixed-handers as a distinct group would clarify the distribution of ability, that is, whether they showed a pattern of superiority or inferiority to consistent right- or left-handers. There was no indication of such a pattern, and therefore mixed-handers were not included as a separate group in the analysis. Moreover, because there was no indication that mixed-handers were closer to left- than to right-handers and for the sake of symmetry, the dividing line between handedness groups was fixed at LQ = 0. For each discipline, the average ranks in each of the four groups mentioned and in each of the four larger groups formed by distinguishing subjects according to just one of the two independent variables were computed, as were interquartile ranges. A computer program was written to calculate (a) the Kruskal-Wallis H statistic, estimating whether each of the four former groups was drawn from the same underlying population, and (b) the Mann-Whitney U (converted to the normal variate z for this large sample) for both of these two subject variables. (Siegel [1956] does not regard a correction for tied ranks important, especially with the proportion of ties involved in the present study; but the program did make such a correction in calculating H).

Right-handers were significantly superior for French, $z(135) = 2.15$, $p < .05$. The Kruskal-Wallis test showed significant differences between the four groups for geography, $H(189) = 9.92, p < .05$, and science, $H(163) = 9.59, p < .05$, which seem in both cases to be due to the inferiority of the discordant groups (left-handers without left-handed relatives and right-handers with left-handed relatives). This same pattern was shown for history, but quite the opposite was shown for English and Latin. Right-handers were the better students in every discipline, except in the relatively small Latin set. One would expect handedness effects to be greatest for disciplines placing the greatest demands on nonverbal intelligence, and this was so for science, but mathematics showed very little effect for handedness. Further, 71 boys in this sample chose between Arts and Science for 'A' level specialization; for this choice, there was no significant effect of handedness.

Study 2

The clinical evidence for atypical cerebral dominance in left-handers comes of course from samples that have not been selected for intelligence. To some extent, direct-grant schoolboys have been selected for ability, although it may well be that a genuine handedness difference in the population is masked by a biased selection for study of only those nonright-handers equally as able as right-handers. Annett (1970), however, found no difference in the proportion of nonright-handers among undergraduates, unselected secondary school children, and enlisted men. Because Study 1 gave at least preliminary evidence of a handedness effect on academic performance, it seemed best to collect further data.

Method

To avoid the problem of biased sampling due to preselection for ability, I chose a comprehensive school—a large, mixed school in Lincolnshire. Comprehensive schools take children of all abilities. The sample consisted of 239 right- and 50 left-handers from Forms 2 and 3 (approximately 12 and 13 years old), for each of whom was recorded an internal grade (scaled from A to E) in each of eleven disciplines: English, mathematics, science, French, geography, history, religious instruction, music, art, needlework/woodwork, cookery/metalwork. All pupils studied the same disciplines, except that girls took needlework and cookery while boys took woodwork and metalwork. Teachers did use categories such as B+ and C−, but less frequently than B or C, so C− and C+, for example, were aggregated with C; this 5-point scale gave a better approximation to a normal distribution of ability than did the more discriminative 15-point scale. The structure of the data made it possible to assess the interactions of handedness with age and sex.

Results

Neither the Kruskal-Wallis or chi-square tests, nor a distribution-free analysis of 2^m factorial designs (Crouse, 1968), nor a parametric analysis of variance for unequal n, (with weighted or unweighted means) (Keppel, 1973) seemed so appropriate as a series of multiple regressions (Cohen, 1971; Kmenta, 1971). The BMDO2R stepwise multiple regression program (Dixon, 1973) was used. In the present case, it did not matter whether contrast coding or dummy variable coding was employed for the explanatory variables.

Although handedness had a significant effect on average ability, $F(1, 287) = 4.72$, $p < .05$, English, $F(1, 287) = 4.02$, $p < .05$, and especially mathematics, $F(1, 287) = 8.24$, $p < .01$, it accounted for only a very small percentage (at most 3%) of the individual variation on these measures. Such a contrast exposes a serious limitation in the significance-testing approach dominating the previous literature (though not Hardyck, Petrinovich & Goldman, 1976). Left-handers were the poorer group for every discipline ($p < .001$ on a sign test).

Gender has been emphasized as a variable in asymmetry research (see, for example, McGlone & Davidson, 1973; McGlone & Kertesz, 1973; and Ray, Morrell & Frediani, 1976). Although the regressions gave no evidence for a Handedness × Sex interaction, right-hander superiority was greater for males in every discipline (again, $p < .001$ on a sign test). This regularity fits the general doctrine that males tend more to the extremes of distributions. There was no sex difference in the incidence of left-handedness, $\chi^2 = .074$, $p < .8$, another issue over which different surveys have disagreed recently. Also, right-hander superiority was greater for the older pupils for every discipline except the two practical crafts ($p = .055$ on a sign test), which seems more consonant with the notion of a developing hemispheric asymmetry than the opposite tendency would have been, though one could hardly speak of a developmental trend on the basis of two closely-spaced age-levels. There was a significant interaction for French marks: Form 2 boys did not show right-hander superiority, unlike Form 2 girls, Form 3 boys, and Form 3 girls. Form 2 boys were also the least knowledgeable, as girls were better than boys at French, so again the notion of developing asymmetry may be relevant.

The marks for mathematics were given a more detailed examination. A hand-worked simple regression provided additional evidence of a significant handedness effect, as did a Mann-Whitney test and a Kolmogorov-Smirnov analysis. Confirmation was obtained of the assumptions of normality (Kolmogorov-Smirnov test) and homoscedasticity (both Kolmogorov-Smirnov and the test recommended by Kmenta, 1971). In contrast to evidence that left-handers generally show greater variance (e.g. for dichotic listening and tachistoscopic recognition, Bryden, 1965), here they showed rather smaller variance (though this did not approach significance). It has sometimes been found that left-handers clump into two modes (Efron, 1963a, 1963b; Satz, 1973), but the histogram of the present data gave no sign of a pathological tail of left-handers.

Mathematics was the discipline having the highest correlation with average ability, whereas English ranked third in this respect; the fact that these were the two disciplines to show a significant handedness effect may have some connection with this. Although it seems antithetical that these disciplines were not the most sensitive in Study 1, it should be borne in mind that the knowledge covered by those older, more able children was quite different.

General Discussion

In spite of the evidence just presented that mathematics showed the largest handedness effect (as in the report of Wittenborn, 1946), the general pattern of results in Studies 1 and 2 did not offer clear-cut support for the hypothesis that left-handers would show a deficit on nonverbal skills or for the more likely hypothesis that a deficit would appear on tasks involving a combination of verbal and nonverbal skills. These studies offer new evidence in showing a significant handedness effect on ability with such large samples (which is not to say that this evidence is especially strong), but Hardyck and Petrinovich (1977) seem to have expressed matters rather appositely when they write, "the teasingly suggestive nature of this relationship (between left-handedness and deficit) is rather striking in its persistence through generations of research workers. There is usually just enough of a relationship to suggest a possible link and never enough of one to establish firmly a solid correlation" (pp. 393–394). The claim cannot be made with any confidence that these studies have uncovered regularities that might feed back to stimulate clinical neuropsychology into discovering a new order, but within a confusing literature they raise an emphasis on familially discordant handedness and on sex differences.

The logic of the interference argument presented by Levy (1969a, 1969b) is not compelling. In most people one hemisphere, the left, governs both speech and the preferred right hand, and this conjunction in the majority has been sufficient to raise the suggestion that when there is any departure from consistent, right-hand preference, the growth of language might be handicapped, or conversely that individuals with difficulties of speech, writing, or spelling might have atypical hand preference. Empirical support exists for both these propositions. But the possibility of language being impaired in left-handers is not really excluded at all by the bicerebrality thesis. Thus, it is an evident non sequitur for Levy (1969b) to assert,". . . to some extent, language is bilaterally organized in sinistrals. This being so it would follow that if language and perception are really incompatible functions, left-handed people, as a group, would be poorer on tests of perceptual function than right-handed people, and it would further follow that their language functions should be significantly superior to their perceptual functions" (p. 85). It seems rather, if language and perceptual functions are competing in some sense for use of the right hemisphere, that either or both of these could be impaired, unless some sort of assumption of biological primacy for one or other of these functions is introduced (a primacy others, e.g., Annett [1964], in this same field have ascribed to the nonverbal functions). Levy and Reid (1978) accept such contrasting predictions, though on somewhat different grounds: " . . . sinistrals tend toward bilateralization of function . . . Those in whom visuospatial organization has invaded the language hemisphere would manifest . . . higher visuospatial than verbal skills . . . Among certain populations, such as artists and architects, the reverse pattern of cognitive ability should be seen in left-handers: reduced verbal abilities and possible superior spatial reasoning" (pp. 123–124).

There are recent reviews of contemporary research linking left-handedness with deficit by Corballis (1983), Bradshaw and Nettleton (1983), who have contributed research of their own (Bradshaw, Nettleton & Taylor, 1981), and Hicks and Kinsbourne (1978), although Swanson, Kinsbourne and Horn (1980) take a more skeptical line. An interacting role for sex is also stressed by Milstein, Small, Malloy and Small (1979), who found a right-hander superiority for arithmetic, and Johnson and Harley (1980) and Sanders, Wilson, and Vandenburg (1982), who also involve ethnicity. Herrman and Van Dyke (1978) looked at mental rotation. For IQ, Hicks and Beveridge (1978) show a right-hander superiority, but with spatial ability Burnett, Lane, and Dratt (1982) found superiority for mixed-handers and those with left-handed relatives. Charman (1980) found no effect of handedness.

One further point must be made. Predictions of an effect of handedness upon cognitive performance, although historically derived from clinical neuropsychology, do not appear logically inextricable from the brain. The mere fact of being a minority group, "left-handed in a right-handers' world," and the age-long pejorative associations attached to the "sinister" hand might be enough to explain the small effects reported. Children who have been forced to switch their handedness-preference by an injury, which may thereby have potently retarded their development, will form a larger proportion of the minority than of the majority group. Anecdotal information suggests that even today the expression of left-handedness may have to weather pedagogic disapproval (buttressed perhaps by Burt's [1950] scientific advice). Writing from left to right is more difficult mechanically for left-handed children unless they hook their hands round in such a way that they can pull a pen across paper without obscuring what they have just written. Implements, machines, and forms tend to be designed for right-handers. All these factors may disadvantage the left-hander. It would be more difficult, though not impossible, to explain specific impairments and, especially, specific gifts of left-handers in these terms; at present such evidence cannot be regarded as established. None of this is to deny that the deleterious influence of environmental disadvantages on the cognitive performance of left-handers might be mediated by their greater bicerebrality or, to put things within a different philosophical framework, that greater bicerebrality might be the neurological expression of both the environmental disadvantages and the impairment of performance.

REFERENCES

Annett, M. (1964). A model of the inheritance of handedness and cerebral dominance. *Nature, 204,* 59–60.

Annett, M. (1970). A classification of hand preference by association analysis. *British Journal of Psychology, 61,* 303–321.

Blakemore, C., Iversen, S., & Zangwill, O. L. (1972). Brain functions: Asymmetry of cerebral hemisphere function. *Annual Review of Psychology, 23,* 433–456.

Bradshaw, J. L., & Nettleton, N. C. (1983). *Human cerebral asymmetry.* New York: Appleton-Century-Croft.

Bradshaw, J. L., Nettleton, N. C., & Taylor, M. J. (1981). Right hemisphere language and cognitive deficit in sinistrals? *Neuropsychologia, 19,* 113–132.

Brown, J. W., & Jaffe, J. (1975). Hypothesis on cerebral dominance. *Neuropsychologia, 13,* 107–110.

Bryden, M. P. (1965). Tachistoscopic recognition, handedness and cerebral dominance. *Neuropsychologia, 3,* 1–8.

Burnett, A. A., Lane, D. M., & Dratt, L. M. (1982). Spatial ability and handedness. *Intelligence, 6,* 57–68.
Burt, C. (1950). *The backward child* (3rd ed.). London: University of London Press.
Charman, D. K. (1980). Note on a failure to find hemispheric asymmetry for a small sample of strongly left-handed and right-handed males and females using verbal and visuospatial recall. *Perceptual and Motor Skills, 51,* 139–145.
Cohen, J. (1971). Multiple regression as a general data-analytic system. In B. Lieberman (Ed.), *Contemporary problems in statistics* (pp. 421–440). New York: Oxford University Press.
Corballis, M. C. (1983). *Human laterality.* New York: Academic.
Crouse, C. F. (1968). A distribution-free method of analyzing a 2^m factorial experiment. *South African Statistical Journal, 2,* 101–108.
Dixon, W. J. (1973). *BMD bio-medical computer programmes* (3rd ed.). Berkeley: University of California Press.
Efron, R. (1963a). The effect of handedness on the perception of simultaneity and temporal order. *Brain, 86,* 261–284.
Efron, R. (1963b). The effect of stimulus intensity on the perception of simultaneity in right- and left-handed subjects. *Brain, 86,* 285–294.
Hardyck, C., & Petrinovich, L. F. (1977). Left-handedness. *Psychological Bulletin, 84,* 385–404.
Hardyck, C., Petrinovich, L. F., & Goldman, R. D. (1976). Left-handedness and cognitive deficit. *Cortex, 12,* 266–279.
Herrman, D. J., & Van Dyke, K. A. (1978). Handedness and the mental rotation of perceived patterns. *Cortex, 14,* 521–529.
Hicks, R. A., & Beveridge, R. (1978). Handedness and intelligence. *Cortex, 14,* 304–307.
Hicks, R. E., & Kinsbourne, M. (1978). Human handedness. In M. Kinsbourne (Ed.), *Asymmetrical function of the brain.* Cambridge: Cambridge University Press.
Johnson, O., & Harley, C. (1980). Handedness and sex differences in cognitive tests of brain laterality. *Cortex, 16,* 73–82.
Keppel, G. (1973). *Design and analysis: A researcher's handbook.* Englewood Cliffs, NJ: Prentice Hall.
Kinsbourne, M. (1975, January). *The ontogeny of cerebral dominance.* Paper presented to the New York Academy of Sciences symposium on developmental psycholinguistics, New York, NY.
Kmenta, J. (1971). *Elements of econometrics.* New York, Macmillan.
Levy, J. (1969a). Possible basis for the evolution of lateral specialization of the human brain. *Nature, 224,* 614–615.
Levy, J. (1969b). Information processing and higher psychological functions in the disconnected hemispheres of commissurotomy patients. *Dissertation Abstracts International, 31,* 1542B. (University Microfilms No. 70-14, 844).
Levy, J., & Reid, M. (1978). Variations in cerebral organisation as a function of handedness, hand posture in writing, and sex. *Journal of Experimental Psychology: General, 107,* 119–144.
Milstein, V., Small, I. F., Malloy, F. W., & Small, J. G. (1979). Influence of sex and handedness on hemispheric functioning. *Cortex, 15,* 439–449.
McGlone, J., & Davidson, W. (1973). The relation between cerebral speech laterality and spatial ability with special reference to sex and hand preference. *Neuropsychologia, 11,* 105–113.
McGlone, J., & Kertesz, A. (1973). Sex differences in cerebral processing of visuospatial tasks. *Cortex, 9,* 313–320.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 9*, 97–113.
Ray, W. J., Morrell, M., & Frediani, A. W., (1976). Sex differences and lateral specialization of hemispheric functioning. *Neuropsychologia, 14*, 391–394.
Sanders, B., Wilson, J. R., & Vandenburg, S. G. (1982). Handedness and spatial intelligence. *Cortex, 18*, 79–80.
Satz, P. (1973). Left-handedness and early brain insult: An explanation. *Neuropsychologia, 11*, 115–117.
Searleman, A. (1977). A review of right hemisphere linguistic capabilities. *Psychological Bulletin, 84*, 503–528.
Siegel, S. (1956). *Nonparametric statistics for the behavioural sciences*. Tokyo: McGraw Hill Kogakusha.
Subirana, H. (1969). Handedness and cerebral dominance. In P. J. Vinken & J. W. Bruyn (Eds.), *Handbook of clinical neurology, Vol. 4*. New York: Wiley.
Swanson, J. M., Kinsbourne, M., & Horn, J. M. (1980). Cognitive deficit and left-handedness: A cautionary note. In J. Herron (Ed.), *Neuropsychology of left-handedness*. New York: Academic.
Williams, S. M. (1986). Factor analysis of the Edinburgh Handedness Inventory. *Cortex, 22*, 325–326.
Wittenborn, J. R. (1946). Correlates of handedness among college freshmen. *Journal of Educational Psychology, 37*, 161–170.

Received October 6, 1986