Writing Hand Position, Birth Stress, and Familial Factors

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The incidence of birth stress was found to be slightly lower in individuals writing with an inverted hand position than in those writing with a normal position, a result in the opposite direction to that reported by Searleman, Porac, and Coren (1982). A familial study suggested that an inverted writing hand position was primarily related to maternal (but not paternal) writing hand position, suggesting a modeling or imitative origin, rather than a genetic basis for writing position.

A significant proportion of subjects write with their hand in an "inverted" position. Since the reports by Levy and Reid (1976, 1978), which suggested that inversion of writing hand was related to cerebral lateralisation of language, the topic has been extensively studied. The original position of Levy and Reid has been much criticized (e.g., Weber & Bradshaw, 1981), although Levy has replied to some of these criticisms (Levy, 1982).

Despite the difficulties of Levy and Reid's neurological model there seems little doubt that a proportion of right-handers, and a rather higher proportion of left-handers, write in the inverted position, and it still remains of some interest to inquire into the origins of inversion, particularly given the apparent association with handedness. Searleman, Porac, and Coren (1982) have recently proposed that individuals with an inverted writing position are more likely to report histories of stressful births. In reporting this they have brought inversion of writing hand position back into the mainstream of laterality research since there has been a substantial number of papers suggesting that left-handedness itself may be secondary to birth complications, although the results of retrospective investigations are confused (Bradshaw & Nettleton, 1983), and in a prospective investigation of some 12,000 births there was no evidence of a relationship between handedness and birth complications (McManus, 1981).

This article describes the results of two studies which failed to replicate the birth stress findings of Searleman et al., thus throwing considerable doubt upon their hypothesis. Data are also reported on familial trends in hand-writing position, and it is suggested that hand-writing position is acquired, perhaps by modeling of the mother's writing position.

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METHOD

Data from two previous studies that have been described in some detail elsewhere (McManus, 1979, 1981) were reanalyzed to determine if there was evidence of a relationship between reported birth stress and inverted writing hand position.

Study 1. Taking part in this survey were 936 undergraduates of the University of Cambridge. A question on writing hand position was only introduced halfway through the study, and thus only a proportion of subjects had information on this item.

Study 2. This questionnaire was distributed to all graduates of the University of Cambridge, on the eve of the graduation ceremony, and was completed both by the undergraduates and by their parents.

In each study a series of questions was asked about handedness for a number of particular tasks (28 tasks in Study 1; 12 tasks in Study 2). These questions have been analyzed extensively elsewhere (McManus, 1979), where it is shown that the single best criterion of handedness is writing hand, and that criterion was used in the present study, with the single exception that the very few subjects who had been forced to use their nondominant hand for writing were excluded from the analysis. Hand writing position was assessed by the subject indicating which of four line-drawings (taken from Levy & Reid, 1976) corresponded most closely to their writing position. In each study subjects were asked if, to their knowledge, they had suffered any complications or trauma during their birth, and, if so, to give details. The fact that parents were present at the time the propositus completed their questionnaire probably accounts for the apparently higher incidence of birth trauma found in the second study, and hence the information from that second study may have had a greater validity (although conceivably it might also have a higher proportion of false positives as well).

RESULTS

Birth Stress

Table 1 shows the percentage of inverted writers in the two studies by handedness, sex, and a reported history of birth stress. For each cell of the table a significance test using the chi-square statistic (with Yates' correction) is shown. Only two of the 27 cells of the table show results significant at the 5% level. Table 2 summarizes a general linear model that was fitted to the data hierarchically using the GLIM program package (Baker & Nelder, 1978), a binomial error distribution and a logistic link function being specified. The model was fitted such that all "design" variables (hand, sex, and study), and their interactions, were fitted prior to the birth stress variable. It is clear that handedness shows a strong relationship to inverted writing hand, 12.02% of right-handers and 29.43% of left-handers reporting an inverted writing hand position ($p<0.001$). No other design effects were significant. The effect of birth stress [illegible]

TABLE 1
The Percentage of Inverted Writers as a Function of Sex, Handedness, and Study (significance levels refer to the particular cells of the table; see Table 2 for an overall analysis)

	TOTAL SAMPLE			LEFT-HANDERS		RIGHT-HANDERS	
	Stress		No Stress	Stress	No Stress	Stress	No Stress
Survey I:							
All cases	4.5	*	16.4	0.0	28.6	4.8	14.6
(380)	(44)		(336)	(2)	(42)	(42)	(294)
Males	6.7		18.0	0.0	33.3	7.1	15.7
(286)	(30)		(256)	(2)	(33)	(28)	(223)
Females	0.0		11.3	-	11.1	0.0	11.3
(94)	(14)		(80)	(0)	(9)	(14)	(71)
Survey II:							
All cases	12.3		14.8	23.1	34.7	9.8	11.2
(463)	(138)		(325)	(26)	(49)	(112)	(276)
Males	15.0		14.3	30.0	34.1	11.3	10.0
(331)	(100)		(231)	(20)	(41)	(80)	(190)
Females	5.3		16.0	0.0	37.5	6.3	14.0
(132)	(38)		(94)	(6)	(8)	(32)	(86)
Total Sample:							
All cases:	10.4		15.6	21.4	31.9	8.4	13.0
(843)	(182)		(661)	(28)	(91)	(154)	(570)
Males:	13.1		16.2	27.3	33.0	10.2	13.1
(617)	(130)		(487)	(22)	(74)	(108)	(413)
Females:	3.8	*	13.8	0.0	23.5	4.3	12.7
(226)	(52)		(174)	(6)	(17)	(46)	(157)

*$p<.05$.

to that reported by Searleman et al., 10.4% of those reporting birth stress being inverted writers, as compared with 15.6% of those not reporting birth stress. There were two significant interactions of birth stress, with sex and with study. The difference in the incidence of inverted writing in those reporting and those not reporting birth stress was greater in females (3.8% vs. 13.8%) than in males (13.1% vs. 16.2%). The difference in the incidence of inverted writing in those reporting or not reporting birth stress was greater in Study 1 (4.5% vs. 16.4%) than in study 2 (12.3% vs. 14.8%).

Familial Factors

Table 3 shows the breakdown of handedness and hand-writing position of 454 offspring in 454 families, by the parental writing hand and hand-writing position. 12.1% of 376 right-handed mothers and 9.0% of 395 right-handed fathers said that they wrote with an inverted writing hand position. 5.72% of mothers and 4.40% of fathers reported that they were left-handed, and of these left-handers, 11.5% of the 23 left-handed mothers and none of the left-handed fathers said that they wrote in an inverted position: thus in the parental generation there was no evidence of a relation-

ship between handedness and writing position, in contradistinction to the situation in the propositi.

Table 4 shows a hierarchical analysis of the data of Table 3, using a log-linear model by means of the GLIM program, with a binomial error distribution, and a logistic link function. The subject's handedness was entered first, and was highly significant as expected ($p<0.001$). Next, maternal and paternal handedness and their interactions with subject's handedness were entered; none had any significant effect upon the rate of inversion. The SH×MH×FH term was aliased due to inadequate numbers of subjects in some cells. Next, the mother's and father's writing hand position was entered; mother's position had a highly significant effect ($p<0.001$), whereas father's position had no significant effect. Entering these variables in the reverse order showed a marginally significant effect of father's position ($p<0.05$) and a very significant effect of mother's hand position, suggesting that the true relationship is with mother's writing position alone. 10.27% of 399 subjects whose mother wrote in the normal position used the inverted writing position, as compared with 34.55% of the offspring of 55 mothers with an inverted writing position. There was no interaction of mother's writing position and father's writing position, but it should be noted that only 14 individuals came from families where both parents used the inverted position (and that 50.0% of their offspring used the inverted writing position).

Among the remaining interactions only two are significant. The interaction of subject's handedness by father's writing position ($p<0.05$) showed that the difference in the rate of inversion between subjects whose father's writing position was

TABLE 2
A Hierarchical Log-Linear Modeling of the Proportion of Inverted Writers as a Function of Handedness, Sex, Study, and Birth Stress

	*Chi*²	*df*	*d Chi*²	*d df*	Significance Level
Constant	59.45	15	-	-	-
Handedness (H)	25.93	14	33.52	1	$p<0.001$
Sex (X)	23.50	13	2.43	1	NS
Study (S)	22.90	12	0.60	1	NS
H×X	20.16	11	2.74	1	NS
H×S	19.16	10	1.00	1	NS
S×X	16.73	9	2.43	1	NS
H×X×S	16.73	8	0.00	1	NS
Birth stress (B)	11.56	7	5.17	1	$p<0.05$
B×H	10.78	6	0.78	1	NS
B×X	6.57	5	4.21	1	$p<0.05$
B×S	2.55	4	4.02	1	$p<0.05$
B×H×X	0.99	3	1.56	1	NS
B×H×S	0.40	2	0.59	1	NS
B×X×S	0.01	1	0.39	1	NS

*d Chi*² = change in *Chi*² value from previous step.

TABLE 3
Percentage of Inverted Writers as a Function of Handedness and Parental Writing Position and Handedess (sample sizes are shown in brackets)

		Right-Handed Propositi			
	MOTHER	FATHER			
Hand	Position	Right Normal	Right Invert	Left Normal	Left Invert
Right	Normal	6.6 (286)	10.0 (20)	7.7 (13)	- (0)
Right	Invert	26.5 (34)	66.6 (9)	0.0 (1)	- (0)
Left	Normal	0.0 (15)	50.0 (2)	0.0 (1)	- (0)
Left	Invert	0.0 (1)	- (0)	0.0 (1)	- (0)
		Left-Handed Propositi			
	MOTHER	FATHER			
Hand	Position	Right Normal	Right Invert	Left Normal	Left Invert
Right	Normal	24.0 (50)	33.3 (3)	50.0 (4)	- (0)
Right	Invert	75.0 (4)	0.0 (4)	- (0)	- (0)
Left	Normal	60.0 (5)	- (0)	- (0)	- (0)
Left	Invert	- (0)	100.0 (1)	- (0)	- (0)

normal or inverted was greater in right-handed propositi (8.24% of 352 vs. 29.0% of 31) than in left-handed propositi (31.75% of 63 vs. 25.00% of 8). The interaction of mother's handedness by father's writing position showed that the effect of father's writing position on the incidence of inversion was greater if the mother was left-handed (13.04% of 23 vs. 66.67% of 3) than if the mother was right-handed (11.73% of 392 vs. 25.00% of 36).

DISCUSSION

The present study not only fails to replicate Searleman et al.'s finding of an increased incidence of inverted writing hand position among those reporting birth stress, but it actually finds a marginally significant effect in the opposite direction. Furthermore, the interaction of birth stress with sex is also in the opposite direction to that reported by Searleman et al., a larger effect of birth stress being found in females than in males. Although the present investigation is a little smaller than that of Searleman et al. (843 vs 1203 individuals), this cannot be invoked as an explanatic findings, since the group of male left-handers, in whom Searleman et al. reported their strongest effect, is larger in the present investigation (96 vs.

TABLE 4
A Hierarchical Log-Linear Modeling of the Proportion of Inverted Writers as a Function of the Propositus' Handedness, and Parental Handedness and Writing Position (abbreviations as in Table 2)

	Chi^2	*df*	*d* Chi^2	*d df*	Significance Level
Constant	65.51	17	-	-	-
Subject's handedness (SH)	46.56	16	18.95	1	<0.001
Mother's handedness (MH)	46.12	15	0.44	1	NS
Father's handedness (FH)	46.11	14	0.01	1	NS
MH×FH	45.43	13	0.68	1	NS
SH×MH	42.00	12	3.43	1	NS
SH×FH	40.99	11	1.01	1	NS
SH×MH×FH	40.99	11	-	-	-
Mother's writing position (MP)	20.04	10	20.95	1	<0.001
Father's writing position (FP)	18.23	9	1.81	1	NS
MP×FP	18.14	8	0.09	1	NS
SH×MP	15.55	7	2.59	1	NS
SH×FP	10.98	6	4.57	1	<0.05
SH×MP×FP	7.37	5	3.61	1	NS
MH×MP	7.01	4	0.36	1	NS
FH×FP	7.01	4	-	-	-
MH×FP	0.61	3	6.40	1	<0.01
FH×MP	0.01	2	0.60	1	NS

58), as a result of the overall sex distribution in the investigation reflecting that in the university as a whole.

Power calculations using the tables of Cohen (1969) suggest that the present investigation had a power of 49% for detecting an effect of birth stress in the total sample (using alpha = 0.05, one-tailed, with the effect size calculated from the effects observed by Searleman et al., and the sample sizes calculated from the actual samples of the present investigation, and combined as a harmonic mean (Cohen, 1969, p. 195). In the male subjects the investigation had a power of 84% of detecting an effect of birth stress, and in the male left-handers the investigation had a power of greater than 99% of detecting an effect of the size described by Searleman et al.

It should be noted that the method of generalized linear modeling is probably more powerful (and less subject to the problems of repeated significance testing) than is the use of repeated chi-square testing, as carried out by Searleman et al. The apparent contradiction in the present investigation between Tables 1 and 2 in that birth stress has no significant effect in Table 1, but does have a significant effect in Table 2, is due to the log-linear model taking "design" variables into account, whereas Table 1 has inappropriately combined tables of differing marginal frequencies (see Everitt, 1984). Similarly, the different incidences of birth stress in Studies 1 and 2 are automatically taken into account in the modeling by being previously included in the analysis as "design" variables.

Given that the present investigation has adequate power for detecting the effects proposed by Searleman et al., there are several reasons that might account for the discrepancy in the two sets of results, as follows.

Different Methods of Measurement

In both investigations inversion of writing hand was assessed from similar diagrams, and gives broadly similar results (incidence of inversion = 13.4%, 10.8%, and 7.8% in the right-handers of Studies I, II, and of Searleman et al., respectively, and 27.3%, 30.7%, and 46.8% in the left-handers of the three data-sets). (However, as Buchtel and Reuckert, 1974, point out, this method may itself introduce unspecified artifacts.) The clear differences between right- and left-handers found by Searleman et al. are strongly replicated in both Studies I and II. The overall incidence of birth stress in the Searleman et al. investigation was 21.5%. Although the incidence of stress in Study I was lower than that, at 11.6%, the incidence in Study II was higher than that of Searleman et al. at 29.8%, the two values straddling the incidence in Searleman et al.'s investigation. In Study II, stress was assessed by the parents in conjunction with the propositus, and thus is possibly more valid than that in Study I. Particular indicators of stress were not specifically itemized as in Searleman et al., and thus the measure may be slightly different from that of Searleman et al. However it is unlikely that these minor changes could have invalidated the results overall, particularly given the incidence of stress. In addition it is worth noting that retrospective accounts of the conditions of birth by mothers in general may well be unreliable (Chamberlain & Johnstone, 1975), thus throwing some doubt on the utility of retrospective surveys in general. The incidence of left-handers in the two investigations was very similar (11.6%, 16.2%, and 11.9% in Studies I, II, and in Searleman et al.), respectively. The sex ratio was different in the two investigations, Searleman et al. having 53.8% females among their subjects, while Studies I and II had only 24.7% and 28.5% females, respectively; however, Searleman et al. found their strongest effects in males, and hence their result should have been relatively easier to replicate in Studies I and II.

Sampling Effects

Taken overall, Searleman et al. found only a marginally significant effect of stress in their total sample (chi square = 3.04), $p = .0812$). Among their left-handed sample they found a more significant effect (chi square = 6.08) that nominally has $p = .014$, but since this particular test was carried out *a posteriori*, a correction should be made for multiple significance testing, and using a conventional method this would suggest that $p = .028$, a result that is also of only marginal significance. The relatively low significance levels of these two results suggests they may either be Type I errors in their own right; i.e., the 1 in 20 of possible investigations that achieve a significance level of 0.05 despite the null hypothesis being true. Alternatively a Type I error may have been produced by the mechanism that Rosenthal (1979) has called the "file-drawer" effect; that is, perhaps 20 researchers around the world have collected data on this problem of which only one achieved results nominally significant at the 0.05 level, and only that one "significant" result has been published, the rest having been consigned to the relative oblivion of the file-drawer.

So serious is this problem that one may calculate using the method of Rosenthal (1979) that even if just three other researchers had examined data for an association between birth stress and writing hand position, and had all failed to find a significant result, then even the most significant result of Searleman et al. (in male left-handers) would be nullified. In view of research interest in handedness generally, that does not seem an unlikely possibility.

It is never possible to tell with certainty whether failures of replication are a result of subtle differences in technique, or differences in culture or social factors between the subjects of the investigations, or of simple statistical fluctuations. In some strict sense no true replication of any study is possible unless one investigates the identical subjects with an identical technique at the same time as the original study; but then of course the study hardly merits the name replication, it being rather an exact facsimile, which although it will necessarily find the identical result cannot be considered as contributing additional independent evidence in support of the original hypothesis. Ultimately the only possible confirmation of the true significance of effects lies in their repeated appearance in independent studies, which are both sufficiently similar to the original investigation to count as a genuine replication, but are sufficiently different to count as being independent of the original investigation. Whether a particular "replication" satisfies those requirements is a difficult question to answer objectively. What does seem clear is that in the presence of an adequately powerful failure to replicate, the onus for further replication must surely lie with the original authors who have proposed the existence of a significant effect.

It is clear from the familial data presented that inversion of writing hand position is related to parental writing position, but is not related to parental handedness. The predominant association with the *mother's* writing hand position, rather than with the father's writing hand position, suggests that imitation or modeling is more likely to be the cause of this association than is a genetic factor. The lack of relationship with parental handedness, except in its interaction with parental writing position, suggests that to a large extent the writing position system is independent of the system determining handedness, thus making it unlikely, although not impossible, that shared genetic factors are reflecting a common neurological process for handedness, language dominance, and writing position (as for instance has been proposed by Levy and Reid, 1978, and Levy, 1982).

The lack of any interactions between handedness and other factors provides no support for the suggestion of Tapley and Bryden (1983) that inverted hand-writing posture may have a different origin in right-handers and left-handers, at least as far as the present variables are concerned.

In conclusion, it would seem that although it is premature to speculate on the causes of a relationship between writing hand position and birth stress, there seems little doubt in view of the strong relationship between inversion and handedness that writing hand position itself should be further studied, the relationship of inversion to maternal writing position not being able to explain the relationship of inversion to handedness itself.

NOTE

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