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Do left-handed children have advantages regarding school performance and leadership skills?

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A handedness polymorphism exists in all human populations so far investigated, at least since the Palaeolithic. Handedness is a heritable trait, and a possible evolutionary explanation for the higher prevalence of right-handers is the association of left-handedness with some deleterious traits. In this context, the persistence of left-handers remains unexplained. Reproductive success has been shown to be dependent on cultural success in many human societies. This study is the first attempt to consider the importance of social status to evolutionary processes related to handedness. We conducted a survey in French public primary schools to look for a possible association between laterality, school performance, and leadership skills. This study revealed only weak associations, and a sex effect. For primary-school girls, we report a negative association between several indicators of left-sidedness and teacher's ratings of school performance and leadership skills. For primary-school boys, we report a positive association between left-handedness for writing and teacher's ratings of school performance. The present study did not reveal any strong relation between laterality and school performance, but has shown that general school performance is not independent of laterality, and that the effect is opposite in males and females. The main difficulty is now to define clearly the different intellectual functions involved.

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Handedness is a polymorphic trait in humans. For a given task, some individuals preferentially use their right hand, and others their left hand. This polymorphism is found in all populations so far investigated, and no left-handedness frequency above 50% is reported for any unimanual task (Faurie, Schiefenhövel, Le Bomin, Billiard, & Raymond, 2005; Raymond & Pontier, 2004). The same situation is found for other lateral preferences, like eyedness and footedness (Porac & Coren, 1981). Cerebral lateralisation, which underlies handedness (Geschwind & Miller, 2001), is probably involved in the development of much human cognition and behaviour, including language. Broca's area, a critical region for speech production in humans, is larger in the left hemisphere than in the right in humans (Foundas, Eure, Luevano, & Weinberger, 1998). The homologous area in great apes is also asymmetrical, and may be associated with gestural communication (Cantalupo & Hopkins, 2001). Thus cerebral lateralisation may also have been involved in the evolution of language (Corballis, 2003). Hand-laterality polymorphism has long been maintained, at least from the upper Palaeolithic, and it seems that right-handedness was already more prevalent (Faurie & Raymond, 2004).

Handedness is probably a complex phenotype, and the relative contributions of genetic and environmental factors are still incompletely understood (McManus, 2002). For evolutionary hypotheses, however, the important point is that a trait be heritable, irrespective of whether that inheritance is cultural or genetic, and published heritability estimates range between 0.23 and 0.66 (Annett, 1973; Longstreth, 1980; McKeever, 2000; McManus, 1991; Risch & Pringle, 1985). Handedness polymorphism is often viewed as a mere consequence of indirect selection. For example, the ''right-shift theory'' states that handedness is a by-product of a factor that induces lateralised speech representation in the brain, and that there is over-dominance at this major genetic factor, RS+/– individuals having an overall cognitive advantage over either RS+/+ or RS–/–, due to interference of RS+ and RS– with distinct cognitive functions (Annett, 1985). However, this model has not received strong empirical support (Cerone & McKeever, 1999; McKeever, Cerone, & Chase-Carmichael, 2000). Actually, laterality is likely to have a more complex genetic determinism (Francks, Fisher, MacPhie, Richardson, Marlow, & Stein, 2002; Laval, Dann, Butler, Loftus, Rue, & Leask, 1998).

The existing publications clearly indicate that handedness is not neutral (Faurie & Raymond, 2003, 2005), and that some costs are probably associated with left-handedness, although these costs are not quantified. The most frequently cited costs are a reduced longevity, a smaller height and weight, late puberty, and a larger developmental instability (for a detailed and critical review of these costs, see e.g., Aggleton, Kentridge, & Neave, 1993; Coren & Halpern, 1991; Gangestad & Yeo, 1997). It is possible that the term ''left-hander'' includes several categories of individuals, with different laterality aetiologies, for example ''pathological left-handers'', whose left-handedness would be due to left-hemisphere damages during development (Bakan, Dibb, & Reed, 1973).

Another indication of the probable heterogeneity of left-handers is the lateralisation of language: although 97% of right-handers demonstrate predominant left-hemisphere language localisation, only 60% of left-handers demonstrate left-hemisphere language dominance, 30% show bi-hemispheric language, and about 10% show right-hemisphere language (Annett, 1985; Geschwind, 1970).

The fitness costs of left-handers do not necessarily concern all categories. This situation suggests caution in the interpretation of the results. However, it does not prevent the study of a ''left-hander'' category. The fitness costs associated with left-handedness could globally be responsible for the higher prevalence of right-handers. But, in this context, how could the persistence of left-handers be explained? Some sort of balancing selection must be acting, maintaining the polymorphism. Thus, some advantages of left-handers have to be found, and a mechanism for the (apparent) stable polymorphism of handedness has to be proposed.

Few studies on evolutionary phenomena in humans, especially on the evolution of handedness, have been concerned with social status effects. However, it is important to consider the possibility that cultural selection pressures act on the evolution of handedness frequencies. A social advantage can be associated with a particular trait, even when this trait is otherwise deleterious. For example, albinism is selected against (albinos are extremely sensitive to sunlight and prone to skin cancer), but in some societies, like Hopi Indians, this trait reaches relatively high frequencies. Woolf and Dukepoo (1969) explained the high incidence of albinism in this society by the fact that albino males are culturally given a sexual advantage.

For these reasons we decided to focus on status-related variables to compare right- and left-handers. Because of differences in brain organisation, laterality could indeed be associated with different personalities or cognitive skills. Before identifying the mechanisms underlying a putative social advantage, it is necessary to determine if there is distinct prevalence of left-handedness in individuals of different social status. The well-known link in traditional societies between reproductive success and social status (for a review see Buss, 1999; Hill, 1984) also exists in the Western world. For example, men who are high in status gain greater sexual access to a larger number of women (Pérusse, 1993). The same is true for sport competitors (Faurie, Pontier, & Raymond, 2004).

This study was conducted in primary schools. School class is one of the first social groups with which an individual is confronted. The variables chosen here to estimate the social status of children are leadership skills, which are an element of the present status of the child in the class, and school performance, which partly reflects the socio-economic status of parents and may be an indication of the potential future socio-economic status of the child. Studying primary schools (which are compulsory in France) has the advantage of sampling in a wide socio-economic range. However, it requires the assumption of some correlation between child and adult social status of an individual.

Data were collected with questionnaires addressed to teachers. This method allows information on a very large sample to be obtained. However, it introduces the risk of non-objective information. We reduced this risk by assessing the validity of teacher evaluations with peer evaluations.

Laterality was assessed using four distinct markers: two measures of hand preference, one measure of foot preference, and one of eye dominance. We have chosen not to compile these markers into a single index of laterality, because these different asymmetries might reflect different aspects of the organisation of the brain, and thus be related differently to school performance and leadership.

METHOD

Subjects

The subjects were first- to fifth-grade children (factor LEVEL, values 1 to 5) attending public primary schools of a French administrative district (Département de l'Hérault, southern France). The survey was addressed to the teachers of 339 schools in March 2001. Only one survey was sent to each school.

Measures

Teacher ratings on school performance and leadership. The teachers were asked to rate each child in the class on a 4-point scale of leadership (variable LEAD) and another of school performance (variable SCOL). School performance was estimated globally, i.e., on the basis of overall learning ability, on language, writing, and mathematics. Teachers are accustomed to this kind of overall evaluation, since they have to give one each trimester in the French school system. Leadership was defined in the survey instructions for the teachers as the ability to lead, to organise, to make decisions, or to take initiatives for the group.

Laterality measures. The teachers obtained laterality data on the basis of performance tests. Four measures of laterality were used: writing handedness, throwing handedness, eyedness, and footedness. With the questionnaire, teachers received instructions to test the laterality of children reliably: writing handedness was recorded during normal school activity, throwing handedness and footedness were evaluated by watching the children aiming at a target, and eyedness was evaluated by asking them to look through a keyhole. The variable LAT has two possible values: left (L) or right (R).

The handedness of the teacher was not recorded. However, the purpose of the study was not explained to the teachers, and several unrelated questions were added to the questionnaire.

Leadership evaluation by peers. As a validation of the leadership evaluation by the teachers, leadership was evaluated by the children themselves as was done by, e.g., Edwards (1994), French and Stright (1991) or Fukada, Fukada, and Hicks (1997): each child of the class was asked to nominate three children in the group that he/she liked best, three children in the group that he/she liked least, and three children who could best play the role of a leader, in an imaginary and extra-school context. A ''friendship'' score, a ''non-friendship'' score, and a ''leadership'' score were calculated for each child; these correspond to the number of nominations that he/she got.

Data analysis

Measures of laterality. The correlation between the four laterality measures was tested using non-parametric Kendall's correlation tests (Siegel & Castellan, 1988).

Comparison between male and female laterality. Independence of the two qualitative variables SEX (male vs female) and LAT was tested, for each laterality measures, with Fisher exact tests on 2 $\times$ 2 contingency tables.

Leadership evaluation validation. We tested the correlation between the factor LEAD (leadership evaluation by the teacher on a 4-point scale) and the leadership score (leadership evaluation by peers). A non-parametric Kendall's test was performed for each of the child groups concerned (one-tailed test, alternative hypothesis: existence of a positive correlation between the two leadership evaluations). A global test was performed by combining individual p values using Fisher's method (Manly, 1985). We also tested the correlation between the leadership score, the friendship score, and the non-friendship score globally (non-parametric Kendall correlation on all classes).

Tests of correlation between laterality, school performance, and leadership. The correlation between the classifying factors SCOL and LEAD was first tested, using the non-parametric Kendall's correlation test. The correlation between LEAD and LAT and the correlation between SCOL and LAT were then tested, using the non-parametric Kendall's correlation test as well. Finally, in order to test the correlation between LEAD and LAT, independently of SCOL, and the correlation between SCOL and LAT, independently of LEAD, the non-parametric Kendall's partial correlation test was used (Siegel & Castellan, 1988). These tests were performed for males and females, and for each of the four laterality measures, separately. All computations were performed using the S-PLUS 6.0 software (Insightful Corp. 1988–2001). All p values given for correlation tests are two-tailed.

RESULTS

Study population

A total of 89 schools responded to the survey: the response rate was thus more than 26%. Eight schools have been excluded because the teachers did not provide any information on laterality. Out of the 81 remaining schools (1703 children), 32 children were excluded, either because sex was missing, or because all the laterality items were missing. Consequently, the sample analysed consisted of 1671 children (881 boys and 790 girls) attending 81 classes in 81 different schools (37 urban, 16 suburban, and 28 rural schools), representing 98.1% of the children in the participating classes. The children were aged between 5 and 13. The mean age of girls was 9.15 years $\pm$ 1.6, and the mean age of boys was 9.05 years $\pm$ 1.6 (standard deviations). This difference is not significant (Mann-Whitney U test, $p = .18$). The sample size differs slightly for the four laterality measures because of missing information on some incomplete questionnaires (1669 for writing handedness, 1626 for throwing handedness, 1601 for eyedness, and 1624 for footedness).

Laterality

Left-handedness was more frequent among males than among females in this sample (Fisher exact tests, two-tailed, writing handedness, ♂: 15.5%, ♀: 11.5%, $p = .04$; throwing handedness, ♂: 13.6%, ♀: 8.5%, $p = .004$); the same situation is found for footedness (♂: 20.0%, ♀: 10.2%, $p = .0004$), but not for eyedness (♂: 36.8%, ♀: 38.0%, $p = .77$). The laterality was measured by one of the authors (CF) in 12 of the schools, and no significant difference was found for the frequency of left-handedness with the whole sample (e.g., writing handedness, all sample 13.56% of left-handers, controlled sample 13.06% of left-handers, Mann-Whitney U test, $p = .83$). Correlation coefficients between the four measures are indicated Table 1.

TABLE 1
Correlation coefficients (Kendall's τ) between the four laterality measures (LAT)

	Writing	*Throwing*	*Eyedness*	*Footedness*
Writing	1	0.67	0.27	0.44
Throwing		1	0.22	0.53
Eyedness			1	0.18
Footedness				1

Tests are two-tailed. All correlation tests give significant results ($p < .00001$).

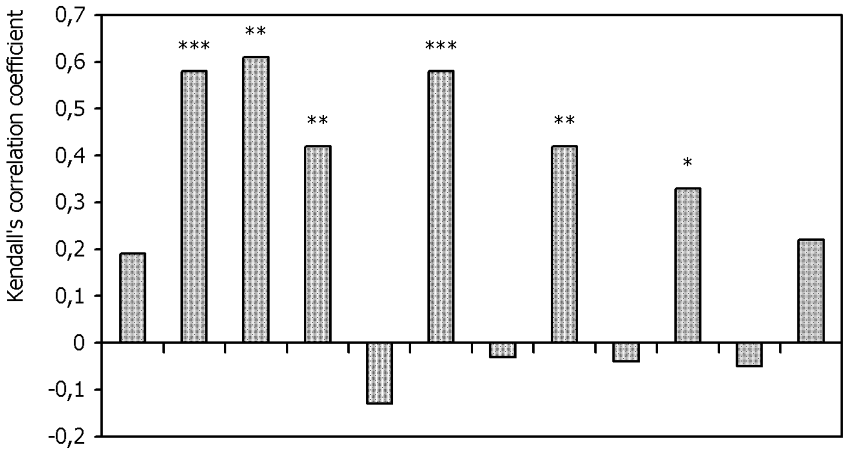


Figure 1. Kendall's coefficient of correlation (τ) between leadership evaluation by teachers and by peers in 12 child groups. Stars indicate significance of a one-tailed Kendall's non-parametric correlation test (alternative hypothesis: positive correlation). *: $p < .05$, **: $p < .01$, ***: $p < .001$. A global test shows a highly significant positive correlation ($p < .00005$). See text for explanations.

Validity of leadership evaluation by the teachers

This validation was performed in 12 of the 81 child groups of the survey. The factor LEAD (leadership evaluation by the teacher) and the leadership score (leadership evaluation by peers) were positively correlated in 8 of the 12 classes studied (Figure 1). A global test shows a highly significant positive correlation ($p < .00005$). The leadership score was positively correlated with the ''friendship'' score (Kendall's $\tau = +0.55$, $p < .00005$), and negatively correlated with the ''non-friendship'' score (Kendall's $\tau = -0.23$, $p < .0001$). These results indicate the validity of using the factor LEAD as a measure of the children leadership.

Tests of correlation between laterality, school performance and leadership

The factors SCOL (school performance) and LEAD (leadership) were positively and significantly correlated (Kendall's $\tau = 0.23$; $p < .0005$). The factor LEVEL is not correlated with neither SCOL nor LEAD (Kendall's $\tau = -0.03$; $p = .14$ and $\tau = 0.04$; $p = .08$, respectively). Moreover, it had no effect on the variables SCOL or LEAD, in a multinomial logit model including the variables SEX and LAT and all possible second order interactions ($p > .05$; details not presented).

The correlation of SCOL and LEAD with each laterality measure was first computed using Kendall's correlation tests (Table 2, left side). The correlation of SCOL and LEAD with each laterality measure was then computed using

TABLE 2
Kendall's correlation tests (τ and *p*-value) between each laterality measure (LAT) and each social status marker (SCOL and LEAD), and Kendall's partial correlation test between each laterality measure and each social status marker controlling the other one

	SCOL and LAT		*LEAD and LAT*		*SCOL and LAT (LEAD controlled for)*		*LEAD and LAT (SCOL controlled for)*	
	τ	*p*	τ	*p*	*Partial* τ	*p*	*Partial* τ	*p*
Writing								
Girls	*−.11*	.00001	−.03	.22	*−.10*	.00002	−.01	.82
Boys	*+.06*	.004	+.01	.64	*+.06*	.005	−.003	.88
Throwing								
Girls	*−.07*	.004	*−.09*	.0002	*−.05*	.04	*−.08*	.002
Boys	+.003	.89	−.02	.38	+.008	.74	−.02	.35
Eye								
Girls	*−.05*	.03	+.03	.18	*−.06*	.01	+.05	.06
Boys	+.03	.26	−.02	.49	+.03	.19	−.02	.34
Foot								
Girls	*−.07*	.007	*−.06*	.01	*−.05*	.03	*−.05*	.04
Boys	−.01	.59	+.02	.30	−.02	.44	+.03	.24

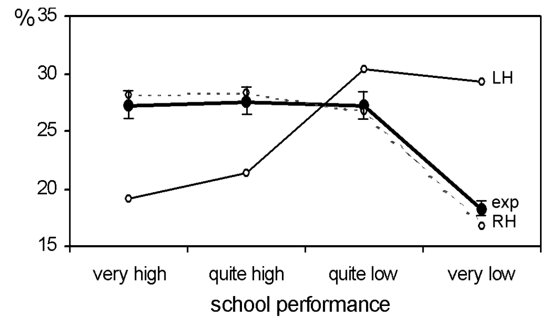
Notes: Positive coefficients indicate a higher status for individuals with left-side preference. Significant correlation coefficients ($p < .05$) are in italic. Tests are two-tailed.

partial correlation tests (Table 2, right side). The correlation between SCOL and writing handedness is significant for both sexes: among boys, left-handed writers display a better school performance; among girls, the inverse phenomenon is observed ($p = .004$ for males and $p = .00001$ for females). The observed frequencies are compared with the frequencies expected under the hypothesis of independence on Figure 2 (a–b). When controlling for LEAD, the correlation remains significant for both sexes, and in the same direction ($p = .005$ for males and $p = .00002$ for females).

The correlation between SCOL and throwing handedness, eyedness, or footedness, is significant for girls only; left-side dominance is again associated with a lower school performance in girls ($p = .004$, $p = .03$ and $p = .007$, respectively). The results are the unchanged when controlling for LEAD ($p = .04$, $p = .01$, and $p = .03$, respectively).

The correlation between LEAD and throwing handedness or footedness is significant for girls, left-sidedness being associated with a lower leadership ($p = .0002$ and $p = .01$, respectively). Among girls, left-handed throwers have lower leadership (Figure 2, c). The same results are obtained when controlling for SCOL ($p = .002$ and $p = .04$, respectively).

a.



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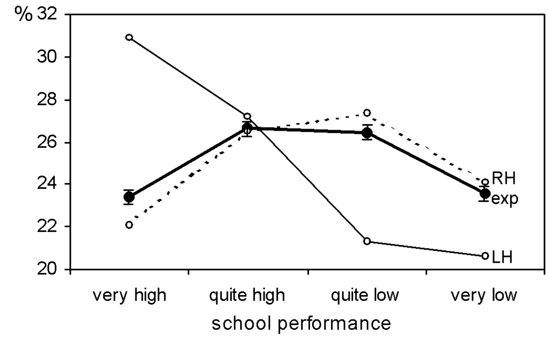

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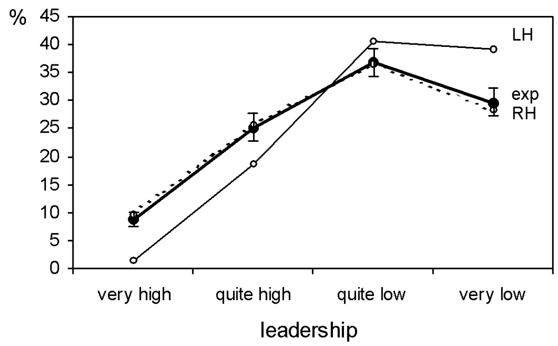

Figure 2. Frequencies of children belonging to each category of school performance (or leadership) among right-handers, among left-handers, and expected under the hypothesis of independence between laterality and school performance (or leadership). (a) Relation between writing handedness and school performance for females (*N* = 788, including 90 left-handed and 698 right-handed). (b) Relation between writing handedness and school performance for males (*N* = 876, including 135 left-handed and 741 right-handed. (c) Relation between throwing handedness and leadership for females (*N* = 766, including 65 left-handed and 701 right-handed). For all cases, the bold line represents the expected frequencies under the independence hypothesis (exp), the plain line the observed frequencies among left-handers (LH), and the dotted line the observed frequency among right-handers (RH). Only cases from Table 2 (left side) displaying a significant correlation ($p < .05$) are depicted.

DISCUSSION

Few studies have looked at a possible role of social status in the evolution of laterality. The present study has investigated the link between laterality, school performance, and leadership skills in primary schools.

In previous studies, school performance was not directly measured, rather several intellectual tasks were used, such as verbal, vocabulary, and symbolic, non-verbal reasoning tests, IQ and memory tests, visual manipulation exercises, reading, drawing or arithmetic abilities, and foreign language learning. Some studies found that left-handers have a lower intellectual performance (Crow, Crow, Done, & Leask, 1998; Hicks & Beveridge, 1978; Lamm & Epstein, 1999; McManus & Mascie-Taylor, 1983; Miller, 1971; Olivier, 1978). However, some studies found no differences between right- and left-handers (Cerone & McKeever, 1999; Gignac & Vernon, 2004; Hardyck, Petrinovich, & Goldmann, 1976; Hicks, 1976; Nettle, 2003; Newcombe & Ratcliff, 1973; Wittenborn, 1946). Finally, some studies found an advantage for left-handers (Annett, 1970; Deutch, 1978; Ehrman & Perelle, 1983; Hicks & Dusek, 1980).

It is difficult to see a clear trend in this published literature, because the various intellectual tests performed do not measure the same intellectual skills. Left- and right-handers may well have performances varying with intellectual tasks. More importantly, there are a large variety of handedness measures in all these studies. Thus, the results are not directly comparable, and no clear relationship emerges between intellectual ability and laterality. One interesting point is the observation that the variance of left-handers on most tasks is considerably greater than that of right-handers (Perelle & Ehrman, 1982). This fact is possibly explained by the existence of distinct categories of left-handers. Consistent with this idea is the work of Annett and Turner (1974): they compared the abilities of laterality groups over a sample constituted of an equal number of left- and right-handed children, and found no significant differences on average vocabulary, reading, drawing, and logical aptitudes. However, when they assessed the laterality of children at the lower extreme of the ability distribution, a slight excess of left-handers was found.

The present work found the presence of a sex effect for the relation between laterality and school performance. Left-side dominance was found to be associated with a lower school performance in girls and a higher school performance in boys. Although the correlation coefficients are rather low (about 0.1), these trends are significant for all measures among girls, and only for writing handedness among boys. The same relation is still observed when controlling for leadership skills.

There is a fairly extensive and complicated literature on sex × handedness interaction effects on cognitive abilities. Gottfried and Bathurst (1983) found that females with consistency of handedness were intellectually precocious compared to females without such consistency, but did not find this relationship for males. However, Inglis and Lawson (1984), using several IQ tests, concluded that there is no significant effect of handedness, nor any reliable interaction between sex and handedness. Annett and Kilshaw (1983) did find a higher prevalence of left-handedness (significant only for males) in classes of higher educational status. Perelle and Ehrman (1994) did not find any handedness frequency difference across educational levels, using their data on writing handedness only. However, further analyses of their data (provided upon request by I. B. Perelle) suggest a significant effect of throwing handedness across educational levels, especially for females (Fisher exact test on 7×2 contingency table, $p = .05$ for both sexes, $p = .008$ for females). As shown in Figure 3, their data reveal a U-shaped curve, consistent with the hypothesis of at least two categories of left-handers.

In conclusion, the relationship between school performance and laterality still needs to be investigated. The present study did not reveal any strong relation between laterality and school performance, but has shown that general school performance is not independent of laterality, and that the effect is opposite in males and females. The main difficulty is now to define clearly the different intellectual functions involved. Their precise identification is required to further understand the selective forces acting on the polymorphism of handedness in Western societies.

As far as we know, the relationship between laterality and leadership or behavioural dominance has never been explored. Our study found a disadvantage for left-handed girls, even when the effect of school performance was controlled for. For boys, no clear effect of laterality on leadership was found.

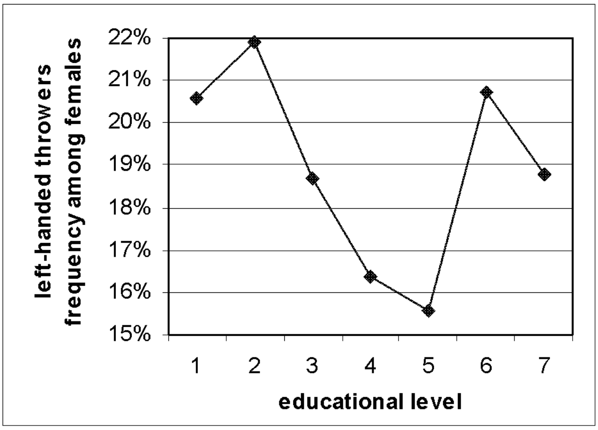

Figure 3. Left-handed throwers frequency across educational levels for females (data provided upon request by I. B. Perelle). 1: pre high school, 2: some high school, 3. completed high school, 4: some college, 5: completed college, 6: some graduate school, 7: completed graduate school.

More generally, no strong relation is expressed between laterality and leadership, as measured here, in the classroom.

Several criticisms could be addressed to this study. First, it is not excluded that information bias could explain some of the findings, given that the response rate at the school level was rather low. However, when teachers were willing to participate, almost all (98%) the children of the classes were considered. Second, school performance and leadership skills in the classroom may be different from the social status of the child at school, and from his/her general social status. It would be interesting to complete these results with a study of status at school but out of the classroom. Third, and more importantly, there is a possibility that childhood social status is not strongly correlated with adulthood social status. Unfortunately, studies on a possible relationship between social class and hand preference in adults are scarce. In a large dataset, McManus (1981) did not find any association between handedness and social class. Similarly, Brito, Brito, Paumgartten, and Lins (1989) failed to find any relationship (using an index of handedness).

At the moment, the persistence of left-handedness in Western human populations remains unexplained. The possibility of a link between laterality and social status still cannot be excluded. It now remains to look at other sources of evidence, especially in adult populations, to test the notion that left- and right-handers differ in socio-economic status.

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