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In praise of ambidexterity: how a continuum of handedness predicts social adjustment [*]

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Abstract

This paper estimates the relationship between handedness and social adjustment. In addition to binary measures of hand preference, we also use a continuous measure of hand skill. Outcomes at ages 7, 11 and 16 are studied. Using a semi-parametric estimator it is shown that non-right-handedness (as hand-preference) is associated with poorer social adjustment but this effect disappears as the individuals age. The continuous measure of hand skill has a non-monotonic effect on social adjustment with poorer social adjustment at the extreme values of the continuum. Poorer social adjustment in childhood has been shown to predict poorer socio-economic outcomes later in life.

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1 Introduction

Handedness is a trait observed in all human populations. While in many species one observes individual "handedness" where an animal preferentially uses one hand/paw or their behaviour (such as turning) is lateralized in some way, humans are unusual in the extent of *population* handedness i.e. in all populations there is a strong dextral bias: most people are right handed[1]. The evidence is that this dextral bias has existed since pre-history and is at least partially under genetic control. In short, a predominance of right-handedness is here to stay.

Arising from this, there is now an extensive literature documenting the cognitive correlates of handedness. Harris (1992) concluded "By now, left- and right-handers have been compared perhaps hundreds of times on dozens of different cognitive tasks, with results going in all directions." Although there have been many subsequent studies, an updated review of the literature would probably lead to much the same conclusion.

By contrast, there is comparatively little research on social and behavioural aspects of handedness. This is unsurprising for two reasons: firstly it is not obvious how handedness might influence socio-economic outcomes; secondly much of the data on handedness relies on small datasets collected by psychologists that are not drawn from the general population and would not permit the type of observational studies used in social sciences. However a number of studies have found handedness predicts delinquency, for example Grace (1987) and Bogaert (2001). In recent years, several papers by economists have appeared considering the consequences of handedness: Denny & O'Sullivan (2007) and Ruebeck *et al* (2006) considered the effects of handedness on earnings, Frijters *et al* (2009) used handedness as an instrumental variable in explaining the dependence of maternal labour supply on child development, while Johnston *et al* (2009) modelled the relationship between handedness, health and cognitive development.

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[1] The proportion of people who are right handed depends on how it is measured amongst other things but typically around 90% are found to be right handed. There is evidence that chimpanzees, and possibly other primates, also have a dextral bias though less than that of humans, see Annett (2006) for example.

This paper contributes to that literature by considering whether handedness predicts social adjustment but it differs from most research by using a continuous measure of handedness in addition to the conventional discrete measures. The idea of handedness as a continuum although relatively uncommon in the literature is not new (for example Hardyck & Petrinovich (1977)). Crow et al. (1998) argued that ambidexterity, in the sense of being equally good at a particular task with both hands, is associated with cognitive deficits. They hypothesized that this equal skill is a marker for failure to develop cerebral dominance of either hemisphere – hence the term "hemispheric indecision"- and that is the cause of the cognitive deficit. The idea that there is a cognitive deficit associated with ambidexterity is not new, going back at least to Binet and Vaschide (1897) who found that the ambidextrous were more "dull"[2]. A re-examination of the Crow et al. data by Denny (2008) showed that this theory was not supported in general however. Kopiez et al. (2006) analysed the relationship between one form of musical ability (sight reading) and a continuous measure of laterality with a sample of 52 pianists. They also found an inverted "U" shaped relationship between the outcome of interest and a measure of laterality: the ambidextrous do best.

It is worth noting that there are other theoretical perspectives which generate very different predictions from the "hemispheric indecision" model. In the Right-shift theory of Annett (2002), the notion of a continuum of handedness is central. Her theory that handedness represents a genetically balanced polymorphism suggests that there are some heterozygote advantages (+/-) relative to homozygotes (both -/- and +/+). Evidence is presented that those close to the centre of a handedness continuum do better on certain cognitive tasks (see her Figures 11.2 and 11.6 for example). Christman (2005), whose work we have drawn on here, develops other ideas of why there may be advantages associated with not being strongly handed one way or the other in particular where particular tasks require the co-ordination of both cerebral hemispheres. A possible morphological basis for this is discussed at the end of the paper.

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[2] See Harriman (1933) for a discussion of other early findings on the subject.

This paper uses both conventional discrete measures of handedness (i.e. hand preference) as well as continuous measures (i.e. hand skill) and investigates whether they predict social behaviour of young people at three points in the life-cycle. These outcomes have been shown, in other work with the same data used here (& cited below), to have socio-economic implications for individuals later in life.

2 Data & methods

2.1 National Child Development Survey

The data for the analysis is based on the 1958 National Child Development Study (NCDS). This is a longitudinal study of all persons living in Great Britain who were born between 3rd and 9th of March 1958. The 1958 perinatal mortality survey has been followed by 6 subsequent waves (NCDS 1-6) at ages 7, 11, 16, 23, 33 and the most recent, at ages 41-42. NCDS 1-3 comprised of interviews with the child, his parent's, his school and the report of a medical examiner. The NCDS is a rich source of information on many domains of an individual's life and includes a number of variables related to handedness and laterality generally. For this reason many contributions to the research literature on laterality have drawn on this data. The data has generated a large volume of research in diverse fields: labour economists have also heavily mined this data in recent years in work on, inter alia, earnings, health and education.

2.2 Measuring social adjustment and laterality

One of the most common measures used to detect child behavioural problem is the Bristol Social Adjustment Guide (BSAG). According to Stott, the originator, (1969, pg. 7) it is used for *"detecting and diagnosing maladjustment, unsettledness or other emotional handicap in children of school age".* The BSAG consists of 146 items of behaviour, each of which represents one of twelve distinct syndromes. From these 146 items the cohort teachers underline whether a particular child exhibits each item. Then for each of the twelve syndromes a score is recorded based on the number of items underlined by the teacher (Ghodsian, 1977). Hence a child could have up to 12 scores of the following syndromes:

Unforthcomingness, Withdrawal, Depression, Anxiety, Hostility towards adults, Writing off adults & standards, Anxiety for acceptance by kids, Hostility towards children, Restlessness, Inconsequential behavior, Miscellaneous symptoms, Miscellaneous nervous symptoms. The sum of each of the scores gives the total BSAG score, which ranges from 0-64, whereby higher values indicate greater levels of social maladjustment. As the BSAG scores are derived from the teacher's impressions of the students, it is possible that the scores may be biased (see Ghodsian for a discussion on this matter). Therefore when interpreting the BSAG scores Ghodsian noted that *"We are looking at the child's behaviour through the eyes of the teacher"* (1977, pg. 27). The NCDS administered the BSAG study at ages 7 and 11. As a third outcome we use a binary variable indicating whether they child had been in trouble with the police. No information on how serious this was (e.g. whether it led to prosecution or conviction) is available. Jackson (2006) showed how the BSAG measures were predictive of an individual's occupational attainment later in life while Silles (2005/06) measured their effects on earnings.

The continuous measure of right-handedness is based on two tasks the cohort members were given at age 11. These were tasks of motor coordination and were administered by a doctor in the course of a medical examination. In one task the child had to mark (with each hand) as many squares as possible in 1 minute. We calculate the laterality quotient for this task as 100*(R-L)/(R+L). The second task measures the time taken to pick up 20 matches. For this task the laterality quotient is 100*(L-R)/(R+L) since a *longer* time reflects poorer performance. In a third task the cohort member was required to catch and bounce a tennis ball with each hand. There were ten attempts with each hand. This variable was not used as virtually everyone had perfect scores. As an aggregate measure of handedness we take the first principal component of the two laterality quotients, labelled "right". This is clearly a measure of hand-skill rather than hand preference. Since this variable has no natural units it is normalized have zero mean and unit variance[3].

At age 7, the cohort member's mother was asked whether her child was right, left or mixed handed: the proportions in these categories are 82.8%, 10.3% and 6.9% respectively.

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[3] The factor loadings are both 0.707. Hence those who are equally good with both hands will still have a score of 0 after this normalization.

This factor was used in the form of two binary variables, right-handed being the omitted category. Figure A1 in the Appendix graphs the distribution of the continuous measure for these three categories. The distributions are located much as one would expect although it is notable that mixed-handers are much closer to right-handers. One can reject the hypotheses that the means and the variances, respectively, are the same across all three categories ($p<0.001$ in both cases).

2.3 Estimation

We estimate the relationship between social adjustment and handedness using semi-parametric regression. This amounts to estimating a model of the form:

$$y = f(z) + \beta x + \varepsilon \qquad (1)$$

x is a set of variables with associated parameter vector β . z is a small number of variables and f(z) is an arbitrary function to be estimated. Typically there are fewer variables in z (often just one) than in x. No assumption about the distribution of the disturbance term ε is required. The advantage of this approach over a fully parametric method like ordinary least squares is that it imposes no assumption about the relationship between y and z so it is ideal where one has little *a priori* knowledge of the particular relationship. Fully non-parametric models are subject to the "curse of dimensionality" and require very large datasets: convergence in distribution to the asymptotic properties of the model is slower than the usual $\sqrt{n}$ speed of parametric estimators. A common parametric way of gaining flexibility is to allow a polynomial in z. However this imposes smoothness and it also means that local features would dominate the global characteristics of the estimated function. This may be undesirable if the underlying function is robust and not, in fact, close to a quadratic, cubic etc. Hence semi-parametric models provide a very useful compromise between fully parametric and fully non-parametric models[4].

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[4] See Carroll , Ruppert & Wand (2003) or Yatchew (2003) for introductions to these methods and Denny & Doyle (2010) for a recent application.

What is new here is a set of B-splines (a combination of basis functions) are used to approximate the nonparametric part and the function f(z) is estimated by using the penalized least squares which optimize the Mean Squared Error (MSE). The roughness of nonparametric function was controlled by a smoothing parameter which was selected by Generalised Cross-Validation (GCV). This method leads to an optimal estimation which allows a balance between the goodness-of-fit and the smoothness of the estimated curve. The use of B-splines also reduces the high computational cost entailed by the multi-dimensional integration of conventional optimization methods.

The model in (1) is one form of semi-parametric model, known as the partially linear model. In the present application, z consists of one variable, the continuum of handedness and x is a set of three dummy variables for left & mixed handedness and for the sex of the individual. In the final model estimated here, a binary outcome is considered so a semi-parametric probit is used instead.

It might be asked why we have used such a simple model explaining social adjustment since clearly other factors, such as socio-economic status or other family characteristics, might affect the outcome. The reason for this is that, almost invariably, such variables are orthogonal to handedness so one would expect their exclusion to generate significant omitted variable bias. We control for sex as right-handedness is generally found to be significantly more common amongst males than females.

3 Analysis

The first outcome to be considered is the measure of social adjustment at age 7 the (BSAG described above). The results of the model are shown in Table 1 and the accompanying Figure 1. One can see that males have a well determined higher score on the BSAG: that is their social adjustment is *worse*. Both left- and mixed-handers also fare worse on this score although the effect is quantitatively smaller (less than half) than that of sex. Nonetheless the results are consistent with the folklore: left-handers at age 7 really are “gauche” it seems. The finding that mixed-handers do worse also is somewhat harder to interpret.

However a different picture emerges when we consider the non-parametric part of the model, this is the f(z) function in equation (1). There is a pronounced “U shaped” curve centered close to the middle of the continuum. That is, people at either extreme of the handedness continuum are likely to behave worse than those close to the center. The confidence intervals are wider at the extremes, as one would expect, as there are fewer observations in the tails.

The same model was then repeated for the BSAG score measured with the children were 11 years of age. The effect of being male is unchanged. However the disadvantage associated with being left-handed is now much smaller than at age 11 and is not statistically significant (p=0.615). Being mixed-handed remains a disadvantage although the effect is approximately one half of what it was at age 7. The non-parametric component of the model is shown in figure 2 below the table. There is a similarity with those for age 7 in the sense that those at the two extremes of the continuum do worse but the relationship is much less symmetric with a lower penalty (in the sense of a higher BSAG score) for the right-most values of the continuum.

Finally we considered delinquency at age 16 in Model 3. In this case hand preference has no statistically significant effect on the probability of an individual getting into trouble with the police (denoted as “cops”). However, with regard to the continuous laterality measure, the U-shaped relationship still exists also although it is shifted to the right relative to those found in models 1 and 2. The curve is clearly asymmetric with the right tail associated with a higher probability of delinquency than the left tail.

The results can therefore be summarized as follows: using conventional discrete measures of handedness, those who are preferentially non-right handed have poorer social adjustment but this effect is absent by age 16. However using a continuous measure and allowing for an arbitrary relationship with social adjustment there is clear evidence that those at or close to the center of the continuum have more desirable outcomes.

4 Conclusions

One of the most interesting recent developments in interdisciplinary social science is the interaction of neuroscience and economics known as neuroeconomics. However this work is concerned only with the interface between two particular modes of research in their respective fields, functional brain imaging and experimental decision theory. There is a lot more to neuroscience and economics than these. Many economists, one suspects, think that neuroscience *is* largely functional brain imaging and are perhaps insufficiently aware of the use of animal models or lesion studies for example. Likewise, while laboratory experiments have provide useful insights into behaviour under uncertainty, discounting and some other topics there are legitimate concerns about their ecological validity.

There are good practical reasons for this concentration of course, nevertheless it is to be hoped that neuroeconomics can break out of this particular niche, if it is to fulfil its potential of providing a neuro-scientific basis for economic behaviour in general. This paper aims to contribute to this process in drawing on ideas and evidence on laterality, a widely studied neuropsychological trait, in modelling the social behaviour of young people. This builds on recent work by labour economists studying the interaction of handedness and the labour market.

It is shown that continuous measures of handedness have a U shaped relationship with several behavioural measures such that those at or around the center, the more ambidextrous, can be considered to have more desirable behaviour. These behavioural variables have been found by others to be predictive of socio-economic outcomes later in life. The results are consistent with a number of studies in behavioural neuroscience discussed in the introduction in that higher cognitive abilities appear to be associated with ambidexterity. Why this association exists is unknown but one possible explanation lies in brain morphology.

There is a body of evidence on handedness and the size of the corpus callosum, the main structure in the brain responsible for inter-hemispheric cortical communication in mammals. The corpus callosum is about 7cm long in an adult human and contains around 200-250 million axons. There have been many studies since Witelson (1985) first reported a larger corpus callosum in left-handers though it is not clear that this bias holds generally. However it has been argued, for example by Beaton (1997) that “any effect of handedness... is as likely to relate to *degree* (my emphasis) as to direction of handedness” i.e. the corpus callosum is larger in mixed-handers. Studies that find this include Witelson and Goldsmith (1991) and Denenberg, Kertesz and Cowell (1991). Extrapolating from brain morphology to actual behaviour, that in the case “bigger” means “better”, is necessarily tentative. For example, the axons are surrounded by a fatty sheath called myelin which provides electrical insulation: a larger corpus callosum may simply be due to greater myelination. Nevertheless one can, at least, speculate that the evidence on callosal size may be a basis for the behavioural surpluses observed here.

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Model 1: Social adjustment at age 7

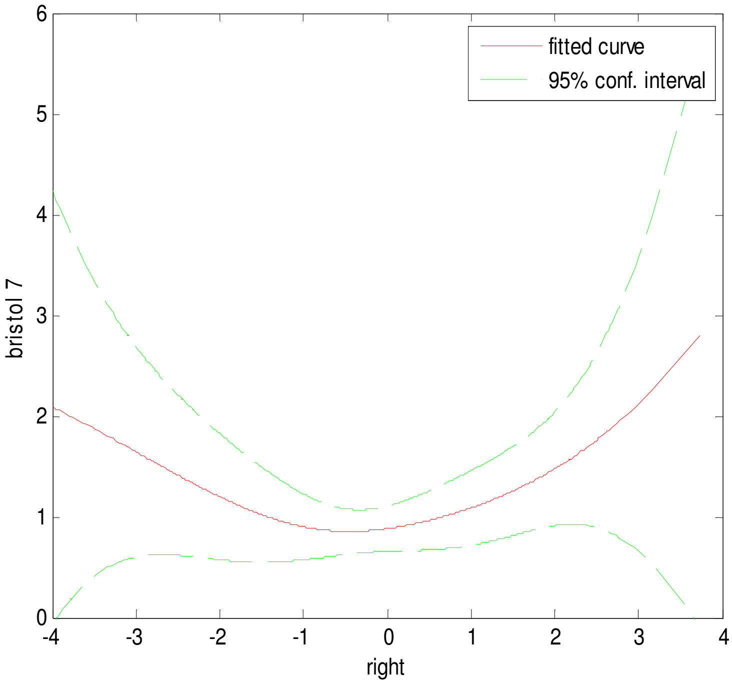
Table 1 shows the parametric component of the model
Figure 1 shows the non-parametric component

Table 1

Parameter	Estimate	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	6.9148731	.1246038	55.495	.000	6.6706253	7.1591209
male	2.6026175	.1687619	15.422	.000	2.2718113	2.9334237
left	.8717005	.2784745	3.130	.002	.3258360	1.4175649
mixed	1.1714274	.3351978	3.495	.000	.5143744	1.8284804

a Dependent Variable: bristol7.

Figure 1 Effect of right-handedness on social adjustment



Note: higher values of the Bristol score reflect *poorer* social adjustment

Model 2: Social adjustment at age 11

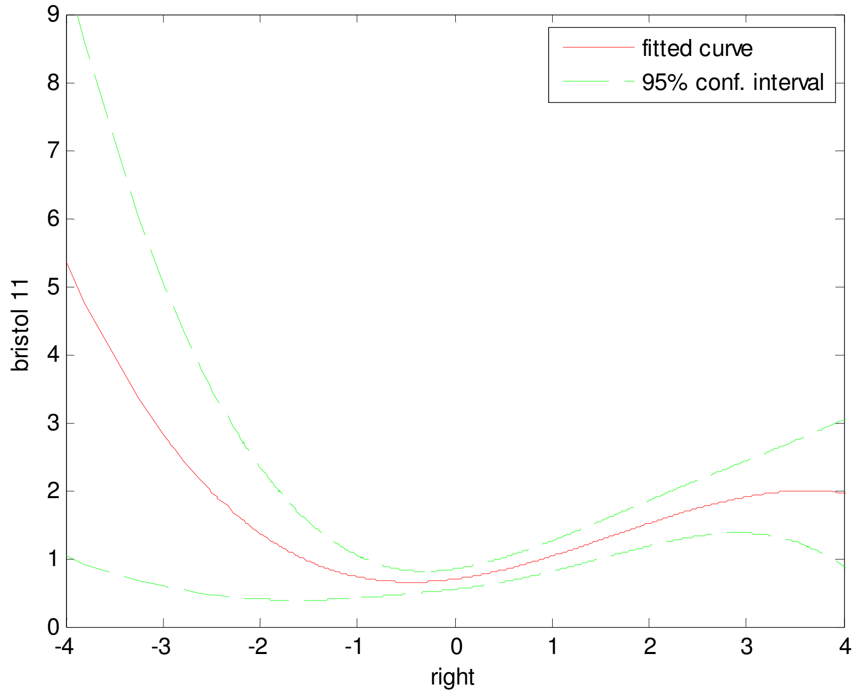
Table 2 shows the parametric component of the model
Figure 2 shows the non-parametric component

Table 2

Parameter	Estimate	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	6.6300910	.1257939	52.706	.000	6.3835105	6.8766715
male	2.6803335	.1703737	15.732	.000	2.3463679	3.0142991
left	.1414610	.2811342	.503	.615	-.4096168	.6925388
mixed	.6858349	.3383991	2.027	.043	.0225066	1.3491632

a Dependent Variable: bristol11.

Figure 2 Effect of right-handedness on social adjustment



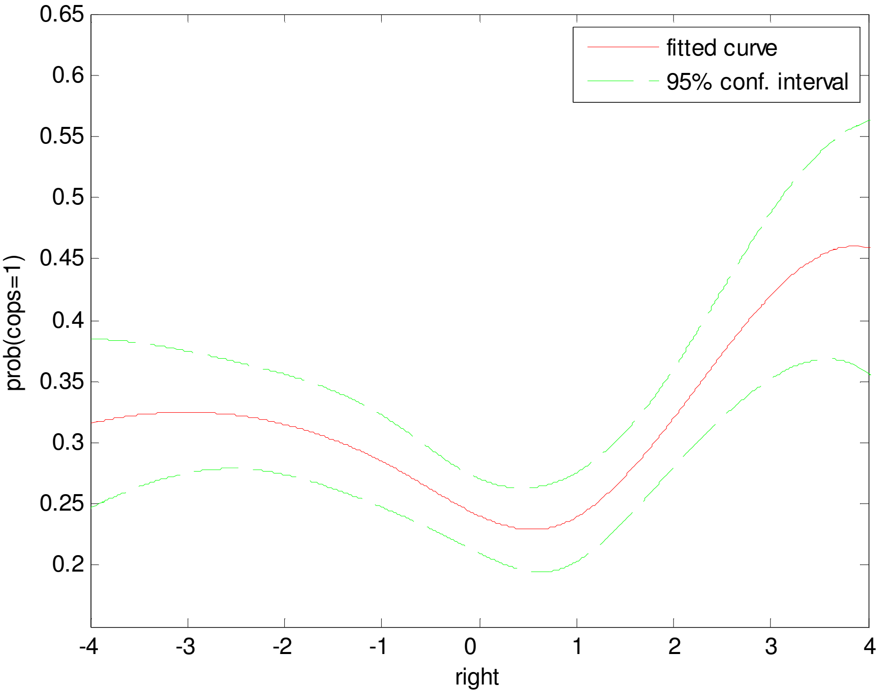
Model 3: Probability of trouble with police ages 16

Results for the semi-parametric model for effect of rhand on Prob (cops=1)

Parameter	Estimate	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	-.0376104	.0137078	-2.744	.006	-.0644818	-.0107391
male	.0624049	.0038071	16.392	.000	.0549420	.0698679
mixed	-.0012627	.0076216	-.166	.868	-.0162032	.0136779
left	.0092894	.0062568	1.485	.138	-.0029757	.0215545

a Dependent Variable: prob (cops=1), age 16 .

Figure 3 Effect of right-handedness on delinquency



Appendix

Figure A1: Empirical distribution of right-handedness by hand preference