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**Cognitive ability and continuous
measures of relative hand-skill: a
note**

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Abstract:

This note re-examines a finding by Crow et al. (1998) that equal skill of right and left hands is associated with deficits in cognitive ability. This is consistent with the idea that failure to develop dominance of one hemisphere is associated with various pathologies such as learning difficulties. Using the same data source but utilising additional data, evidence is found of a more complex relationship between cognitive ability and relative hand skill.

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1 Introduction

The majority of the numerous papers on the cognitive correlates of handedness are concerned with the question of whether left or right-handers have higher cognitive ability. Few papers are concerned with the strength, as opposed to the direction, of handedness. However Crow et al.(1998) examined the question of whether individuals who are equally good with both hands have an associated deficit in cognitive ability. Using data from the British National Child Development Survey (NCDS), they found a negative association between equal hand skill and scores on four tests of ability: mathematics, verbal and non-verbal reasoning and reading comprehension. It was hypothesized that this equal skill is a marker for failure to develop cerebral dominance of either hemisphere – hence the term “hemispheric indecision”- which is the cause of the cognitive deficit. Mayringer and Wimmer (2002) have re-examined the Crow et al.(1998) hypothesis and found no evidence of cognitive deficits associated with ambidexterity. Kopiez et al. (2006) analysed the relationship between one form of musical ability (sight reading) and a continuous measure of laterality. They found that it is the ambidextrous that did best: there is a cognitive surplus at the point of “hemispheric indecision”. This note re-examines the hypothesis of Crow et al.(1998) using the same data source but using an additional measure of relative hand skill not utilized in the original study. For the theory to be robust one would expect it hold for any reasonable measure of laterality.

It is also worth noting that there are other theoretical perspectives which generate very different predictions. 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. While the Right-shift theory is not without critics (e.g. McManus (1985)) it is a coherent alternative to the hemispheric indecision model. There is also a sizeable literature that looks at associations between behaviour and a trichotomy of strong right-, mixed- and strong left-handers and there seems to be a clear pattern of advantages and disadvantages of being mixed handed¹.

2 Data and methods

Three of the four outcomes of interest used in Crow et al.(1998) are used: measures of verbal ability, reading comprehension and mathematics. The results for verbal and non-verbal ability are virtually identical. Two measures of relative hand skill are used, that of Crow et al. (1998) and one other. When the cohort members were aged 11, a doctor administered a series of tests of motor co-ordination. In one, children were required to tick as many squares as possible from a printed sheet within one minute. This was done separately with each hand. From these scores, a measure of relative hand skill $(R-L)/(R+L)$ is defined which is essentially that used by Crow et al.(1998). In a second task, the children were timed picking up 20 matches. In this case I define the variable $(L-R)/(R+L)$ as a measure of relative hand skill since a longer time with any hand is associated with lower skill. These variables are referred to as “Square” and “Match” respectively².

For both measures the means are greater than zero and are lower for left-handers as expected. McManus (1985) pointed out the possibility of recording biases for the Match task. There is evidence of “digital preference” with a larger number of scores ending in 0 or 5 than would be expected by chance but this is unlikely to skew the estimated distribution of

¹ See Christman (2006) for numerous examples

² A third task involves bouncing and catching a ball but since most individuals had a perfect or near perfect score with both hands it is not used. Further details of the data are in an earlier version of the paper , Denny (2006)

handedness either way. The Square task is not without its own problems, as pointed out by Crow et al. (1998): children who have more experience of writing (for example because of higher cognitive ability or better school attendance) may display a greater difference in hand skill. An important question is whether one should use both measures. There is no *a priori* reason for preferring one measure over the other and it is possible that they have independent effects so I suggest that fundamentally this is an empirical question. Since they are correlated with each other (albeit weakly, $\rho = 0.156$) and with the other covariates (hand preference and sex), it is necessary to allow them to have simultaneous effects to avoid omitted variable bias. Neither of the tasks was open-ended in that in all cases there was a maximum score one could achieve: squares marked (200 in one minute) and obviously 0 seconds is the highest score one could achieve for the “Match” task (those taking more than 100 seconds were coded as 99). Hence Square and Match provide metrically sound measures of relative hand-skill. Peters (1998) argues that in constructing handedness questionnaires one should include items that cover skilled and unskilled activities. One can argue on the same basis, that it makes sense in the present context to use a number of indices of relative hand skill and certainly not rely exclusively on one that could be influenced by practice at writing (and hence by education, socio-economic background etc).

The means and standard deviations for all variables by hand preference (right, left & mixed) are given in Table 1. One can see that, as expected, the Square and Match variables are positive for right-handers, negative for left-handers with values in between for mixed-handers. It is also noticeable that there is more variation in the Square variable than the Match variable across hand preference types.

An alternative approach to measuring lateralization would be based on hand preference as reflected by the various handedness inventories. However aside from writing, the only other tasks measured with both hands are kicking a ball and throwing so this is not feasible.

To estimate the relationship between hand skill and cognitive ability, I allow each of the three ability measures to be simultaneously a function of the two measures of relative hand skill and two control variables: binary indicators for hand preference and sex. No functional form restriction on the relationship between ability and hand skill is made and no assumption is made about the distribution of the error term (ε_i). The model is given by:

$$y_i = f_S(Square_i) + f_M(Match_i) + \beta X + \varepsilon_i \quad (1)$$

y_i is the score on the test in question. X is the set of control variables and β is the vector of associated parameters. This approach is semi-parametric in that it allows the effect of the variables of interest (the two continuous laterality measures) to take an arbitrary form but allows other variables (the X 's, here binary indicators of hand preference and sex) to take the conventional linear/parametric form. Graphs of the $f(\cdot)$ functions are presented along with 95% point-wise confidence intervals.

3 Results and discussion

Figure 1 shows the relationship between the three measures of cognitive ability with respect to the two measures of relative hand-skill based on equation (1) above. For both mathematics and verbal ability one can clearly see a deficit corresponding to equal hand skill based on the Square task (panels a & e) consistent with Crow et al. (1998). Such a deficit is much less apparent (if at all) with regard to reading comprehension (panel c). For all three outcomes there is also evidence that those with the lowest values (i.e. relatively better left-hand performance) do worse. However the wide confidence bands in the tails arising from the small

number of observations there implies that these are necessarily imprecise estimates. For the Match variable, there is no evidence of cognitive deficit at the point of “hemispheric indecision”. For both verbal ability and comprehension there is a downward relationship: those who are relatively more skilled with their right hands have lower scores (panels b and d). Interestingly, however, the curves are fairly flat where individuals are ambidextrous. For mathematics (panel f), the *highest* level of ability corresponds to the point of equal hand skill. Overall there is only limited support for the hypothesis of Crow et al. (1998). These results might lead one to ask which of the two tasks best captures cerebral lateralization. While it is well known that language lateralization is correlated with hand preference³ and hand preference is also correlated with relative hand skill it does not follow that relative hand skill will be correlated with language or other forms of cerebral lateralization. One might speculate that the square marking task is a better indicator since performance on it is better predicted by writing hand but it is an open question in the absence of any direct evidence.

The results here can be contrasted with Leask and Crow (2006) who also use the match and square tasks but consider verbal ability only. The relationship between relative hand-skill and verbal ability is considered for left-handers and right-handers separately which makes it difficult to compare directly either with the results presented here (or Crow et al (1998)). In other words the research question is whether individuals who are right or left handed are “better off” if they are very right or landed by relative skill. By “better off” is meant both in terms of performance on the task in question (e.g. whether R is correlated with R-L) and with regard to verbal ability. In general however their results are not consistent with the idea that there is a cognitive deficit corresponding to ambidexterity. If anything, the results point to the opposite conclusion: they find (for the Square task) the highest ability corresponds to a value of

³ See Knecht et al (2000) for example.

the laterality index of -20% and +20% for left and right-handers respectively. If one imagines superimposing these results (the two panels of their Fig 5a) then a deficit close to the point of equal skill would likely be observed. In that sense the cognitive deficit found in Crow et al (1998) with regard to the square task may be an artifact. For the Match task the results (Fig 5b,c) this is not the case with some evidence of the highest performance being achieved for both left and right handers where the index is at or close to 0.

As Leask & Crow (2006) observe writing hand partitions the squares task into two populations but this is less true for the match task. This may well reflect practice effects. If this is the case the square task may be a poorer indicator of an underlying or latent laterality. This depends on the deeper question of which comes first, hand preference or hand skill. This is difficult to unlock although the evidence of McManus et al (1992) from autistic children suggest that it is preference that comes first. Either way, the results in this paper control for hand preference hence the figures are showing the additional effect of relative hand skill.

In a review of the extensive literature documenting the cognitive and behavioural 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.” An updated review would hardly lead to a very different conclusion. This note provides evidence contrary to one particular hypothesis, namely that the absence of hemispheric dominance (to the extent that it corresponds to being ambidextrous) leads to lower cognitive ability in general. The evidence shows that there is no general pattern between relative hand-skill and ability. What seems perplexing here is finding widely differing results with regard to seemingly similar tasks taken on the same occasion. However while the tasks are similar they are certainly not identical and different combinations of skills may be required – the correlation between the two laterality variables (0.156) is consistent with that. I

conjecture that the results here may reflect a combination of Annett's heterozygote advantage theory (that handedness is a genetically balanced polymorphism) and Crow et al's developmental theory.

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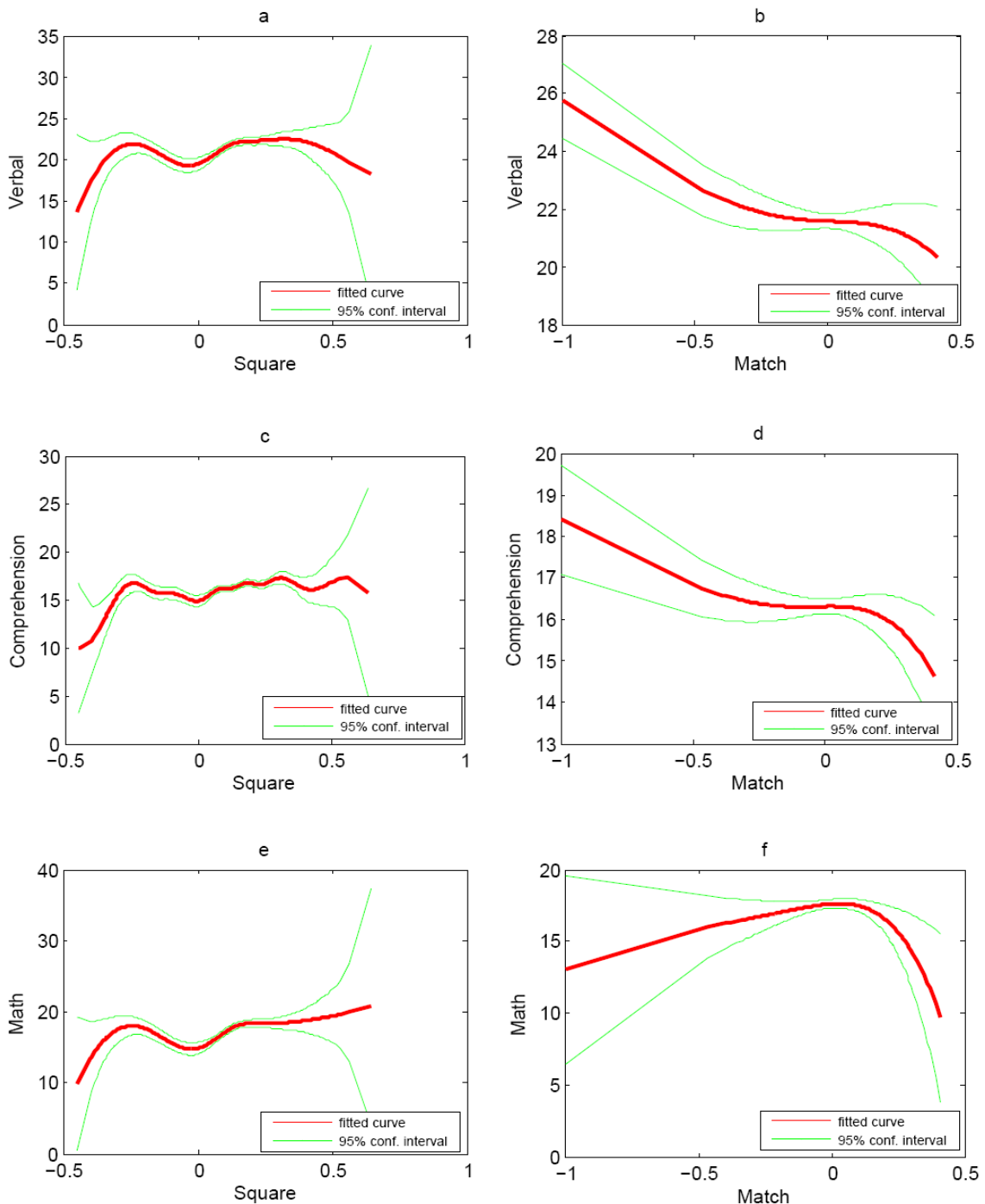
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Figure 1: Cognitive ability and relative hand skill



Note: Estimates are computed using 4th order B-spline basis functions to minimize the Mean Square Error. Smoothing parameters are chosen using Generalized Cross-Validation. Matlab-14 was used for the computations. See Carroll et al (2003) for a general introduction and Ramsay & Silverman (2005) for details of the estimator.

Table 1 : Descriptive statistics

	Right	Mixed	Left
Verbal	22.80 (9.17)	21.46 (9.20)	21.65 (9.45)
Comprehension	16.36 (6.17)	15.96 (6.53)	15.95 (6.40)
Mathematics	17.39 (10.26)	16.42 (10.34)	16.57 (10.34)
Male	.494 (.500)	.611 (.488)	.569 (.495)
Square	.1635 (.093)	.098 (.141)	-.133 (.120)
Match	.009 (.087)	-.002 (.089)	-.036 (.100)
n	8723 (82.8%)	728 (6.9%)	1086 (10.3%)

Note: The table gives means of the variables used with standard deviations in parentheses by hand preference at age 7.