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Handedness and Child Development

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Abstract
Left-handedness is historically associated with poorer outcomes for adults. Yet recent work has suggested that there may be positive labour market returns for left-handed males. This paper examines whether handedness is also associated with poorer outcomes for children and whether this differs by genders. The paper examines a wide set of outcomes for children as they age from 42 months to 14 years. We find the main penalty is not from being left-handed, but is from not having a dominant hand early in life. This penalty is larger for girls than boys by age 14, indicating that early deficits of non-right handed boys appear to fall as they age. For girls, being left-handed and especially mixed-handed at early ages is associated with persistent cognitive attainment deficits, mainly focused at the lower end of the ability distribution.

Keywords: Handedness, child outcomes

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1. Introduction

Historically, left-handedness has been associated with being clumsy, defective and even evil (Coren, 1992). In the epidemiological literature of the 1960s to 1980s left-handedness was associated with deficiencies ranging from health problems such as sleep disorders, atopic diseases, autoimmune problems and depression to delayed physical maturation, learning disabilities and delinquency (Perelle and Ehrman, 2005, and Coren, 1992). Recently, the relationship between left-handedness and labour market returns has been examined. Denny and Sullivan (2007) examine a UK cohort born in the late 1950s and Ruebeck et al. (2007) examine a US cohort born at a similar time. Both papers find a positive association of left-handedness on earnings for men. In contrast, there appears to be no positive labour market return for women: Denny and Sullivan find a negative effect of left-handedness on women's earnings and Ruebeck et al. find no effect.

If these findings indicate a causal relationship, we might expect to find a similar effect for cognitive and behavioural outcomes for children. If left-handers (or at least left-handed men) have better outcomes in adulthood, we might expect that they have better outcomes in childhood too. However, in a study of a recent cohort of Australian children of school entry age (4 to 5 years), Johnston et al. (2007) find that left-handed children – and those who use both hands to write – do worse on a range of cognitive and behavioural outcomes.

This poses somewhat of a puzzle. If the foundations for later life are laid in the early years as is suggested by much recent research (see for example Klebanov et al., 1998; Dearing et al., 2001; Taylor et al., 2004; Aughinbaugh and Gittleman, 2003; Carneiro and Heckman, 2004), why do non-right-handed children do less well at school entry, but appear to be better rewarded in later life, at least if they are male? Selection may be one reason: left-handed adult men observed in work may be from the more able part of the left-handed ability distribution, though selection of this kind would not explain the penalty for left-handed women. But it may also be the case that non-right-handed children experience problems early in life, because they have not fully adapted to being in a right-handed world, but that once they adapt – at least if they are male - they do better.

In this paper we address this paradox by examining the impact of not being right-handed on outcomes as children age. Specifically, we examine the impact of handedness on a range of learning and behavioural outcomes for children as they move from early childhood (specifically age 42 months) through to age 14. The early outcomes are similar to those studied by Johnston et al. (2007). The later ones include both behavioural outcomes and cognitive outcomes, the last of which have been shown in cohort studies for the UK to be strongly correlated with adult labour market outcomes (Heckman et al., 2006; Blanden et al., 2007). We study a contemporary cohort of children who are born in the early 1990s in the UK. Thus, we both replicate the Johnston et al. study for a larger sample and extend this study to later years in childhood. In contrast to the research on adults by Denny and Sullivan (2007) and Ruebeck et al. (2007) – but as Johnston et al. (2007) – we distinguish between being left-handed and being mixed-handed, as mixed-handedness is relatively common in early childhood[1].

Theories of handedness (reviewed below) suggest that handedness may be partly genetic (parental handedness, particularly maternal handedness, is associated with the child's handedness), partly caused by early physical trauma (during pregnancy, birth or early infancy) and also related to maternal mental health early in the child's life. Medical evidence also suggests that being mixed-handed in early childhood is not just a sign of potential ambidextrousness (which is rare), but also possibly a sign of harm to brain development (Sattler, 1993). Late development of a preferred hand – mixed-handedness – may also be due to lack of parental stimulation: children who are given little opportunity to engage in activities such as drawing or painting may be late in developing a preferred hand for writing, where the hand used for writing or holding a pen is often used as the marker in social surveys for handedness.

Genetic factors which determine handedness are orthogonal to socio-economic status. However, damage during pregnancy or in early life, maternal mental health and low parental stimulation are likely to be socially graded. Thus in investigating whether there is a penalty to non-right-handedness for children, it is important to control for factors which are both potentially associated with handedness and themselves determine childhood outcomes. For example, if left-handedness comes about through birth trauma, it may be the birth trauma rather than the handedness that causes the poor outcome. Equally, children who have little interaction with their

[1] The mixed-handed category covers children who favour one hand for some tasks and the other hand for other tasks as well as children who use either hand for the same task. Precise definitions are given below.

parents might both receive less stimulation and be more likely to be classified as mixed-handed by their parents.

The data used in this paper allows us to attempt to isolate the impact of the random component of handedness. Our data is rich in medical as well as social outcomes. It contains information on parental handedness, birth trauma, measures of handedness early in childhood and later in mid-childhood, and a large number of cognitive and behavioural and non-behavioural outcomes from early to late childhood as well as standard socio-demographic information on the child and her parents. We begin by establishing whether and when during childhood there is a penalty to not being right-handed. We then attempt to control for the three different determinants of handedness: the genetic transmission of left-handedness, potential damage pre- and post-birth, and lack of parental interest in child development as well as more standard measures of socio-economic status (SES). This approach allows us to examine whether any association of handedness with cognitive and behavioural outcomes that we might find remains after we control for the fact that handedness may be a marker of other factors that will reduce child development. We also distinguish between girls and boys, as the research on adults finds gender differences in the relationship between handedness and labour market performance.

We find that left-handed children perform less well than right-handed children on cognitive outcome measures and mixed-handed children perform below their right-handed peers on cognitive as well as non-cognitive outcome measures. However, after controlling for SES, lack of parental stimulation, early physical damage to the child’s brain and possible heritability, we find it is primarily being mixed- rather than left-handed that is associated with developmental deficits in childhood. These deficits occur both before and after entry to school. Developmental gaps are also evident in measures of value added, indicating that these children are making slower progress than their right-handed contemporaries. In terms of gender difference, we find some evidence that left-handed girls fare worse than their male counterparts on cognitive outcomes in late childhood, but stronger evidence that *mixed*-handed girls have worse cognitive outcomes than their male counterparts. For non-cognitive outcomes the gender difference is less clear, with mixed-handed girls *and* boys performing worse than their right-handed peers.

The paper is organized as follows. Section 2 overviews the literature on theories of handedness and its potential links with development. Section 3 presents our method and data. Section 4 presents the results and section 5 concludes.

2. Theories of Handedness

Denny and O'Sullivan (2007) and Ruebeck et al. (2007) review evidence on differential – and generally poorer – performance of left-handers. Here we focus on discussion of the causes of left- and mixed-handedness to understand the extent to which handedness may confer advantages or disadvantages and the extent to which it is random, inherited or socially graded.

Different theories have been suggested to explain why right-handedness is dominant in all societies while there is always a minority of people who prefer their left hand. For example,[2] there is the theory of the warrior who holding his shield in his left hand and fighting with the weapon in his right hand has a higher survival probability because he can better protect his heart. Consequently, right-handedness provides an evolutionary advantage. However, since fighting with a shield and weapon was an important occupation only for a relatively short period in the long history of mankind, this theory is rather partial. To give another example, the observation that left-handedness runs in families gave rise to genetic theories of handedness. Theories based on classic Mendelian theory, however, fail to predict handedness correctly, because we observe right-handed children whose parents are both left-handed. In fact, the majority of children with two left-handed parents are right-handed, though children of two left-handed parents are more likely to be left-handed than children of two right-handed parents.

More recent genetic models of handedness incorporate an element of randomness to reconcile the data with the belief that handedness is inherited. They also incorporate the finding that most right-handers process language in the left hemisphere of the brain, whereas only three in four left-handers do so (see, for example, Pujol et al, 1999). Since muscle control is contralateral, i.e. the left hemisphere of the brain controls the right hand and vice versa, it is efficient for individuals with lateralisation of language in the left hemisphere to write with their right hand. Thus (inherited) lateralisation of speech processes influences handedness over and above the random factors determining handedness.

Lateralisation of speech processes is also the starting point of the theory of the pathological left-hander. It assumes that damage to one hemisphere causes verbal processing to shift to the other hemisphere, consequently turning a destined right-hander into left-hander. The brain may have

[2] These examples of theories of handedness are taken from Beaton (2003).

been damaged pre-, peri- or postnatally, causing not only a shift in handedness but also neurological impairment. This theory might explain why the proportion of left-handers is higher in the population of cognitively impaired people than in the general population (see, for example, Pipe, 1988), though the theory of the pathological left-hander fails to explain why people without any noticeable neurological impairment are left-handed. In addition, the proportion of left-handers is also higher in the extremely gifted population than in the general population (see, for example, Benbow, 1986).

For this reason, Perelle and Ehrman (1982, 2005) reject the assumption that there is an archetypic left-hander and state that investigations into the aetiology of handedness have to account for the heterogeneity of the left-handed population. They claim that there are at least two types of lefthanders, probably three. One type of left-hander is the pathological left-hander. Another type is the natural left-hander, individuals whose brains are functionally mirror images of right-handers, i.e. they process verbal information in the right hemisphere and therefore it is efficient for them to write with their left hand. A third – and by their own account probably most controversial – type is the learned left-hander. These individuals have not suffered brain damage and they process speech in their left hemisphere, but a chance event turns them into left-handers: very early in life they picked up a toy with their left hand. Using the left hand made it more skilful, reinforcing its use. When these individuals were later offered a pencil, they also picked it up with their left hand. Since they still process language in their left hemisphere, writing with the left hand is neurologically inefficient. To reduce the time for interhemisphere transfer, some develop an additional verbal centre in the right hemisphere, making spatial information, which is processed in the right hemisphere, easily accessible[3]. So, according to Perelle and Ehrman, left-handers with bilateral speech processing may be highly gifted learned left-handers and left-handers with a verbal centre in the right hemisphere may be pathological left-handers or natural left-handers.

Theories of mixed-handedness are less common, but the ideas of anomalous hemispheric specialisation and loss of anatomical asymmetries in the brain crop up in the literature. Geschwind and Galaburda (1987) hypothesise that influences in pregnancy reduce the structural

[3] The three types of left-handers may explain the distribution of language lateralisation in left-handers. As mentioned above, about three in four left-handers process verbal information in the left hemisphere like right-handers. The remaining quarter use either the right hemisphere or both hemispheres. Pujol et al. (1999), for example, found activation of the right hemisphere in 10% of left-handers and bilateral activation in 14% of left-handers. The distribution of language lateralisation in left-handers shows that – in contrast to right-handers – left-handers are not a homogenous group.

asymmetry of the brain. They suggest that factors related to male sex such as testosterone "produce a shift from left predominance to symmetry". Sattler (1993) claims that mixed-handed people have suffered oxygen deprivation during the perinatal period, which caused more serious injuries to the dominant brain hemisphere. These injuries result in unstable handedness during childhood, but later they will settle upon using one hand. This line of argument resembles the theory of the pathological left-hander, which also refers to the finding that the dominant hemisphere has an elevated blood flow and therefore a higher oxygen requirement, making it more susceptible to oxygen deprivation. Recently, researchers have found a link between antenatal maternal anxiety or distress and mixed-handedness (Obel et al., 2003; Glover et al., 2004 and Gutteling et al., 2007). These hypotheses have in common the idea that adverse conditions during brain development cause mixed-handedness, suggesting that mixed-handers are a more homogeneous group than left-handers, comprising mainly neurologically impaired people.

In sum, these theories suggest that both left- and mixed-handedness is a marker for early brain deficits which may translate into deficits in later life (for evidence on some of these non-earnings deficits, see Denny and O'Sullivan, 2007, and Ruebeck et al., 2007). Left-handers may also contain a group with greater ability. In addition, there are environmental reasons why both left- and mixed-handed individuals may have poorer performance, as the world is geared towards right-handers.

3. Methods and Data

3.1 Estimation method

Our focus is the impact of not being right-handed on a range of outcomes as children move through childhood. For most of our analyses we estimate equations of the following form:

$$O_i = \alpha + L_i\gamma_L + M_i\gamma_M + X_i\beta + \varepsilon_i \ ,$$

where i indexes the child. O_i is one of 11 outcomes which occur at different ages, L_i is an indicator variable that takes the value 1 if the child is left-handed and 0 otherwise, M_i is an indicators variable that takes the value 1 if the child is mixed-handed and 0 otherwise. The coefficients of interest are γ_L and γ_M. To maximise sample size, we include observations with item non-response in the *X* vector by adding missing indicators and replacing the missing value with the mean if the variable is continuous. We estimate robust standard errors.

In our analysis we first estimate the raw correlation between handedness and the outcomes and then add in sets of controls to attempt to isolate the effect of handedness from other variables. X_i is a vector of controls for family SES plus the three sets of factors reflecting the literature discussed above – parental interest in children, pre-, peri- or postnatal insult to the left brain hemisphere and genetic heritability of handedness. So first we condition on potential cofounders, socio-economic position and parental stimulation, to look at the picture for all typologies of left-handedness. We then split off typologies, firstly brain insult, then hereditary, to focus on apparently random handedness. We also examine the impact of handedness on value added measures, primarily in cognitive development. These control for prior attainment, so control for many of the child and parental fixed characteristics that may be determinants of handedness. The value added measures thus both reduce the potential impact of unobserved heterogeneity as well as showing whether children who are not right-handed progress at a different rate to their right-handed peers.

3.2 Data

Our data are from a rich data set for a cohort of children born in one region of the UK in the early 1990s. The Avon Longitudinal Study of Parents and Children (ALSPAC) is a population-based study of parents and children. Pregnant women resident in the former Avon Health Authority were invited to participate if their estimated date of delivery was between the 1st April 1991 and the 31st December 1992. The Avon area is broadly representative of the UK as a whole. Approximately 85% of eligible mothers enrolled, resulting in a cohort of approximately 12,000 live births[4]. Respondents were interviewed at high frequency compared to any of the UK cohort studies. The ALSPAC survey also contains data from sources other than self-completion questionnaires. The ALSPAC team have run a number of clinics for children from the age of seven (and from a younger age for a selected sub-sample) in which they are able to directly assess various aspects of the children's development. Records from other agencies have been matched to the individual children and we use data from schools on standardised national tests and teachers assessments of the pupils. In our analyses we use data from some fifteen questionnaires, three clinics and three school tests covering the dates between 8 weeks gestation and the 11th year of the child.

[4] Our estimation samples are smaller than this due to post-birth sample attrition and item non-response.

Outcome measures

We analyse cognitive outcomes, early development and behavioural outcomes. Our cognitive outcome measures are performance on tests taken at school at different ages and a measure of IQ. The school-based measures of cognitive development are the entry assessment test taken at age 4 or 5, the Key Stage 1 assessment which is administered in Year 2 at age 7, the Key Stage 2 assessment in Year 6 at age 11 and the Key Stage 3 assessment Year 9 at age 14. The latter three are national tests administered to all school children in the public sector[5]; the former is a test that was Avon specific but designed along similar lines to the now national school entry test. Each test is composed of four sub-scores that capture ability in reading, writing, mathematics and language skills (entry assessment only), spelling (Key Stage 1 only) or science (Key Stage 2 and 3 only). We compute the average of the four sub-scores to create an overall score[6]. The measure of IQ is the short form of the Wechsler Intelligence Scale for Children[7] (WISC-III UK), administered to children at a clinic at the age of 8. This is the most widely used individual ability test world-wide[8].

Our measures of early development are a language development score, a social development score, a fine motor skills score and a gross motor skills score. The language score is derived from responses to the 38-month child-based questionnaire completed by the mother[9]. It is composed of four sub-scores that each capture a slightly different aspect of the child's language development, such as vocabulary or grammar. The social development score and the motor skills scores are derived from responses to the 42-month questionnaire. The questions were adapted from the Denver Development Screening Test (Frankenburg and Dodds, 1967), a test designed to detect children with developmental delays. [10]

[5] Only a small minority of children under age 11 (around 5%) are educated outside the public sector.

[6] For the Key Stage 2 and 3 assessments we construct a finer measure for each subject using additional information on pupils' marks before averaging over the four sub-scores. A detailed description of this procedure is available from the authors.

[7] Wechsler, Golombok and Rust (1992)

[8] It comprises five verbal sub-tests: information, similarities, arithmetic, vocabulary and comprehension; and five performance sub-tests: picture completion, coding, picture arrangement, block design and object assembly. We combine the sum of the verbal subtests and the sum of the performance subtests into an overall score using the technique of factor analysis.

[9] Questions adapted from the MacArthur Infant Communication Questionnaire (Fenson, Dale, Reznic et. al., 1991).

[10] The social development score covers questions such as "she is able to drink from a cup without spilling" or "he can put on a T-shirt by himself". The fine motor score covers activities such as drawing a circle or building a tower of 4/6/8 bricks and the gross motor score includes questions on being able to throw a ball or balancing on one foot for at least four seconds.

Behaviour is measured by responses to the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997), which comprises 25 questions relating to five dimensions of behaviour – pro-social, hyperactivity, emotional, conduct and peer relations[11]. Respondents were asked to indicate the extent to which 25 statements matched the study child's behaviour over the last six months. We use the SDQ completed by the mother when the child was 81 months old[12]. A maximum of ten can be scored for each component. Using factor analysis, we combine four of the sub-scores into one overall score, excluding the pro-social score, which we use as a separate outcome variable. A higher total behaviour score indicates more behavioural problems, whereas a higher pro-social score indicates more positive social behaviours. For presentational purposes we reverse the total behaviour score so that – in line with the other outcome measures – a higher score indicates better behaviour.

We standardise all outcome variables to have a mean of 100 and a standard deviation of 10. The magnitudes of our regression estimates, therefore, are directly comparable across all 10 measures. As a guide to interpreting the size of our estimates, assuming a normal distribution an increment of 1 point (i.e. a tenth of a standard deviation) results in a shift from the median to the 54th percentile, while an increment of 2.5 points (or a quarter of a standard deviation) results in a shift from the median to the 60th percentile.

Handedness measure

We derive a measure of handedness from responses to the 42-month child-based questionnaire completed by the mother. Mothers were asked to indicate, for six activities, if their child uses the left hand, the right hand, either hand or does not do this activity at all. We use four of the six activities, excluding holding a knife when cutting things, since this question may be inappropriate for a 42 month old child, and hitting things, because this action does not require dexterity.

Children who perform all four activities – drawing, colouring in, brushing their teeth and throwing a ball – with the same hand are classified accordingly. If the mother ticked "either" for all four activities, we classify the child as mixed-handed. Children who use the same hand for 3 out of 4 activities are classified according to the hand they mainly use. Children who use the

[11] This measure is a good predictor of conduct, emotional, hyperactivity and any psychiatric disorders in children of the age we examine (Goodman et al., 2000).

[12] The same questionnaire at age 8 completed by the teacher is for a much smaller sample; therefore, we use it only in robustness checks.

right hand for 2 activities and the left hand for the other 2 activities are recorded as mixed-handed. We also assign mixed-handedness to children with the following patterns: eerl, rrel, ller (where r = right, l = left, e = either). Children with the patterns rree and llee are classified as right-handed and left-handed, respectively. We also include children for whom one activity is missing, classifying as right-handed children with the patterns rrr, rrl, rre, as left-handed children with lll, llr, lle and as mixed-handed children with eee, eel, eer, rle.

Table A1 indicates about 10% of the children in our sample are left-handed, which is in line with proportions found in the global population (see, for example, Perelle and Ehrman, 2005). The proportion of mixed-handed children in our sample is about 7.5%, a proportion similar to the one found in the 1958 National Child Development Survey (NCDS) at age 7 years (see Denny and O' Sullivan, 2007).

Controls

We have three sets of controls in addition to gender and standard SES measures, which also include family size and an indicator for being non-white (the last to allow for the fact that in some groups left-handedness may be less socially acceptable). Our measures of parental SES are father's occupational class, mother's age at birth, mother's highest educational qualification, housing tenure when the child is 21 months old and the log of the average of equivalised net household income at ages 33 and 47 months, expressed in June 1995 prices[13]. Our measure of family size is the number of siblings when the child is 47 months old. Descriptive statistics of the data are provided in table A1.

One set controls for parental handedness, capturing the possibility that non-right-handedness is inherited. 13% of left-handed children have a left-handed mother, whereas this proportion is only 7% for the total sample. This difference is less pronounced for the father's handedness, with 12% of left-handed children having a left-handed father compared to 10% for the total sample (see Table A1).

Another set of controls captures the possibility that non-right-handedness is caused by insults to the foetus's or infant's brain that might damage one hemisphere, converting a destined right-

[13] Income data from the ALSPAC data is banded. We impute a median value for each band using data from the Family Expenditure Survey, convert the income variables to real values using the 1995 RPI as a base and equivalise using the OECD modified scale. We also impute the value of housing benefit for families who do not directly receive housing payments. Finally, we average over the two measures to reduce measurement error and take the log of the variable.

hander into a pathological left-hander. As an indicator of perinatal neurological insult, Bakan (1971) suggested high-risk birth order position, which he defined as first born and fourth or later birth. We therefore include indicators for first pregnancy and fourth or higher order pregnancy. Since birth order as an indicator of potentially brain-damaging birth stress may be problematic, we also control for some of the birth stressors identified in the medical literature (Searleman et al.1989). We use information on the method of delivery which identifies whether the mother had a Caesarean section and whether this was an emergency Caesarean or a planned Caesarean[14]. Other direct indicators of birth stress listed by Searleman et al. (1989) are maternal age at birth, which is one of our SES controls, and low birth weight and premature birth, which we control for by including the birth weight to gestation ratio. We cannot, however, control for birth stressors such as slow labour, breathing difficulties or Rh incompatibility.

As a further indicator of potentially brain-damaging prenatal stress in the foetus we include a measure of maternal mental health – the Crown Crisp Experiential Index (CCEI) – at 18 weeks gestation. The CCEI is a scale measuring mental ill health that consists of six sub-scales. The ALSPAC data contain the three sub-scales which measure free-floating anxiety, somatic concomitants and depression were employed. Each sub-scale consists of 8 items with scores between 0 and 2. A higher score indicates that the mother is more affected. To control for postnatal neurological insult, we include a variable indicating whether the child has been dropped or had a bad fall since he was 6 months old, a question answered by the mother in the 15-month child-based questionnaire.

A third set controls for parental interest in the child. Misclassification of handedness may arise if mothers cannot recall their child's hand preference when filling in the questionnaire and so indicate "either". But mothers may be more ignorant of their child's handedness if they give their child less opportunities to perform uni-manual activities such as drawing or painting. Being offered less such activities may result in worse outcomes. Thus, we might find that mixed-handedness is associated with worse outcomes, whereas in fact a lack of stimulation generates the association. To control for this potential confounder, we include in our controls a parenting score which indicates the range and volume of activities mothers undertake with their children.

[14] For about 2% of mothers we only know that they had a Caesarean section.

The parenting score is derived from responses to the 24-month child-based questionnaire completed by the mother[15].

The association between controls and handedness

Table 1 presents a multinomial logit model of handedness which reveals significant associations between the controls and being left- or mixed-handed. We block the results into the four possible sources of handedness: sex, heritability, early trauma, parenting and parental SES. The fit of the model is low, indicating that despite the associations we find there is a high degree of chance in handedness. We see that girls are less likely to be left- or mixed-handed. In terms of possible genetic factors, having a left-handed or a mixed-handed mother significantly increases the probability of being left-handed or mixed-handed. Larger coefficients on the indicator variables for maternal left- or mixed-handedness in the left-handedness equation suggest a stronger genetic component for left-handedness than for mixed-handedness. In addition, paternal left-handedness increases the probability of being left-handed.

Supporting the hypothesis that non-right-handedness is associated with possible damage to the brain at or before birth, being either left- or mixed-handed is associated with having a lower birth weight to gestation ratio and being delivered by Caesarean section after onset of labour. Additionally, being mixed-handed is associated with being born as a 4th or higher order pregnancy and being dropped between six and fifteen months[16]. Mental ill health during pregnancy – proxied by the CCEI at 18 weeks gestation – is also associated with left-handed offspring.

There is some indication that classification as mixed-handed may be associated with lack of parental awareness and/or stimulation of the child (which themselves are socially graded). Children who are offered fewer stimulating activities by their parents are more likely to be classified as mixed-handed and also those born to a mother who experienced more mental ill health during pregnancy.

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[15] The mother is asked to report how often she: lets her child play with paints, mud or other messy objects; lets her child use objects to build towers or other creations; sings to her child; reads him stories; goes out to the park or playground with him. The scores for each component range from 1 (rarely) to 4 (every day), so the maximum parenting score is 20.

[16] The coefficient on fall/drop 6-15 months is 0.20 (s.e. = 0.12) in the mixed-handed equation when excluding observations with missing control variables.

We also find – in contrast to findings of Johnston et al. (2007) for contemporary Australian children – that children of lower socio-economic status are more likely to be mixed-handed. Left-handedness is not associated with socio-economic status, though in our sample mothers who have an A-level are less likely to have a left-handed child[17].

In summary, we find non-right-handedness to be associated with many of the factors suggested in the medical literature and mixed-handedness to have some association with socio-economic status and parental behaviours post-birth.

4. Results

4.1 Primary results

The top panel of Table 2 shows the association between handedness and the outcome variables conditioning just on gender. Non-right-handedness is associated with gender (see Table 1); boys also develop more slowly than girls and so we need to avoid mixing gender and handedness. These regressions indicate that left-handers perform significantly worse than right-handers on the cognitive outcome measures and on the gross motor score at 42 months, whereas mixed-handers perform significantly worse than right-handers on nearly all of the outcome measures, with no clear pattern across the different types of outcomes.

The second panel of Table 2 shows the association between handedness and the outcome measures after also controlling for basic socio-economic variables (including family size and ethnicity), but not for heritability, insults to the child's brain or parenting. The handedness coefficients fall by around one-third for the cognitive outcomes, less for the non-cognitive outcomes[18]. For left-handers, the coefficients are still significantly negative for the IQ score, the Key Stage 2 and 3 scores and the gross motor score at 42 months; for mixed-handers all coefficients are still significantly negative. So whilst the associations between handedness and the individual socio-economic indicator variables in Table 1 are weak, their inclusion in the model is important in the sense they collectively impact on the handedness coefficients. The next

[17] This finding is not an artefact caused by our definition of handedness. In a logit model of left-handedness at age 7 – this handedness measure is taken at a clinic at age 7, where the tester noted which hand the child used to write with – we find the same association: mother has O-level = -0.13 (s.e. = 0.11), mother has A-level = -0.28 (s.e. = 0.13), mother has degree = -0.00 (s.e. = 0.15).

[18] Since we find that children from lower socio-economic backgrounds are more likely to be mixed-handed, we would expect the coefficients on mixed-handedness to drop when controlling for SES. For left-handedness, however, we do not find a clear correlation with socio-economic variables, but the coefficients on left-handedness drop when controlling for these variables. This drop is probably partly driven by the somewhat odd association between left-handedness and mother's education (see Table 1).

panel adds in the parenting score to remove the effect of a possible lack of parental involvement in the association with mixed-handedness. The coefficients on left-handed are essentially unchanged, whereas the coefficients on mixed-handed fall a fraction.

So far we have attempted to control for confounding variables that may reflect poor early stimulation of the child and are reflected in poor identification of handedness. The results in Panel III can be thought of the average gap associated with handedness rather than reflecting social deprivation. However, as discussed in the section on theories of handedness, there are different typologies of handedness and one in particular, pathological left-handers, may experience handedness very differently from other non-right handed children. We now try and explore the potential impact of brain insults. Panel IV of Table 2 adds in the controls for pre-, peri- and postnatal insults to the child's brain, so isolating the effect of handedness from the physical effects of a difficult birth. The handedness coefficients drop a little (by up to 10%), but their significance levels are largely unchanged. This suggests that non-right-handedness as a result of birth difficulties does not lie at the heart of handedness differentials.

Finally, the bottom panel of Table 2 adds in controls for the heritability of handedness by including parents' handedness. The fall in the coefficients is again modest and leaves the significance levels unchanged.

In comparison to the sex-standardised correlations presented in the top panel, the net effect of controlling for SES, parenting, insults to the child's brain and heritability is to considerably reduce the correlation between left-handedness and poorer cognitive outcomes. Left-handed children perform worse than right-handed ones in terms of cognitive outcomes at ages 8, 11 and 14, and gross motor skills at age 42 months, but the size of the coefficients is small, indicating a performance differential between right- and left-handed children of under a tenth of a standard deviation. Controlling for heritability and brain insults does not change the effect of left-handedness and suggests little variation in attainment gaps according to the typologies of left-handed groups.

For mixed-handers, though the size of the coefficients drops by between 10% and 50% when controlling for SES, parenting, brain insults and heritability, their performance remains significantly worse on nearly all of the outcome measures. They perform worse on all types of outcome measures, though there appears to be more effect on outcomes early in life than at ages

8, 11 or 14. The size of the gap between mixed-handed and right-handed children is moderate. The largest coefficient – for the early fine motor score – is -2.9 and suggests that (assuming a normal distribution) being mixed-handed would result in a drop from the median to the 39th percentile of the distribution. Mixed-handed children score about one-fifth of a standard deviation below right-handed children on social development and gross motor skills and about one-eight of a standard deviation below on language. The largest cognitive test deficit is for IQ, where mixed-handed children score 1.2 points below right-handed children, which – again assuming a normal distribution – is equivalent to a drop from the median to the 45th percentile. In terms of behaviour, the gap is largest for behavioural problems, where mixed-handed children score 1.5 points less than right-handed children, which is equivalent to a shift from the median to the 44th percentile of the distribution.

The coefficients on the control variables, which are presented in Table A2, allow comparison of the importance of handedness with more studied determinants of child outcomes[19]. Handedness is less important than other determinants of outcomes such as parental education or parenting behaviour. For example, a parenting score of only 4, where the lower quartile of the parenting score distribution is 13, offsets the effect of being mixed-handed on Key Stage 1, 2 and 3 scores, WISC score, early development and behaviour. But the impact of mixed-handedness is around half the gap between boys and girls for early development and behaviour and more than twice as large as the effect of having one more sibling for cognitive outcomes.

As non-right-handedness is associated with gender and as earlier research has shown differences in outcomes for men and women, Tables 3a and 3b therefore investigate whether the negative effects associated with being left- or mixed-handed differ by gender. The tables present coefficient estimates from regressions that sequentially add our controls for socio-economic status, parenting, insults to the child's brain and heritability as before, first for the boys-only

[19] Gender, the birth weight to gestation ratio, the mother's mental health at 18 weeks gestation, income and the parenting score at 24 months are significant for nearly all of the outcome measures. The coefficients have the expected signs: girls' outcomes are better than boys'; a higher birth weight to gestation ratio, higher income and a higher parenting score are associated with better outcomes; poorer maternal mental health is associated with worse outcomes. The controls for SES – as indicated by other measures than income – are significant mainly for our measures of cognitive ability and show the usual social gradient. Parents' handedness is not systematically associated with all of the child outcomes, though parental left-handedness, either maternal or paternal, seems to be related with lower school performance. Distress at birth – as measured by delivery by caesarean section – also has no systematic association with outcomes, but there is some suggestion of a negative association with cognitive ability and behaviour.

sample and then the girls-only sample, respectively. The cost is smaller sample sizes, which reduces the precision of the estimates.

For left-handedness, the basic correlations suggest that left-handed boys score below right-handed boys on the entry assessment, the Key Stage 2 and 3 tests, the IQ test and the social development score at 42 months. Left-handed girls perform worse than their right-handed counterparts in the Key Stage 1, 2 and 3 tests. For these three outcomes, the gap between left-handed girls and right-handed girls is larger than the gap between left-handed boys and right-handed boys. Mixed-handers of both genders do less well than right-handed children across a wider range of outcomes. The coefficients for mixed-handed boys and girls are similar for the early development and behaviour scores, but the coefficients for mixed-handed girls are much larger than the ones for mixed-handed boys for the cognitive outcomes. When including SES controls, the coefficients on left-handed and mixed-handed drop by about one-quarter to one-third for the cognitive outcome measures for boys and girls. They remain unchanged for the early development and the behavioural measures. Adding the parenting score slightly increases the coefficients on left-handed for boys and girls, reduces the coefficients on mixed-handed for boys and does not changes the coefficients on mixed-handed for girls.

The controls for insults to the child's brain reduces boys' significant coefficients on left-handed (entry assessment and early development measures) by around 10% and changes girls' coefficients on left-handed by relatively little. Boys' coefficients on mixed-handed drop slightly and girls' coefficients on mixed-handed drop by 3% to 13%. Subsequently adding controls for heritability of handedness changes the coefficient estimates for left-handers and mixed-handers by relatively little, though they tend to drop for boys and increase for girls.

The final coefficient estimates suggest that left-handed boys perform less well on two early measures – entry assessment at age 5 and social development at age 42 months – but otherwise perform as well as their right-handed counterparts. Left-handed girls, on the other hand, perform less well at ages 11 and 14 on the cognitive scores. But again the larger penalties are for the mixed-handed children. Mixed-handed boys perform significantly worse than right-handed boys on the early development measures, the behaviour measures and the entry assessment score at age 5. The largest deficit is for fine motor skills, where mixed-handed boys score 3.3 points below their right-handed counterparts, which – assuming a normal distribution – is equivalent to a drop from the median to the 37th percentile. For mixed-handed girls we find that they perform significantly worse than right-handed girls on the cognitive outcome measures and the social development, fine motor and gross motor scores. The deficit is -2.6 points for the entry assessment at age 5, around -1.8 points for the Key Stage 1 test at age 7, the Key Stage 2 test at age 11 and the IQ test at age 8, and still -1.6 points for the Key Stage 3 test at age 14, which is equivalent to a drop from the median to the 44th percentile. For the early development measures, the largest deficit is for the fine motor score, with a point estimate of -2.2, equivalent to a drop from the median to the 41st percentile.

Interestingly, although mixed-handed boys perform worse than right-handed boys on the early development measures and the earliest cognitive measure, there are no significant differences for the later cognitive outcome measures. Mixed-handed girls, however, perform worse than right-handed girls on the early development measures as well as the later cognitive outcome measures. There is no sense of catching up among non-right handed girls.

The approach adopted allows us to say something about differences among typologies of left-handedness. Introducing controls for brain insults and heritability allows us to see if coefficients change as we focus in on the base group of apparently random left- or mixed-handedness. The results suggest little evidence of differences in performance across these typologies. Next, we explore whether there is evidence of a different distribution of attainment by handedness.

Table 4 attempts to examine where in the distribution of each outcome the deficit for non-right-handers arises, allowing for differences between genders. It presents the coefficient estimates from quantile regressions for interaction terms of handedness and sex for the entry assessment score, the Key Stage 2 and 3 test scores, the fine motor skills and the total behavioural score, controlling for the full set of confounders. The results for the other early development measures are similar to the results for the fine motor skills and the results for the Key Stage 1 test score are similar to the results for the Key Stage 2 and 3 test scores and are available from the authors. Column 1 shows the coefficients on the interaction terms obtained using OLS. They are similar to the coefficients from the separate OLS regressions for boys and girls reported in Tables 3.a and 3.b. Columns 2 to 10 present the quantile regression estimates for the 9 deciles.

For left-handers the results suggest that the poorer performance of left-handers and right-handers in cognitive ability arises from (moderate) differences at the lower end of the conditional distribution. Left-handed boys perform worse on the Key Stage 2 assessment at the 0.10 quantile and on the IQ test at the 0.10, 0.20. 0.30 and 0.40 quantiles (but the size of the gap diminishes as we move up the distribution). Interestingly, there is an indication that left-handed boys perform better at the very top of the IQ distribution[20]. Left-handed girls score lower on the Key Stage 2 and 3 assessments at the bottom and the middle (the 0.10 to 0.60 quantiles) of the distribution[21]. In terms of motor skills, left-handers score less than right-handers only at the lower end of the distribution. The total behavioural score is lower for left-handed girls, though not boys, at the bottom of the distribution (0.10 and 0.20 quantiles).

In contrast, for mixed-handers the results show that being mixed-handed is broadly associated with worse cognitive outcome measures and lower motor skills scores across the whole range of the conditional distribution, particularly for girls. The cognitive outcome results suggest that mixed-handed girls are affected across the whole range of the conditional distribution. Mixed-handed boys seem to perform worse at the Key Stage 2 and 3 tests at the 0.10 to 0.40 quantiles, whereas for girls the estimates are significant at nearly all of the quantiles. Nevertheless, for the Key Stage 2 test score the coefficient on being a mixed-handed girl at the 0.10 quantile is three times as large as the coefficients on mixed-handed girl at the middle and the top of the distribution, so that – whilst the penalty to being a mixed-handed girl runs higher up the distribution than for their male counterparts – both boys and girls have largest deficits at the bottom end. For behaviour we find effects mainly at the bottom end of the distribution.

So far we have looked at outcomes at certain ages and found a penalty to being non-right-handed. The Key Stage 1, 2 and 3 assessments, which both measure the same underlying ability – academic performance – but at different ages, 7, 11 and 14 years, allow us to investigate whether non-right-handedness also impacts on children's *progress* at school by controlling for the Key Stage 1 score in the Key Stage 2 outcome and the Key Stage 2 score in the Key Stage 3 outcome. Additionally, controlling for the previous Key Stage score provides estimates of the effects of left- or mixed-handedness conditional on unobserved factors, such as genetics, that determine the earlier outcome but might also influence the later outcome.

Table 5 shows that even conditional on prior attainment left-handed girls and mixed-handed girls and boys perform worse at the Key Stage 2 assessment, though the size of the effect is relatively

[20] Larger and more significant are the estimates at the very top of the distribution: The coefficient on boy & left for the 0.95 quantile is 2.11 (s.e. = 1.14) and for the 0.975 quantile 2.75 (s.e. = 1.17). These results echo Benbow's (1986) findings of a link between left-handedness and extreme intellectual precocity.
[21] The coefficient on girl & left is 1.39 (s.e. = 0.64) for the 0.95 quantile.

small, about the same as reducing the Key Stage 1 score by 1 point.[22] Controlling for the Key Stage 2 score in the Key Stage 3 equation, however, gives a significantly negative coefficient only on girl & left, suggesting that mixed-handed children's progress between age 11 and age 14 is similar to their right-handed peers, whereas left-handed girls still progress at a slower rate than right-handed children.

The Key Stage 2 and 3 scores are the average of sub-scores in English, maths and science. The worse performance of left- and mixed-handed girls may be driven by a lower English score due to difficulties with handwriting. To test this, we undertook regressions using the three sub-scores as outcome variables. The results show that the penalty to being a left-handed girl is largest in science and that mixed-handed girls' performance in maths is particularly poor[23], suggesting that left-handers' handwriting problems such as illegible and smudged writing do not account for the performance differential.

4.2 Robustness checks

Definition of handedness

As we find the largest deficit is for children who are classified as mixed- rather than left-handed, we examine whether the results are robust to alternative definitions of handedness. Table 6 reports estimates of the association between handedness and child outcomes using the components of our handedness measure – drawing, colouring in, brushing teeth and throwing a ball – separately to define handedness, thus avoiding the potential pitfalls that arise when we have to choose a cut-off to separate the three types on a multidimensional measure of handedness (see Bishop, 1990). The regressions include our full set of control variables. The results do differ somewhat according to the activity that defines handedness. For example, children who use their left hand for drawing or colouring in score significantly less on Key Stage 2 and 3 assessments, WISC and early development measures, whereas children who hold their toothbrush with their

[22] Results are similar when including a measure of prior attainment in the early development regressions. For example, regressing the social development score at age 42 months on handedness, the social development score at age 30 months and our standard set of controls, we obtain the following coefficient estimates: left = -0.39 (s.e. = 0.27), mixed = -0.93 (s.e. = 0.34), social development score at 30 months = 0.60 (s.e. = 0.01).

[23] The coefficient estimates for the Key Stage 2 sub-scores are for left-handed girls -0.84 (s.e. = 0.46) for English, -0.91 (s.e. = 0.50) for maths and -1.26 (s.e. 0.48) for science and for mixed-handed girls -1.49 (s.e. = 0.63) for English, -2.32 (s.e. 0.73) for maths and -1.15 (s.e. = 0.65) for science. The estimates for the Key Stage 3 sub-scores are for left-handed girls -0.96 (s.e. = 0.48) for English, -1.14 (s.e. = 0.51) for maths and -1.45 (s.e. = 0.50) for science and for mixed-handed girls -1.08 (s.e. = 0.63) for English, -2.23 (s.e. = 0.65) for maths and -1.43 (s.e. = 0.65) for science. Controls are heritability, insults to child's brain, socio-economic status and parenting.

left hand score significantly less only on Key Stage 2 and 3 assessments and WISC, and children who throw a ball with their left hand score significantly less only on gross motor skills.

So which activity is the best one to define handedness? Perelle and Ehrman (2005) argue the writing hand determines handedness. Whereas people can learn to do mechanical tasks equally well with either hand, only very few persons can *write* equally well with either hand. As 3 ½ year olds come closest to writing when they draw or colour in, we focus on these two activities. We find the estimates of the negative effect of being left-handed are larger and more significant when using the drawing or colouring-in hand to define handedness than when using our multidimensional measure of handedness. For nearly all of the outcomes, being mixed-handed is associated with a smaller, though still significant, penalty when using the drawing or colouring-in hand to define handedness instead of our multidimensional measure of handedness. The smaller coefficient size is possibly due to downward bias caused by measurement error, which increases when using a one-dimensional handedness measure[24].

Our handedness measure is mother reported. We investigate the robustness of this by combining it with a handedness measure taken at a clinic at the later age of 7, where a tester noted which hand the child used to write with (right or left)[25]. We find that for children who are mixed-handed at 42 months, adding in information on the hand used for writing at age 7 does not seem to modify the effect of mixed-handedness at age 42 months for most of the outcomes (results available from the authors)[26]. We also examine the results using only the hand the child used to write with at the clinic at age 7 as a measure of handedness (Table A3). Using this definition we would conclude, as for our preferred classification at age 42 months, that left-handed children score worse on several of the cognitive outcomes and the fine motor skills. But we would miss the finding that mixed-handedness in early childhood is associated with larger negative effects on nearly all outcomes. In addition, the negative effects on left-handedness as defined by writing

[24] For example, of the 1049 children who – according to their mother – draw with either hand, 151 use the same (right or left) hand for the other three activities. Thus, these children probably have a strongly preferred hand, but their mother could not recall which hand they prefer for drawing and therefore ticked "either".

[25] For children who did not attend the clinic at age 7 but attended one of the clinics at ages 8 and 9 we use a similar variable from these clinics. About 20% of children in the sample do not have a later measure of handedness as they did not attend any of these clinics.

[26] Children for whom we do not have a later handedness measure perform worse on nearly all outcome measures regardless of their handedness at age 42 months. Generally, children who do not attend the clinics are from lower socio-economic backgrounds. As we control for socio-economic background as well as parental input, the negative coefficients on right-missing, left-missing and mixed-missing capture unobserved differences between parents who take their child to the clinics and those who do not, possibly differences in parents' interest in their children's development. Within this group of possibly less active parents, we find that left-handed children score below right-handed children and mixed-handed children score below left-handed children on the early development measures, the entry assessment and the Key Stage 3 test.

hand at 7 are probably driven by the children who were mixed-handed at age 42 months, so classification on the basis of writing hand at age 7 would suggest these negative effects are associated with left-handedness.

In conclusion, these checks suggest that our multi-dimensional measure of handedness in early childhood – which also allows for unstable handedness – is informative and robust.

Possible biases from maternal reporting

Several of the measures we examine are reported by mothers. In some cases we have independent assessments of the same or similar activities. In particular, the mother-reported motor skills at age 42 months have an independently assessed counterpart: one made in a clinic, but at the later age of 7. The assessment of behaviour by the mother at age 81 months has an independent counterpart in an assessment – using exactly the same questionnaire – by the child's teacher when the child was 8 years old. By comparing the non-maternal assessments with those of the mother, we are able to establish whether our results might be affected by maternal bias.

For the motor skills we find no indication of maternal bias. The performance differential is larger for mixed-handed children. For left-handed children the differential is larger for the test of gross motor skills than for the tests of fine motor skills. These findings are consistent with our results using mother-reported motor skills[27, 28]. For the behavioural outcomes we find some indication of maternal bias. Using the teacher-reported total behaviour score we estimate that – controlling for our full set of variables – mixed-handed children score 0.64 (s.e. = 0.56) points below right-handed children, whereas using the mother-reported score we find a larger and statistically

[27] Using the results from two tests of fine motor skills as outcome variables in regressions including the full set of controls, we find that left- and mixed-handers perform worse than right-handers. One test, known as "placing pegs", required the child to insert twelve pegs, one at a time, into a peg board, holding the board with one hand and inserting the pegs with the other. This test was repeated using the non-preferred hand, in which left- and mixed-handed children performed better than their right-handed counterparts. In the other test, known as "threading lace", children had to thread a lace through holes in a wooden board, using only one hand while holding the board with the other hand. The time taken to complete these tasks indicates the skill level. In our regressions we use test results standardised to have a mean of 100 and a standard deviation of 10. The estimated coefficients are: placing pegs with preferred hand: left = 0.77 (s.e. = 0.42), mixed = 1.04 (s.e. = 0.54); placing pegs with non-preferred hand: left = -1.54 (s.e. = 0.39), mixed = -2.08 (s.e. = 0.46); threading lace: left = 0.92 (s.e. = 0.49), mixed = 1.05 (s.e. = 0.56).

[28] Controlling for the full range of controls, we also find that left- and mixed-handed children perform worse on a test of gross motor skills. This test involved the child attempting to throw a bean bag underarm into a box whilst standing behind a line at a distance of six feet from the box. The number of successful throws out of ten was scored. Using the standardised test result (mean = 100, s.d. = 10), we estimate the following coefficients: left = -1.32 (s.e. = 0.42), mixed = -1.41 (s.e. = 0.49).

significant performance differential of -1.53 (s.e. = 0.53)[29]. One reason for the insignificant estimate of the effect of mixed-handedness on teacher-assessed behaviour might be the smaller sample size (n = 4628). On the other hand, mothers' reports might be biased. For instance, if mixed-handedness really caused developmental delays, mothers of mixed-handed children might be more stressed and consequently rate them more difficult than they objectively are. Teachers, however, may have their own biases, making their assessment another subjective – but independent – assessment of the same underlying behaviour.

Missing data

The nature of the data means that observations may have missing data on some of the controls, as information is collected at different ages and from a variety of sources. To deal with this in the analyses above we include an additional dummy variable indicating missingness and replace missing observations with the mean value if the variable is continuous. To test the robustness of our results to this imputation method, we re-ran all analyses excluding observations with missing controls. This resulted in sample sizes which were considerably smaller than those reported in Table 2 (samples are mainly between 4,000 and 6,000). Table A4 shows our results for mixed-handedness are not affected by our imputation of missing values, but the estimates for left-handedness indicate that there is no deficit attached to being left-handed in this smaller sample.

5. Conclusions

This paper has examined whether there are developmental deficits associated with not being right-handed in a sample of contemporary children. These are children for whom left-handedness is not a social stigma. Theories of handedness suggest that non-right-handedness may indicate damage to the brain during very early life, whilst a minority of left-handers may have brain advantages that have positive pay-offs later in life.

We examine a range of outcomes measured between the ages of 42 months and 14 years and employ a rich set of controls, allowing us to control for causes or correlates of left- or mixed-handedness that also independently might cause worse outcomes. Specifically, we include standard socio-economic status and parenting behaviour controls, which may both result in classification of a child by the mother as mixed-handed and be a marker for lower stimulation in

[29] For the teacher-reported pro-social behaviour sub-score the coefficient on mixed is insignificant and positive (0.27, s.e. = 0.56, n = 4664), as opposed to the significantly negative coefficient estimated using mother-reported pro-social behaviour.

the early learning environment, plus controls for heritability of handedness and brain damage in early life. We find that while there is some penalty to being left-handed, particularly for girls, the main penalty is to children who do not have a dominant hand early in life. This latter group have lower development which first appears in the early years but remains present at age 14, particularly for girls. The size of the penalty is not large, but on average it is about half the size of the penalty in early development associated with being male. While our finding of a negative effect associated with not having a dominant hand by 42 months does not suggest that mixed-handedness *causes* lower test scores, our results are robust to controlling for reporting error on the part of parents that may itself be associated with lower inputs. We also examine value added, which controls for unobserved attributes of children and families. We find mixed-handed children make less progress. Therefore, our results suggest that mixed-handedness may be a *marker* of some difference in brain structure and functionality, resulting in poorer outcomes on a number of dimensions of development. Whatever the exact route, the poorer performance observed in mixed-handed children before they enter school appears to persist out to age 14.

Our finding of negative effects for being a left-handed boy at school entry age echoes the work of Johnston et al. (2007) on a smaller sample of Australian children of the same age. But in contrast to this work, we are able to follow children into later childhood, where we find that by ages 11 and 14, at which we look at cognitive outcomes only, the penalty to being left-handed for boys has disappeared. It still remains for girls, for whom there is no sign of catch-up, and is primarily focused at the lower part of the ability distribution. Given the association found in other studies of cognitive performance in mid-childhood and later labour market outcomes (Heckman et al. 2006, Blanden et al.2007), our findings might provide a possible answer to the paradox that at early ages left-handed boys suffer, whilst in terms of earnings as adults, they do better than their right-handed counterparts. However, for girls the deficits persist into adulthood. Our research suggests that the differences across genders emerge by mid-childhood.

Finally, our results suggest that schools could use mixed-handedness as a marker for children who are likely to need greater intervention (see also Sattler 2001). As tests for mixed-handedness are simple to administer, they would be a cheap way of identifying children who otherwise might slip behind their peers.

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Table 1: Multinomial logit model of handedness

	Left-handed		Mixed-handed	
Female	-0.46***	(0.07)	-0.64***	(0.08)
Heritability				
Mother left-handed	0.80***	(0.11)	0.30**	(0.14)
Mother mixed-hand.	0.59***	(0.16)	0.48***	(0.18)
Mother's handedness missing	0.66**	(0.27)	-0.39*	(0.23)
Father left-handed	0.31***	(0.11)	0.09	(0.13)
Father mixed-handed	-0.40*	(0.22)	0.21	(0.20)
Father's handedness missing	-0.28	(0.25)	0.45**	(0.20)
Insults to child's brain				
1st pregnancy	-0.05	(0.08)	0.11	(0.09)
4th+ pregnancy	-0.18	(0.11)	0.26**	(0.12)
#pregnancies missing	0.04	(0.24)	0.15	(0.26)
Caesarean section w/o labour	-0.05	(0.17)	-0.23	(0.21)
Caesarean section with labour	0.34**	(0.17)	0.35*	(0.19)
Caesarean, type unknown	-0.16	(0.25)	0.17	(0.25)
Caesarean missing	0.11	(0.15)	-0.13	(0.18)
Birth weight/gestation	-0.01**	(0.00)	-0.01***	(0.00)
Birth weight/gestation missing	0.29	(0.28)	-0.29	(0.40)
CCEI at 18 weeks gestation	0.01***	(0.00)	0.01**	(0.01)
CCEI missing	-0.03	(0.11)	0.22*	(0.12)
Fall/drop 6-15 months	0.01	(0.08)	0.10	(0.09)
Fall/drop missing	0.01	(0.15)	0.11	(0.17)
Parenting				
Parenting 24 months	0.03*	(0.01)	-0.04**	(0.02)
Parenting missing	0.09	(0.12)	-0.20	(0.15)
Socio-economic status (SES)				
Father's occup.: managerial	0.01	(0.13)	-0.21	(0.15)
Father's occup.: skilled non-manual	0.05	(0.15)	-0.10	(0.18)
Father's occup.: skilled manual	0.08	(0.14)	-0.01	(0.16)
Father's occup.: semi-skilled manual	-0.03	(0.17)	-0.21	(0.20)
Father's occup.: unskilled manual	0.21	(0.23)	-0.35	(0.30)
Father's occupational class missing	-0.04	(0.19)	-0.10	(0.21)
Mother's age	-0.00	(0.01)	-0.02**	(0.01)
Mother's age missing	1.29	(0.90)	-30.19	(4.7×10^6)
Mother has O-level	-0.05	(0.10)	-0.03	(0.11)
Mother has A-level	-0.26**	(0.12)	-0.12	(0.13)
Mother has degree	-0.09	(0.14)	-0.16	(0.17)
Mother's education missing	-0.36	(0.43)	-0.07	(0.39)
Housing tenure: rented	-0.13	(0.16)	-0.00	(0.17)
Housing tenure: council	0.11	(0.13)	0.24*	(0.13)
Housing tenure: other	0.12	(0.24)	0.15	(0.27)
Housing tenure missing	-0.16	(0.14)	0.10	(0.16)
Ln(income)	0.02	(0.09)	-0.06	(0.10)
Income missing	-0.01	(0.14)	0.20	(0.15)
#siblings at 47 months	0.04	(0.04)	-0.05	(0.05)
#siblings missing	-0.01	(0.13)	-0.14	(0.15)
Non-white	-0.11	(0.18)	-0.78***	(0.26)
Ethnicity missing	-0.18	(0.20)	0.11	(0.20)
Observations	9980		9980	
Pseudo R-squared	0.0283			
F-test: SES variables = 0	19.99		40.00	
Prob > F	0.584		0.0108	

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%
CCEI = Crown Crisp Experiential Index (indicator of maternal psychopathology)

Table 2: Estimates of the association between handedness and cognitive ability, motor skills and behavioural outcomes

	Entry assess., age 5	Key Stage 1, age 7	Key Stage 2, age 11	Key Stage 3, age 14	WISC (IQ), age 8	Language score at 38 months	Social develop. score at 42 months	Fine motor score at 42 months	Gross motor score at 42 months	Total behaviour score at 81 months	Pro-social behaviour sub-score at 81 months
I. Controlling only for gender											
Left	**-0.63**	**-0.73****	**-1.22*****	**-1.38*****	**-1.05****	**-0.42**	**-0.41**	**-0.52**	**-0.62***	**-0.59**	**0.31**
	(0.40)	(0.35)	(0.36)	(0.38)	(0.46)	(0.37)	(0.33)	(0.32)	(0.35)	(0.42)	(0.37)
Mixed	**-2.92*****	**-1.46*****	**-2.01*****	**-2.09*****	**-2.06*****	**-1.66*****	**-2.42*****	**-3.30*****	**-1.99*****	**-2.19*****	**-1.05****
	(0.48)	(0.44)	(0.45)	(0.47)	(0.54)	(0.49)	(0.44)	(0.42)	(0.45)	(0.53)	(0.47)
Adjusted R-squared	0.03	0.02	0.00	0.01	0.00	0.02	0.08	0.07	0.01	0.01	0.03
II. Controls for sex and socio-economic status											
Left	**-0.31**	**-0.46**	**-0.83****	**-0.94*****	**-0.77***	**-0.37**	**-0.40**	**-0.41**	**-0.66***	**-0.49**	**0.30**
	(0.37)	(0.33)	(0.33)	(0.33)	(0.43)	(0.36)	(0.33)	(0.31)	(0.35)	(0.42)	(0.37)
Mixed	**-2.37*****	**-0.72***	**-1.24*****	**-1.24*****	**-1.37*****	**-1.53*****	**-2.44*****	**-3.15*****	**-2.04*****	**-1.84*****	**-1.13****
	(0.44)	(0.40)	(0.41)	(0.40)	(0.49)	(0.49)	(0.44)	(0.42)	(0.45)	(0.53)	(0.47)
Adjusted R-squared	0.17	0.17	0.21	0.25	0.17	0.04	0.09	0.09	0.01	0.04	0.03
III. Controls for sex, socio-economic status and parenting											
Left	**-0.36**	**-0.48**	**-0.86*****	**-0.97*****	**-0.85****	**-0.46**	**-0.50**	**-0.52***	**-0.75****	**-0.52**	**0.25**
	(0.37)	(0.32)	(0.33)	(0.33)	(0.43)	(0.36)	(0.32)	(0.31)	(0.34)	(0.42)	(0.36)
Mixed	**-2.30*****	**-0.69***	**-1.18*****	**-1.21*****	**-1.27*****	**-1.32*****	**-2.28*****	**-2.98*****	**-1.91*****	**-1.74*****	**-1.03****
	(0.44)	(0.40)	(0.41)	(0.40)	(0.49)	(0.49)	(0.44)	(0.41)	(0.45)	(0.53)	(0.47)
Adjusted R-squared	0.18	0.18	0.21	0.26	0.18	0.08	0.11	0.12	0.03	0.04	0.05
IV. Controls for sex, socio-economic status, parenting and insults to child's brain											
Left	**-0.28**	**-0.41**	**-0.80****	**-0.87*****	**-0.80***	**-0.42**	**-0.45**	**-0.46**	**-0.69****	**-0.37**	**0.29**
	(0.37)	(0.32)	(0.32)	(0.33)	(0.42)	(0.36)	(0.32)	(0.31)	(0.34)	(0.41)	(0.36)
Mixed	**-2.22*****	**-0.60**	**-1.09*****	**-1.12*****	**-1.22****	**-1.27*****	**-2.22*****	**-2.93*****	**-1.86*****	**-1.58*****	**-0.95****
	(0.44)	(0.40)	(0.41)	(0.41)	(0.49)	(0.48)	(0.44)	(0.41)	(0.45)	(0.53)	(0.47)
Adjusted R-squared	0.18	0.19	0.22	0.27	0.19	0.08	0.12	0.13	0.03	0.09	0.05
V. Controls for sex, socio-economic status, parenting, insults to child's brain and heritability											
Left	**-0.23**	**-0.34**	**-0.78****	**-0.84*****	**-0.81***	**-0.40**	**-0.45**	**-0.42**	**-0.64***	**-0.36**	**0.27**
	(0.37)	(0.32)	(0.32)	(0.33)	(0.43)	(0.35)	(0.32)	(0.31)	(0.35)	(0.42)	(0.37)
Mixed	**-2.19*****	**-0.56**	**-1.07*****	**-1.07*****	**-1.24****	**-1.25*****	**-2.22*****	**-2.91*****	**-1.87*****	**-1.53*****	**-0.96****
	(0.44)	(0.40)	(0.41)	(0.40)	(0.49)	(0.48)	(0.44)	(0.41)	(0.45)	(0.53)	(0.47)
Adjusted R-squared	0.19	0.19	0.22	0.27	0.19	0.08	0.12	0.13	0.03	0.09	0.05
Observations	6822	8812	8405	7735	5776	9038	9965	9970	9979	6868	7690

Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. WISC = Wechsler Intelligence Scale for Children.

Table 3a: Estimates of the association between handedness and child outcomes for boys

	Entry assess., age 5	Key Stage 1, age 7	Key Stage 2, age 11	Key Stage 3, age 14	WISC (IQ), age 8	Language score at 38 months	Social develop. score at 42 months	Fine motor score at 42 months	Gross motor score at 42 months	Total behaviour score at 81 months	Pro-social behaviour sub-score at 81 months
I. No controls											
Left	**-1.33****	**-0.48**	**-0.96****	**-1.15****	**-1.26****	**-0.84**	**-0.75***	**-0.69**	**-0.68**	**-0.41**	**-0.15**
	(0.53)	(0.47)	(0.49)	(0.51)	(0.63)	(0.52)	(0.45)	(0.44)	(0.45)	(0.55)	(0.51)
Mixed	**-2.57*****	**-0.35**	**-1.22****	**-1.26****	**-1.47****	**-2.13*****	**-2.73*****	**-3.56*****	**-1.80*****	**-2.15*****	**-1.64*****
	(0.57)	(0.55)	(0.56)	(0.59)	(0.69)	(0.66)	(0.58)	(0.54)	(0.54)	(0.69)	(0.63)
Adjusted R-squared	0.01	-0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
II. Controls for socio-economic status											
Left	**-0.99****	**-0.24**	**-0.61**	**-0.66**	**-0.82**	**-0.78**	**-0.81***	**-0.63**	**-0.75***	**-0.24**	**-0.18**
	(0.50)	(0.44)	(0.45)	(0.45)	(0.59)	(0.52)	(0.45)	(0.44)	(0.45)	(0.55)	(0.51)
Mixed	**-2.19*****	**0.06**	**-0.82**	**-0.88***	**-1.03**	**-2.17*****	**-2.88*****	**-3.61*****	**-1.91*****	**-1.86*****	**-1.77*****
	(0.54)	(0.51)	(0.52)	(0.52)	(0.64)	(0.67)	(0.58)	(0.55)	(0.54)	(0.69)	(0.62)
Adjusted R-squared	0.13	0.15	0.20	0.24	0.16	0.02	0.02	0.02	0.01	0.02	0.01
III. Controls for socio-economic status and parenting											
Left	**-1.03****	**-0.25**	**-0.64**	**-0.69**	**-0.94**	**-0.86***	**-0.92****	**-0.74***	**-0.82***	**-0.27**	**-0.24**
	(0.50)	(0.44)	(0.45)	(0.44)	(0.59)	(0.51)	(0.45)	(0.43)	(0.44)	(0.55)	(0.51)
Mixed	**-2.06*****	**0.14**	**-0.72**	**-0.83**	**-0.90**	**-1.84*****	**-2.56*****	**-3.31*****	**-1.71*****	**-1.75****	**-1.60*****
	(0.54)	(0.51)	(0.52)	(0.52)	(0.64)	(0.66)	(0.56)	(0.54)	(0.54)	(0.69)	(0.62)
Adjusted R-squared	0.14	0.16	0.21	0.25	0.17	0.06	0.06	0.06	0.03	0.02	0.02
IV. Controls for socio-economic status, parenting and insults to child’s brain											
Left	**-0.93***	**-0.18**	**-0.59**	**-0.59**	**-0.91**	**-0.83**	**-0.82***	**-0.67**	**-0.77***	**-0.04**	**-0.18**
	(0.49)	(0.44)	(0.45)	(0.44)	(0.59)	(0.52)	(0.45)	(0.43)	(0.44)	(0.54)	(0.51)
Mixed	**-2.00*****	**0.16**	**-0.68**	**-0.79**	**-0.86**	**-1.83*****	**-2.51*****	**-3.30*****	**-1.70*****	**-1.69****	**-1.57****
	(0.54)	(0.51)	(0.52)	(0.52)	(0.65)	(0.66)	(0.56)	(0.54)	(0.54)	(0.68)	(0.62)
Adjusted R-squared	0.15	0.16	0.21	0.25	0.17	0.06	0.06	0.07	0.03	0.07	0.02
V. Controls for socio-economic status, parenting, insults to child’s brain and heritability											
Left	**-0.85***	**-0.05**	**-0.55**	**-0.56**	**-0.92**	**-0.79**	**-0.81***	**-0.67**	**-0.71**	**-0.02**	**-0.21**
	(0.49)	(0.44)	(0.44)	(0.44)	(0.59)	(0.51)	(0.45)	(0.43)	(0.45)	(0.55)	(0.51)
Mixed	**-1.96*****	**0.24**	**-0.64**	**-0.77**	**-0.89**	**-1.78*****	**-2.51*****	**-3.25*****	**-1.70*****	**-1.57****	**-1.57****
	(0.54)	(0.51)	(0.52)	(0.53)	(0.65)	(0.66)	(0.57)	(0.54)	(0.54)	(0.68)	(0.62)
Adjusted R-squared	0.15	0.17	0.21	0.25	0.17	0.06	0.06	0.07	0.03	0.07	0.02
Observations	3542	4518	4284	3948	2899	4640	5154	5157	5166	3506	3936

Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. WISC = Wechsler Intelligence Scale for Children.

Table 3b: Estimates of the association between handedness and child outcomes for girls

	Entry assess., age 5	Key Stage 1, age 7	Key Stage 2, age 11	Key Stage 3, age 14	WISC (IQ), age 8	Language score at 38 months	Social develop. score at 42 months	Fine motor score at 42 months	Gross motor score at 42 months	Total behaviour score at 81 months	Pro-social behaviour sub-score at 81 months
I. No controls											
Left	**0.44**	**-1.03***	**-1.55*** **	**-1.66*** **	**-0.72**	**0.16**	**0.08**	**-0.28**	**-0.54**	**-0.85**	**0.93***
	(0.60)	(0.53)	(0.54)	(0.57)	(0.69)	(0.48)	(0.46)	(0.45)	(0.55)	(0.67)	(0.52)
Mixed	**-3.62*** **	**-3.34*** **	**-3.36*** **	**-3.49*** **	**-3.05*** **	**-0.90**	**-1.93*** **	**-2.86*** **	**-2.32*** **	**-2.24*** **	**-0.09**
	(0.86)	(0.70)	(0.76)	(0.76)	(0.87)	(0.70)	(0.68)	(0.63)	(0.82)	(0.83)	(0.70)
Adjusted R-squared	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
II. Controls for socio-economic status											
Left	**0.66**	**-0.74**	**-1.11****	**-1.32*** **	**-0.79**	**0.15**	**0.08**	**-0.17**	**-0.58**	**-0.83**	**0.89***
	(0.56)	(0.48)	(0.48)	(0.49)	(0.61)	(0.48)	(0.45)	(0.44)	(0.55)	(0.65)	(0.52)
Mixed	**-2.72*** **	**-2.05*** **	**-2.00*** **	**-1.85*** **	**-1.94*** **	**-0.52**	**-1.71****	**-2.36*** **	**-2.31*** **	**-1.61***	**0.03**
	(0.75)	(0.63)	(0.66)	(0.65)	(0.75)	(0.69)	(0.68)	(0.63)	(0.81)	(0.84)	(0.71)
Adjusted R-squared	0.16	0.17	0.21	0.26	0.19	0.03	0.01	0.04	0.00	0.05	0.00
III. Controls for socio-economic status and parenting											
Left	**0.59**	**-0.75**	**-1.14****	**-1.34*** **	**-0.83**	**0.06**	**0.02**	**-0.26**	**-0.67**	**-0.86**	**0.85***
	(0.56)	(0.48)	(0.48)	(0.49)	(0.61)	(0.46)	(0.45)	(0.43)	(0.55)	(0.65)	(0.52)
Mixed	**-2.75*** **	**-2.05*** **	**-1.98*** **	**-1.86*** **	**-1.91****	**-0.49**	**-1.70****	**-2.35*** **	**-2.30*** **	**-1.56***	**0.01**
	(0.75)	(0.63)	(0.66)	(0.65)	(0.75)	(0.69)	(0.69)	(0.63)	(0.81)	(0.85)	(0.70)
Adjusted R-squared	0.17	0.17	0.22	0.27	0.20	0.07	0.03	0.06	0.02	0.05	0.01
IV. Controls for socio-economic status, parenting and insults to child's brain											
Left	**0.61**	**-0.73**	**-1.17****	**-1.33*** **	**-0.69**	**0.14**	**0.03**	**-0.20**	**-0.59**	**-0.81**	**0.91***
	(0.55)	(0.48)	(0.47)	(0.49)	(0.61)	(0.46)	(0.45)	(0.43)	(0.55)	(0.63)	(0.51)
Mixed	**-2.57*** **	**-1.81*** **	**-1.82*** **	**-1.62****	**-1.83****	**-0.30**	**-1.65****	**-2.21*** **	**-2.16*** **	**-1.28**	**0.15**
	(0.73)	(0.62)	(0.66)	(0.63)	(0.74)	(0.66)	(0.68)	(0.62)	(0.80)	(0.84)	(0.70)
Adjusted R-squared	0.18	0.19	0.23	0.28	0.20	0.07	0.03	0.07	0.02	0.10	0.02
V. Controls for socio-economic status, parenting, insults to child's brain and heritability											
Left	**0.61**	**-0.71**	**-1.17****	**-1.34*** **	**-0.73**	**0.15**	**0.04**	**-0.16**	**-0.57**	**-0.79**	**0.90***
	(0.55)	(0.48)	(0.47)	(0.49)	(0.61)	(0.46)	(0.45)	(0.43)	(0.55)	(0.63)	(0.51)
Mixed	**-2.57*** **	**-1.84*** **	**-1.83*** **	**-1.62****	**-1.86****	**-0.30**	**-1.64****	**-2.18*** **	**-2.14*** **	**-1.26**	**0.16**
	(0.73)	(0.62)	(0.66)	(0.63)	(0.73)	(0.67)	(0.68)	(0.62)	(0.80)	(0.84)	(0.70)
Adjusted R-squared	0.18	0.19	0.23	0.28	0.21	0.07	0.03	0.07	0.02	0.10	0.02
Observations	3280	4294	4121	3787	2877	4398	4811	4813	4813	3362	3754

Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. WISC = Wechsler Intelligence Scale for Children.

Table 4: Quantile regression estimates for cognitive ability, fine motor skills and behaviour; handedness interacted with child's sex

		Quantile								
	OLS	0.10	0.20	0.30	0.40	Median	0.60	0.70	0.80	0.90
Entry Assessment score (n = 6822)										
Boy & left	**-0.80**	**-1.34**	**-0.92**	**-0.41**	**-0.28**	**-0.11**	**0.30**	**-0.90**	**-0.73**	**-1.14***
	(0.49)	(0.91)	(0.66)	(0.66)	(0.65)	(0.68)	(0.55)	(0.60)	(0.67)	(0.69)
Girl & left	**0.63**	**-0.23**	**-0.73**	**0.61**	**1.01**	**0.80**	**0.12**	**1.00**	**0.98**	**1.11**
	(0.55)	(1.07)	(0.81)	(0.80)	(0.79)	(0.83)	(0.67)	(0.73)	(0.81)	(0.82)
Boy & mixed	**-1.96*****	**-0.86**	**-0.34**	**-0.68**	**-1.74****	**-1.18**	**-1.55****	**-2.63*****	**-2.52*****	**-3.01*****
	(0.54)	(1.04)	(0.76)	(0.75)	(0.73)	(0.77)	(0.62)	(0.67)	(0.76)	(0.78)
Girl & mixed	**-2.66*****	**-3.08****	**-2.58****	**-3.09*****	**-3.72*****	**-3.04*****	**-2.03****	**-2.12****	**-1.37**	**-0.95**
	(0.73)	(1.33)	(1.01)	(0.99)	(0.97)	(1.02)	(0.82)	(0.90)	(1.00)	(1.01)
Constant	78.29***	69.80***	69.98***	71.81***	75.53***	76.89***	78.16***	81.28***	84.78***	97.92***
	(2.09)	(4.09)	(3.00)	(2.97)	(2.92)	(3.07)	(2.48)	(2.70)	(2.98)	(3.04)
Key Stage 2 score (n = 8405)										
Boy & left	**-0.54**	**-2.00****	**-0.61**	**-0.58**	**-0.44**	**0.22**	**0.07**	**-0.31**	**-0.22**	**-0.16**
	(0.44)	(0.86)	(0.57)	(0.51)	(0.52)	(0.41)	(0.41)	(0.41)	(0.35)	(0.40)
Girl & left	**-1.08****	**-1.50**	**-1.77*****	**-1.75*****	**-1.51****	**-0.57**	**-1.02****	**-0.54**	**-0.30**	**-0.40**
	(0.47)	(0.99)	(0.67)	(0.60)	(0.61)	(0.48)	(0.48)	(0.48)	(0.41)	(0.47)
Boy & mixed	**-0.61**	**-2.06****	**-0.96**	**-1.45****	**-1.69*****	**0.31**	**0.34**	**-0.08**	**0.36**	**0.40**
	(0.52)	(0.97)	(0.65)	(0.58)	(0.59)	(0.46)	(0.46)	(0.46)	(0.39)	(0.45)
Girl & mixed	**-1.84*****	**-5.07*****	**-2.67*****	**-1.02**	**-1.56****	**-1.22****	**-0.94**	**-1.38****	**-1.49*****	**-1.62*****
	(0.65)	(1.27)	(0.83)	(0.75)	(0.77)	(0.61)	(0.60)	(0.61)	(0.52)	(0.60)
Constant	80.63***	56.65***	68.91***	77.15***	81.15***	85.67***	88.48***	92.04***	94.52***	100.29***
	(1.77)	(3.75)	(2.58)	(2.30)	(2.33)	(1.82)	(1.81)	(1.82)	(1.55)	(1.74)
Key Stage 3 score (n = 7735)										
Boy & left	**-0.53**	**-0.90**	**-0.76**	**-0.70**	**-0.77**	**-0.40**	**-0.48**	**-0.17**	**0.13**	**-0.16**
	(0.44)	(0.90)	(0.65)	(0.57)	(0.49)	(0.51)	(0.47)	(0.45)	(0.46)	(0.48)
Girl & left	**-1.25*****	**-1.62**	**-2.31*****	**-1.68****	**-1.56*****	**-1.03***	**-0.78**	**-0.48**	**0.04**	**-0.50**
	(0.48)	(1.05)	(0.76)	(0.67)	(0.57)	(0.59)	(0.54)	(0.53)	(0.53)	(0.57)
Boy & mixed	**-0.70**	**-2.20****	**-1.54****	**-1.00**	**-0.71**	**-0.66**	**-0.24**	**0.46**	**0.64**	**0.10**
	(0.53)	(1.01)	(0.72)	(0.64)	(0.54)	(0.56)	(0.52)	(0.51)	(0.51)	(0.53)
Girl & mixed	**-1.68*****	**-2.44***	**-1.62***	**-1.27**	**-1.57****	**-1.39***	**-1.19***	**-1.53****	**-0.59**	**-0.54**
	(0.63)	(1.30)	(0.94)	(0.83)	(0.71)	(0.73)	(0.68)	(0.66)	(0.66)	(0.69)
Constant	77.77***	57.21***	64.99***	73.91***	77.21***	80.97***	82.81***	85.45***	91.02***	97.54***
	(1.86)	(3.93)	(2.91)	(2.56)	(2.17)	(2.25)	(2.07)	(2.00)	(2.03)	(2.16)

WISC score at F@8 (n = 5776)										
Boy & left	**-0.87**	**-2.19****	**-2.11*****	**-1.73****	**-1.20***	**-0.65**	**0.20**	**0.55**	**-0.29**	**1.36***
	(0.59)	(0.99)	(0.70)	(0.76)	(0.65)	(0.64)	(0.60)	(0.64)	(0.69)	(0.73)
Girl & left	**-0.72**	**-1.89**	**-1.21**	**-0.09**	**-0.29**	**-0.37**	**-0.27**	**-0.04**	**0.15**	**-0.04**
	(0.61)	(1.17)	(0.82)	(0.89)	(0.76)	(0.75)	(0.71)	(0.76)	(0.81)	(0.84)
Boy & mixed	**-0.88**	**-1.41**	**-1.55***	**-1.62***	**-1.60****	**-1.14**	**-0.83**	**0.13**	**-0.41**	**-0.41**
	(0.65)	(1.19)	(0.83)	(0.91)	(0.78)	(0.76)	(0.72)	(0.77)	(0.83)	(0.87)
Girl & mixed	**-1.84****	**-1.96**	**-2.89*****	**-2.52****	**-1.05**	**-0.66**	**-1.09**	**-1.41**	**-0.83**	**-2.61****
	(0.73)	(1.44)	(1.06)	(1.16)	(0.99)	(0.97)	(0.92)	(0.99)	(1.03)	(1.12)
Constant	78.91***	68.48***	68.91***	73.17***	75.04***	77.22***	80.08***	82.93***	88.13***	91.99***
	(2.35)	(4.55)	(3.16)	(3.46)	(2.98)	(2.92)	(2.74)	(2.95)	(3.11)	(3.21)
Fine motor score at 42 months (n = 9970)										
Boy & left	**-0.60**	**-2.24*****	**-1.14**	**-0.92***	**-0.64**	**-0.35**	**0.11**	**-0.32**	**-0.40**	**0.00**
	(0.43)	(0.81)	(0.71)	(0.55)	(0.52)	(0.45)	(0.39)	(0.30)	(0.25)	(0.00)
Girl & left	**-0.19**	**0.64**	**0.62**	**-0.38**	**-0.55**	**-0.40**	**-0.62**	**-0.31**	**-0.06**	**-0.00**
	(0.43)	(0.97)	(0.85)	(0.66)	(0.63)	(0.54)	(0.46)	(0.36)	(0.30)	(0.00)
Boy & mixed	**-3.24*****	**-6.27*****	**-4.75*****	**-4.21*****	**-3.74*****	**-3.17*****	**-2.45*****	**-2.50*****	**-1.89*****	**-2.46*****
	(0.54)	(0.91)	(0.80)	(0.62)	(0.59)	(0.50)	(0.43)	(0.34)	(0.29)	(0.00)
Girl & mixed	**-2.34*****	**-3.17*****	**-3.71*****	**-3.07*****	**-2.63*****	**-2.17*****	**-1.77*****	**-1.23*****	**-1.04*****	**0.00**
	(0.62)	(1.19)	(1.04)	(0.82)	(0.77)	(0.66)	(0.57)	(0.45)	(0.38)	(0.00)
Constant	82.76***	63.43***	70.05***	75.04***	76.71***	81.38***	86.19***	91.05***	98.57***	110.55***
	(1.81)	(3.57)	(3.11)	(2.45)	(2.32)	(1.99)	(1.71)	(1.33)	(1.10)	(0.00)
Total behavioural score at 81 months (n = 6868)										
Boy & left	**-0.07**	**-0.46**	**-1.09**	**-0.52**	**-0.37**	**0.26**	**0.02**	**0.69**	**0.62**	**0.09**
	(0.55)	(1.11)	(0.82)	(0.75)	(0.66)	(0.50)	(0.53)	(0.47)	(0.51)	(0.41)
Girl & left	**-0.79**	**-3.17****	**-2.08****	**-0.71**	**-0.06**	**0.31**	**-0.03**	**0.48**	**0.38**	**0.94***
	(0.64)	(1.30)	(0.98)	(0.89)	(0.78)	(0.60)	(0.63)	(0.56)	(0.61)	(0.49)
Boy & mixed	**-1.63****	**-3.88*****	**-3.35*****	**-1.84****	**-1.98*****	**-0.89**	**-0.75**	**-0.81**	**-1.02***	**-0.41**
	(0.68)	(1.26)	(0.95)	(0.86)	(0.75)	(0.58)	(0.61)	(0.54)	(0.59)	(0.48)
Girl & mixed	**-1.32**	**-6.14*****	**-2.34***	**-0.70**	**-0.38**	**-0.98**	**-1.15**	**-0.86**	**-0.24**	**1.24****
	(0.83)	(1.58)	(1.22)	(1.11)	(0.96)	(0.74)	(0.78)	(0.69)	(0.75)	(0.60)
Constant	-113.50***	-138.32***	-129.26***	-120.16***	-112.93***	-107.88***	-104.57***	-103.65***	-101.53***	-96.50***
	(2.35)	(5.06)	(3.75)	(3.38)	(2.93)	(2.25)	(2.38)	(2.09)	(2.24)	(1.82)

Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. WISC = Wechsler Intelligence Scale for Children.
Controls are gender, socio-economic status, heritability, insults to child's brain and parenting.

Table 5: Estimates of the association between handedness and Key Stage 2 and 3 results, controlling for prior attainment

	Key Stage 2, age 11		Key Stage 3, age 14	
Boy & left	**-0.40**	(0.31)	**-0.03**	(0.27)
Girl & left	**-0.65****	(0.33)	**-0.62****	(0.28)
Boy & mixed	**-0.76****	(0.36)	**0.21**	(0.33)
Girl & mixed	**-0.87***	(0.47)	**-0.15**	(0.39)
Key Stage 1 score	**0.70*****	(0.01)		
KS1 score missing	0.39	(0.66)		
Key Stage 2 score			**0.76*****	(0.01)
KS2 score missing			-8.75***	(0.83)
Observations	8405		7735	
Adjusted R-squared	0.60		0.73	

Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.
Controls are gender, socio-economic status, heritability, insults to child’s brain and parenting.

Table 6: Estimates of the association between handedness and child outcomes using the individual components of handedness measure to define handedness

	Entry assess., age 5	Key Stage 1, age 7	Key Stage 2, age 11	Key Stage 3, age 14	WISC (IQ), age 8	Language score at 38 months	Social develop. score at 42 months	Fine motor score at 42 months	Gross motor score at 42 months	Total behaviour score at 81 months	Pro-social behaviour sub-score at 81 months
A. Drawing											
Left	**-0.54**	**-0.46**	**-0.98*****	**-1.14*****	**-1.07*****	**-0.66***	**-0.81****	**-0.82*****	**-0.76****	**-0.60**	**0.22**
	(0.36)	(0.32)	(0.32)	(0.32)	(0.41)	(0.35)	(0.32)	(0.31)	(0.34)	(0.40)	(0.36)
Mixed	**-1.68*****	**-0.80****	**-0.87*****	**-0.89*****	**-0.43**	**-1.09*****	**-2.08*****	**-2.35*****	**-1.60*****	**-1.23*****	**-0.52**
	(0.37)	(0.33)	(0.33)	(0.33)	(0.41)	(0.39)	(0.35)	(0.32)	(0.35)	(0.44)	(0.40)
Component missing	-3.40	-3.98	-1.04	-3.84	0.91	0.27	-10.78**	-6.81*	-6.95	-2.64	0.28
	(4.03)	(2.61)	(1.84)	(3.34)	(2.38)	(1.91)	(4.87)	(3.68)	(5.13)	(2.40)	(2.71)
Adjusted R-squared	0.19	0.19	0.22	0.27	0.19	0.08	0.12	0.13	0.03	0.09	0.05
#left	751	969	910	848	644	961	1080	1081	1081	733	828
#mixed	730	921	866	823	557	924	1045	1046	1049	674	768
#component missing	11	16	15	12	8	13	17	17	17	12	11
B. Colouring in											
Left	**-0.48**	**-0.44**	**-0.91*****	**-1.09*****	**-1.07****	**-0.65***	**-0.80****	**-0.81*****	**-0.94*****	**-0.74***	**0.25**
	(0.37)	(0.32)	(0.32)	(0.32)	(0.42)	(0.36)	(0.32)	(0.31)	(0.34)	(0.41)	(0.36)
Mixed	**-1.50*****	**-0.47**	**-0.71****	**-0.75****	**-0.68**	**-0.90****	**-1.87*****	**-2.40*****	**-1.69*****	**-0.34**	**-0.40**
	(0.39)	(0.35)	(0.35)	(0.35)	(0.43)	(0.42)	(0.37)	(0.35)	(0.39)	(0.46)	(0.43)
Component missing	-4.04***	-6.48***	-4.15**	-8.42***	-3.23**	-8.69***	-15.50***	-16.82***	-10.99***	7.48***	-4.34**
	(1.47)	(1.52)	(1.74)	(1.88)	(1.47)	(2.67)	(2.00)	(1.69)	(2.17)	(2.02)	(1.98)
Adjusted R-squared	0.19	0.19	0.22	0.27	0.19	0.08	0.13	0.15	0.04	0.09	0.05
#left	741	948	897	831	635	952	1065	1066	1066	727	820
#mixed	614	777	728	696	468	774	886	887	889	575	652
#component missing	45	63	48	50	40	52	74	74	74	39	47

C. Brushing teeth											
Left	-0.56	-0.42	-1.00***	-0.91***	-1.12***	-0.38	-0.41	-0.55*	-0.41	-0.30	0.04
	(0.37)	(0.32)	(0.32)	(0.32)	(0.42)	(0.35)	(0.32)	(0.31)	(0.34)	(0.41)	(0.37)
Mixed	-1.02**	-1.08***	-0.81**	-1.09***	-0.51	-0.80*	-1.28***	-1.22***	-1.11***	-1.31***	-0.25
	(0.41)	(0.36)	(0.36)	(0.37)	(0.45)	(0.43)	(0.37)	(0.35)	(0.39)	(0.48)	(0.41)
Component missing	-2.13*	-3.29***	-1.72*	-2.44**	-0.04	-3.58**	-10.90***	-7.43***	-5.76***	3.29**	-4.26***
	(1.16)	(1.19)	(1.04)	(1.02)	(1.22)	(1.70)	(1.64)	(1.51)	(1.69)	(1.39)	(1.32)
Adjusted R-squared	0.18	0.19	0.22	7735	0.19	0.08	0.13	0.13	0.04	0.09	0.05
#left	727	928	871	0.27	617	931	1050	1051	1051	720	802
#mixed	572	709	681	817	459	745	827	827	827	549	621
#component missing	67	86	79	630	56	87	102	102	102	59	68
				71							
D. Throwing a ball											
Left	-0.16	0.04	-0.53	-0.45	-0.58	-0.28	-0.16	-0.53	-0.83**	-0.55	0.14
	(0.40)	(0.35)	(0.36)	(0.35)	(0.47)	(0.38)	(0.34)	(0.33)	(0.38)	(0.46)	(0.41)
Mixed	-0.54*	-0.53**	-0.43*	-0.68***	-0.37	-0.60**	-1.08***	-1.46***	-1.18***	-1.32***	-0.68**
	(0.28)	(0.25)	(0.24)	(0.25)	(0.31)	(0.26)	(0.24)	(0.24)	(0.25)	(0.30)	(0.29)
Component missing	1.96***	-1.37*	-0.84	0.13	-0.99	-1.02	-4.11***	-3.27***	-4.21***	2.77***	-2.37***
	(0.75)	(0.72)	(0.74)	(0.79)	(0.85)	(0.81)	(1.04)	(0.98)	(1.07)	(1.03)	(0.91)
Adjusted R-squared	0.18	0.19	0.22	0.27	0.19	0.08	0.12	0.13	0.04	0.09	0.05
#left	587	741	690	639	490	736	830	832	832	572	634
#mixed	1410	1832	1756	1626	1134	1886	2093	2093	2096	1389	1569
#component missing	107	149	139	123	111	145	165	165	165	102	117
Observations	6822	8812	8405	7735	5776	9038	9965	9970	9979	6868	7690

Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. WISC = Wechsler Intelligence Scale for Children.
Controls are gender, socio-economic status, heritability, insults to child's brain and parenting.

Appendix

Table A1: Descriptive statistics for the data set for which child's handedness is not missing (9980 observations)

	Right		**Left**		**Mixed**		**Total**	
Proportion	0.823		0.103		0.074		1	
Observations	8217		1026		737		9980	
	Mean	(St. dev).	Mean	(St. dev.)	Mean	(St. dev.)	Mean	(St. dev.)
Child's gender								
Female	0.50		0.40		0.35		0.48	
Heritability								
Parents' handedness								
Mother right-handed (reference cat.)	0.80		0.70		0.76		0.79	
Mother left-handed	0.07		0.13		0.08		0.07	
Mother mixed-handed	0.03		0.05		0.05		0.04	
Mother's handedness missing	0.10		0.12		0.11		0.10	
Father right-handed (reference cat.)	0.75		0.72		0.70		0.74	
Father left-handed	0.09		0.12		0.10		0.10	
Father mixed-handed	0.04		0.02		0.04		0.03	
Father's handedness missing	0.12		0.14		0.16		0.13	
Insults to child's brain								
Birth order								
1st pregnancy	0.33		0.33		0.36		0.34	
4th+ pregnancy	0.14		0.13		0.16		0.14	
Missing	0.02		0.03		0.03		0.03	
Caesarean section (CS)								
No CS (reference category)	0.849		0.833		0.834		0.847	
CS, never had any labour	0.044		0.043		0.035		0.043	
CS, after being in labour	0.031		0.043		0.045		0.033	
CS, no details about labour	0.021		0.019		0.024		0.021	
Missing	0.054		0.062		0.061		0.056	
Birth weight/gestation	86.4	(12.3)	85.9	(12.8)	85.3	(13.6)	86.3	(12.5)
Missing	0.01		0.02		0.01		0.01	
CCEI at 18 weeks gestation	13.1	(6.9)	13.8	(7.3)	14.0	(7.3)	13.2	(7.0)
Missing	0.13		0.13		0.16		0.13	
Accidents								
Child dropped or fell between 6 and 15 months	0.22		0.22		0.24		0.22	
Missing	0.06		0.07		0.07		0.06	
Parenting								
Parenting score	14.7	(2.4)	14.7	(2.3)	14.3	(2.5)	14.7	(2.4)
Missing	0.09		0.11		0.10		0.09	

Socio-economic status								
Father's occupational class								
Professional (reference category)	0.11		0.10		0.09		0.10	
Managerial	0.33		0.31		0.26		0.32	
Skilled non-manual	0.12		0.12		0.12		0.12	
Skilled manual	0.26		0.28		0.30		0.26	
Semi-skilled manual	0.08		0.08		0.08		0.08	
Unskilled manual	0.02		0.03		0.02		0.02	
Missing	0.08		0.08		0.12		0.09	
Mother's age at delivery	28.7	(4.7)	28.6	(4.7)	27.8	(4.9)	28.6	(4.7)
Missing	0.001		0.002		0		0.001	
Mother's education								
CSE/none (reference category)	0.16		0.18		0.20		0.17	
Vocational/O-level	0.44		0.46		0.47		0.44	
A-level	0.24		0.21		0.21		0.24	
Degree	0.14		0.14		0.11		0.14	
Missing	0.01		0.01		0.01		0.01	
Housing tenure at 21 months								
Owner occupied (reference cat.)	0.74		0.73		0.67		0.73	
Rented private/housing assoc.	0.06		0.05		0.06		0.06	
Rented from council	0.09		0.11		0.15		0.10	
Other	0.02		0.02		0.02		0.02	
Missing	0.09		0.09		0.10		0.09	
Income (£ per week)	226.4	(95.2)	222.3	(94.9)	212.7	(93.6)	225.0	(95.1)
Missing	0.09		0.10		0.11		0.09	
#siblings at 47 months	1.3	(0.91)	1.3	(0.92)	1.2	(1.03)	1.28	(0.92)
Missing	0.10		0.10		0.10		0.10	
Ethnicity								
Non-white	0.04		0.04		0.02		0.04	
Missing	0.05		0.05		0.08		0.05	

CCEI = Crown Crisp Experiential Index (indicator of maternal psychopathology),
CSE=Certificate of Secondary Education

Table A2: Coefficient estimates for control variables in Table 2

	Entry assess., age 5	Key Stage 1, age 7	Key Stage 2, age 11	Key Stage 3, age 14	WISC (IQ), age 8	Language score at 38 months	Social develop. score at 42 months	Fine motor score at 42 months	Gross motor score at 42 months	Total behaviour score at 81 months	Pro-social behaviour sub-score at 81 months
Left	**-0.23**	**-0.34**	**-0.78****	**-0.84*****	**-0.81***	**-0.40**	**-0.45**	**-0.42**	**-0.64***	**-0.36**	**0.27**
	(0.37)	(0.32)	(0.32)	(0.33)	(0.43)	(0.35)	(0.32)	(0.31)	(0.35)	(0.42)	(0.37)
Mixed	**-2.19*****	**-0.56**	**-1.07*****	**-1.07*****	**-1.24****	**-1.25*****	**-2.22*****	**-2.91*****	**-1.87*****	**-1.53*****	**-0.96****
	(0.44)	(0.40)	(0.41)	(0.40)	(0.49)	(0.48)	(0.44)	(0.41)	(0.45)	(0.53)	(0.47)
Female	3.18***	2.51***	0.61***	1.14***	-0.24	2.44***	5.38***	4.98***	1.54***	2.03***	3.52***
	(0.22)	(0.19)	(0.18)	(0.19)	(0.24)	(0.20)	(0.19)	(0.19)	(0.20)	(0.23)	(0.23)
Heritability											
Mother left-handed	-0.25	-0.80**	-0.53	-0.17	0.35	-0.37	0.09	-0.87**	-0.46	0.05	0.39
	(0.43)	(0.36)	(0.36)	(0.37)	(0.45)	(0.41)	(0.36)	(0.37)	(0.39)	(0.42)	(0.42)
Mother mixed-hand.	-0.29	-0.35	0.40	-0.17	0.23	-0.03	-0.42	-0.10	-0.18	-0.72	-0.02
	(0.56)	(0.53)	(0.50)	(0.51)	(0.62)	(0.52)	(0.56)	(0.50)	(0.53)	(0.66)	(0.59)
Mother's handed. miss.	0.44	0.09	0.46	0.78	-1.17	0.56	0.23	1.56**	-0.15	2.38**	0.71
	(0.77)	(0.76)	(0.76)	(0.71)	(1.01)	(0.79)	(0.70)	(0.70)	(0.70)	(1.08)	(0.88)
Father left-handed	-0.74*	-0.50	-0.53*	-0.97***	0.03	-0.37	-0.17	-0.04	-0.30	-0.36	-0.15
	(0.38)	(0.32)	(0.32)	(0.32)	(0.38)	(0.35)	(0.31)	(0.31)	(0.35)	(0.39)	(0.37)
Father mixed-handed	-0.38	-0.55	-0.55	-0.47	-0.19	-0.09	0.44	0.15	0.79	0.00	1.04*
	(0.60)	(0.54)	(0.49)	(0.51)	(0.59)	(0.57)	(0.49)	(0.48)	(0.52)	(0.61)	(0.58)
Father's handed. miss.	-1.42**	-1.35**	-1.10	-1.38**	0.77	-0.14	0.25	-0.15	1.12*	-2.11**	-0.26
	(0.67)	(0.67)	(0.68)	(0.63)	(0.89)	(0.64)	(0.62)	(0.62)	(0.60)	(0.95)	(0.74)
Insults to child's brain											
1^{st} pregnancy	0.91***	1.05***	0.88***	1.08***	0.37	0.78***	-0.18	0.55**	-0.02	-0.15	-0.43
	(0.26)	(0.23)	(0.22)	(0.23)	(0.29)	(0.23)	(0.22)	(0.22)	(0.23)	(0.28)	(0.27)
4^{th}+ pregnancy	-0.15	-0.68**	-0.39	-0.58*	-0.03	0.16	0.11	0.16	0.38	0.63	0.15
	(0.36)	(0.31)	(0.31)	(0.31)	(0.39)	(0.38)	(0.32)	(0.32)	(0.32)	(0.40)	(0.39)
#pregnancies missing	0.20	-0.58	-1.23	-1.44*	-2.76***	1.07	0.38	0.86	0.50	0.76	0.25
	(0.81)	(0.75)	(0.81)	(0.75)	(1.05)	(0.84)	(0.73)	(0.71)	(0.77)	(1.00)	(0.90)
CS w/o labour	-1.36**	-0.33	-0.24	-0.62	-0.13	-0.88	-0.46	-0.37	-0.51	-1.24**	0.31
	(0.55)	(0.47)	(0.47)	(0.48)	(0.58)	(0.58)	(0.48)	(0.44)	(0.50)	(0.60)	(0.57)
CS with labour	-0.29	-0.60	-0.84	-0.97*	-1.49**	0.34	0.23	0.61	-0.63	-0.68	0.81
	(0.60)	(0.52)	(0.57)	(0.53)	(0.65)	(0.52)	(0.48)	(0.48)	(0.57)	(0.63)	(0.55)

CS, type unknown	-1.48**	-1.84***	-0.98*	-1.22*	0.11	0.10	0.35	1.01*	0.47	-0.12	0.30
	(0.73)	(0.67)	(0.60)	(0.68)	(0.86)	(0.55)	(0.54)	(0.53)	(0.64)	(0.83)	(0.79)
CS missing	-0.94*	-1.78***	-0.94*	-0.89*	-0.32	-0.06	-1.02**	-0.51	-1.02*	-0.58	-0.11
	(0.52)	(0.47)	(0.50)	(0.48)	(0.68)	(0.55)	(0.51)	(0.51)	(0.56)	(0.70)	(0.62)
Birth weight/gestation	0.06***	0.05***	0.04***	0.05***	0.06***	0.01	0.04***	0.05***	0.03***	0.03***	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Birth weight/gest. miss.	2.23*	0.03	2.42***	2.42***	1.56*	0.25	-0.17	0.06	-0.15	-0.30	-0.43
	(1.14)	(0.94)	(0.69)	(0.74)	(0.94)	(0.85)	(1.05)	(1.02)	(1.24)	(1.04)	(1.14)
CCEI at 18 weeks gest.	-0.06***	-0.04***	-0.04***	-0.05***	-0.05**	-0.07***	-0.03**	-0.03**	-0.02*	-0.30***	-0.07***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
CCEI missing	0.51	-0.15	-0.04	0.04	0.45	-0.32	-0.09	-0.06	-0.18	-0.24	-0.08
	(0.34)	(0.32)	(0.31)	(0.32)	(0.39)	(0.35)	(0.31)	(0.31)	(0.33)	(0.43)	(0.37)
Fall/drop 6-15 months	0.20	0.27	0.27	0.55**	0.30	-0.01	-0.03	0.13	-0.30	-1.21***	-0.46*
	(0.27)	(0.23)	(0.23)	(0.23)	(0.28)	(0.23)	(0.22)	(0.22)	(0.23)	(0.28)	(0.27)
Fall/drop missing	-0.77	-0.39	-0.60	-0.81*	0.10	-0.17	0.58	-0.21	-0.30	0.51	0.18
	(0.48)	(0.44)	(0.45)	(0.44)	(0.66)	(0.52)	(0.43)	(0.46)	(0.49)	(0.62)	(0.59)
Parenting											
Parenting 24 months	0.33***	0.24***	0.29***	0.28***	0.41***	0.81***	0.71***	0.73***	0.57***	0.37***	0.45***
	(0.05)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)
Parenting missing	-0.02	-0.62*	-0.48	-0.44	-0.41	-0.83*	-0.25	-0.50	-0.30	-0.02	0.20
	(0.42)	(0.37)	(0.37)	(0.37)	(0.53)	(0.46)	(0.38)	(0.38)	(0.40)	(0.53)	(0.50)
Socio-economic status											
Managerial	-1.26***	-1.60***	-1.36***	-1.81***	-1.50***	-0.23	0.00	0.00	0.52	-0.13	-0.16
	(0.44)	(0.33)	(0.28)	(0.35)	(0.39)	(0.30)	(0.35)	(0.32)	(0.37)	(0.38)	(0.39)
Skilled non-manual	-2.03***	-2.08***	-1.59***	-2.13***	-2.03***	-0.64	-0.05	-0.21	0.76*	0.05	-0.15
	(0.52)	(0.40)	(0.36)	(0.42)	(0.48)	(0.39)	(0.42)	(0.39)	(0.43)	(0.47)	(0.48)
Skilled manual	-2.49***	-2.95***	-2.94***	-3.44***	-3.01***	-0.62*	0.26	-0.08	1.04**	-0.65	0.56
	(0.47)	(0.37)	(0.33)	(0.39)	(0.44)	(0.35)	(0.39)	(0.36)	(0.41)	(0.44)	(0.43)
Semi-skilled manual	-3.11***	-3.24***	-3.59***	-4.21***	-4.30***	-1.09**	0.10	-0.56	0.79	-0.49	0.87
	(0.56)	(0.46)	(0.43)	(0.47)	(0.58)	(0.48)	(0.46)	(0.46)	(0.50)	(0.56)	(0.54)
Unskilled manual	-3.61***	-4.94***	-4.79***	-5.79***	-4.64***	-1.61*	-0.28	-2.19***	0.30	-1.74*	-0.30
	(0.76)	(0.71)	(0.80)	(0.71)	(0.85)	(0.83)	(0.71)	(0.75)	(0.76)	(0.92)	(0.91)
Father’s class missing	-2.17***	-3.19***	-2.97***	-3.97***	-3.67***	-1.48**	0.31	-0.39	0.55	-1.20	-0.48
	(0.67)	(0.56)	(0.54)	(0.57)	(0.70)	(0.69)	(0.56)	(0.53)	(0.60)	(0.75)	(0.65)

Mother's age	0.11***	0.08***	0.09***	0.11***	0.09***	-0.13***	-0.15***	-0.14***	-0.08***	0.04	-0.05*
	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)
Mother's age missing	-1.55	-2.11	-0.05	-0.12	0.00	5.20***	5.56***	2.07	3.62		
	(3.24)	(1.89)	(3.85)	(4.60)	(0.00)	(1.80)	(1.86)	(1.96)	(2.32)		
Mother has O-level	2.07***	2.56***	2.68***	2.61***	2.24***	0.22	0.48*	0.80***	-0.35	0.49	-0.14
	(0.31)	(0.29)	(0.31)	(0.28)	(0.39)	(0.36)	(0.28)	(0.29)	(0.29)	(0.40)	(0.35)
Mother has A-level	3.03***	3.20***	4.29***	4.63***	4.04***	0.56	0.44	1.44***	-1.12***	0.62	-0.47
	(0.38)	(0.33)	(0.34)	(0.33)	(0.44)	(0.40)	(0.33)	(0.33)	(0.33)	(0.44)	(0.40)
Mother has degree	5.62***	5.47***	7.16***	7.84***	7.45***	1.29***	-0.45	0.68*	-1.87***	0.31	-1.88***
	(0.48)	(0.40)	(0.39)	(0.41)	(0.51)	(0.44)	(0.40)	(0.39)	(0.42)	(0.50)	(0.48)
Mother's educ. miss.	-0.43	4.62***	4.63***	4.40***	6.05**	-0.33	1.42	0.20	-0.98	4.04*	1.18
	(1.45)	(1.22)	(1.28)	(1.35)	(2.39)	(1.85)	(1.12)	(1.12)	(1.43)	(2.16)	(2.25)
Housing tenure: rented	-1.35***	-0.63	-0.67	-0.69	0.09	0.08	-0.02	-0.08	0.12	-0.18	-0.64
	(0.51)	(0.43)	(0.42)	(0.44)	(0.58)	(0.43)	(0.41)	(0.41)	(0.39)	(0.57)	(0.53)
Housing tenure: council	-1.62***	-2.55***	-2.86***	-3.09***	-1.59***	-0.28	0.51	-1.01***	0.04	-0.63	-0.18
	(0.41)	(0.39)	(0.42)	(0.38)	(0.53)	(0.45)	(0.34)	(0.38)	(0.37)	(0.54)	(0.46)
Housing tenure: other	-0.41	0.58	1.01	1.35**	0.30	-0.48	0.94	0.15	0.50	-0.07	1.32
	(0.94)	(0.67)	(0.63)	(0.68)	(0.96)	(0.67)	(0.58)	(0.59)	(0.62)	(0.72)	(0.82)
Housing tenure miss.	-0.43	-0.97**	-1.48***	-1.53***	-1.94***	-0.71	-0.44	-1.02**	-0.71	-0.59	-0.60
	(0.45)	(0.41)	(0.42)	(0.40)	(0.56)	(0.50)	(0.42)	(0.41)	(0.47)	(0.58)	(0.53)
Ln(income)	1.98***	1.63***	1.89***	2.42***	1.49***	0.50*	0.88***	0.66***	0.47*	1.30***	0.29
	(0.30)	(0.26)	(0.26)	(0.26)	(0.33)	(0.28)	(0.25)	(0.24)	(0.26)	(0.33)	(0.30)
Income missing	0.25	0.34	-0.41	-0.47	0.41	-0.29	0.28	-0.55	-0.59	-0.01	-0.03
	(0.47)	(0.41)	(0.40)	(0.41)	(0.55)	(0.51)	(0.39)	(0.42)	(0.43)	(0.55)	(0.50)
#siblings at 47 months	-0.88***	-0.53***	-0.32***	-0.32***	-0.60***	-0.11	0.57***	0.16	0.20	0.48***	-0.29*
	(0.14)	(0.12)	(0.12)	(0.12)	(0.16)	(0.15)	(0.12)	(0.11)	(0.12)	(0.19)	(0.17)
#siblings missing	-0.97**	-1.33***	-0.64*	-1.05***	-1.20**	0.13	0.49	0.51	1.56***	-0.30	-0.05
	(0.43)	(0.39)	(0.37)	(0.39)	(0.58)	(0.45)	(0.37)	(0.38)	(0.37)	(0.59)	(0.52)
Non-white	-0.85	1.22**	1.35***	0.80	1.19*	-0.38	0.25	0.68	1.26**	-0.22	-0.07
	(0.65)	(0.55)	(0.51)	(0.55)	(0.70)	(0.53)	(0.50)	(0.50)	(0.49)	(0.75)	(0.61)
Ethnicity missing	0.43	-0.35	-0.11	0.05	-0.42	-0.46	-0.20	0.35	-0.29	0.01	0.48
	(0.65)	(0.60)	(0.63)	(0.59)	(0.72)	(0.71)	(0.55)	(0.54)	(0.61)	(0.82)	(0.71)
Observations	6822	8812	8405	7735	5776	9038	9965	9970	9979	6868	7690
Adjusted R-squared	0.19	0.19	0.22	0.27	0.19	0.08	0.12	0.13	0.03	0.09	0.05

Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.
WISC = Wechsler Intelligence Scale for Children, CS = Caesarean Section, CCEI = Crown Crisp Experiential Index (indicator of maternal psychopathology).

Table A3: Estimates of the association between handedness at age 7 years and child outcomes

	Entry assess., age 5	Key Stage 1, age 7	Key Stage 2, age 11	Key Stage 3, age 14	WISC (IQ), age 8	Language score at 38 months	Social develop. score at 42 months	Fine motor score at 42 months	Gross motor score at 42 months	Total behaviour score at 81 months	Pro-social behaviour sub-score at 81 months
Left at age 7 years	**-0.52**	**-0.41**	**-0.93*****	**-0.81****	**-0.59**	**-0.47**	**-0.29**	**-0.80****	**-0.28**	**-0.65**	**-0.21**
	(0.38)	(0.33)	(0.33)	(0.33)	(0.39)	(0.36)	(0.32)	(0.33)	(0.35)	(0.41)	(0.37)
Handedness at	-1.91***	-1.80***	-1.74***	-2.29***		-1.24***	-1.03***	-0.93***	-0.38	-0.29	-0.33
age 7 years missing	(0.29)	(0.26)	(0.25)	(0.26)		(0.29)	(0.27)	(0.25)	(0.27)	(0.36)	(0.34)
Observations	6822	8812	8405	7735	5776	9038	9965	9970	9979	6868	7690
Adjusted R-squared	0.19	0.19	0.22	0.28	0.19	0.08	0.11	0.12	0.03	0.09	0.05
#left at 7/8/9	638	820	764	708	700	826	905	906	906	696	779
#missing at 7/8/9	1557	1949	1835	1754	0	1941	2356	2356	2360	948	1089

Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. WISC = Wechsler Intelligence Scale for Children. Controls are gender, socio-economic status, heritability, insults to child's brain and parenting.

Table A4: Estimates of the association between handedness and child outcomes using only observations with no missing control variables

	Entry assess., age 5	Key Stage 1, age 7	Key Stage 2, age 11	Key Stage 3, age 14	WISC (IQ), age 8	Language score at 38 months	Social develop. score at 42 months	Fine motor score at 42 months	Gross motor score at 42 months	Total behaviour score at 81 months	Pro-social behaviour sub-score at 81 months
Left	**0.25**	**0.42**	**-0.38**	**-0.05**	**-0.28**	**-0.30**	**-0.40**	**-0.37**	**-0.33**	**-0.14**	**0.17**
	(0.50)	(0.40)	(0.41)	(0.42)	(0.54)	(0.42)	(0.42)	(0.39)	(0.43)	(0.49)	(0.46)
Mixed	**-2.31*****	**-0.08**	**-0.89***	**-1.05****	**-1.33****	**-1.35****	**-1.77*****	**-2.67*****	**-1.83*****	**-1.63****	**-1.69*****
	(0.59)	(0.49)	(0.51)	(0.53)	(0.62)	(0.59)	(0.55)	(0.53)	(0.57)	(0.64)	(0.58)
Observations	3919	5127	4884	4492	3820	5512	5749	5751	5757	4534	4991
Adjusted R-squared	0.17	0.16	0.19	0.23	0.17	0.09	0.12	0.14	0.04	0.10	0.05

Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. WISC = Wechsler Intelligence Scale for Children. Controls are gender, socio-economic status, heritability, insults to child's brain and parenting.