Do differences in sex hormones affect handwriting style? Evidence from digit ratio and sex role identity as determinants of the sex of handwriting

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Abstract

This study investigated whether there could be a biological determinant of the judged gender of handwriting. It further investigated the potential interplay between these variables and sex role identification. The biological marker used was 2D:4D digit ratio (of index to ring finger length) which is negatively associated with prenatal testosterone and positively with prenatal oestrogen. Handwriting samples of 120 participants (half of each sex) were presented on computer to be rated for gender by 20 raters. Feedback on accuracy was given after each trial. These raters accurately identified the gender of two thirds of the sample and the rated difference between the sexes was large ($d = 0.75$). These ratings of handwriting gender correlated significantly with digit ratio and the femininity scale of the BSRI. A more conservative analysis this time within each sex found that women's right hand digit ratio correlated with relative sexuality of handwriting, but there was no corresponding relationship for the males. These findings suggest that prenatal hormonal influences can affect later female handwriting performance and might even affect developmental inter-hemispheric differences, but do not appear to impact on males.
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1. General introduction

In spite of the extensive use of handwriting analysis by industries in many countries (e.g. King & Koehler, 2000; Shackleton & Newell, 1994) there is little solid evidence for a connection between handwriting and personality or occupation (e.g. Eysenck & Gudjonsson, 1986; Furnham & Gunter, 1987; Klimoski & Rafaeli, 1983; Neter & Ben-Shakhar, 1989; Tett & Palmer, 1997). The only research that shows a consistent relationship with handwriting is the judgement of sex of handwriting (e.g. Goodenough, 1945; Hamid & Loewenthal, 1996; Hartley, 1991; Hayes, 1996; Lester, McLaughlin, Cohen, & Dunn, 1977). Most research into handwriting and sex has been conducted in the USA and in Britain, however, Hamid and Loewenthal (1996) also found a consistent difference in the gender of handwriting both in English and Urdu, with similar levels of accuracy of identification (68%). Whereas Western reports of handwriting find that female handwriting has greater circularity (e.g. Lester et al., 1977), handwriting in Urdu was judged to be more ''delicate and decorative'' than for men. Even though there may be slight differences in the manifestations of these sex differences, it is interesting to find a report of a cross-cultural similarity suggesting that differences in handwriting arise not so much from a social context but more from a biological determinant. The present study investigates the likelihood that potential differences in sex hormones are a significant influence on differences in writing styles between the sexes.

One candidate for possible influence is the effect of androgens that ''masculinise'' behaviours and conceivably neural substrates during the critical prenatal period. A particularly sensitive period when there is an increase in androgens is from 7 to 24 weeks with an optimum level in the 18th week (Wilson, 1999). Recent work on prenatal differences in androgen experience has focussed on the possibility of markers that are associated with such androgen production. If these markers are associated with a behaviour, this would suggest that prenatal levels were linked to (or as they are an antecedent, even had a role in causing) this behaviour. Physical measures include waist-to-hip ratios and the ratios between the lengths of the index and ring fingers—often referred to as the 2D:4D ratio.

In the present study we chose the 2D:4D ratio which has already had much recent attention (e.g. Lippa, 2003; Manning, 2002; Manning, Scutt, Wilson, & Lewis-Jones, 1998; Robinson & Manning, 2002). There is a tendency for the ratio in females to be above one with the index finger longer than the ring finger and vice versa in males. Research has shown that from at least 2 years the 2D:4D ratio remains consistent despite fluctuations in hormonal influences during puberty indicating that the prenatal influence of hormones crucially determines the extent of the ratio (Manning, 2002; Manning et al., 1998). Furthermore, to give just one finding from this work, number of sperm is negatively related to 2D:4D in men's right hand, in other words a relatively lower index finger in the right hand is associated with a higher sperm count (Manning et al., 1998). If there is a biological determinant to the sex of handwriting, it seems that a connection between 2D:4D ratio and handwriting style would be a promising candidate for investigation.

A further area of exploration is the relationship between these variables and sex role identification. The Bem Sex Role Inventory (BSRI, Bem, 1974) has been one of the most influential measures of gender differences based as it is on stereotypes of female nurturance and expressiveness and male instrumentality and autonomy. Wiggins and Broughton (1985) demonstrated that the

BSRI feminine scale is strongly related to love, whereas the masculinity scale is associated with dominance. The relationship between the BSRI and finger length ratio and sex of handwriting will be of particular interest. This will allow us to examine whether sex role identification could be associated with prenatal hormonal development or whether it is independent of this. If it were independent, would sex role identification nevertheless exert an influence on the judged gender of handwriting?

2. Method

2.1. Sample

The experiment was in two phases; the first tested participants (referred to as the ''handwriters'') who produced a sample of handwriting and filled in a questionnaire. The second group (the ''raters'') sat at a computer rating the handwriting for gender. The majority of the handwriters were recruited from the School of Psychology's undergraduate experimental requirement programme (EPR) as part of their first year of study. There were 120 participants, half of whom were female. When the data were analysed gender was coded as a dummy variable with males represented by ''1'' and females by ''2''. The handwriters had a mean age of 21.81 years (SD 6.81 years) and ranged in age from 18 to 55 years. There was a minority of left handers (6 male, 7 female) and one male ambidextrous writer. The raters were similarly recruited from the EPR, but these were second year students in order to minimise the possibility of them being familiar with any of the handwriting. There were 20 who volunteered (18 female, 2 male) and these had a mean age was 21.00 years (SD 2.07 years). They ranged in age from 19 to 27 years old.

2.2. Procedure

The handwriters completed a questionnaire, to be described, and then had their 2nd and 4th digit finger lengths measured for both hands. They placed each hand in turn on an A4-size ''sandwich'' of two thin perspexes with a photocopied transparency of a matrix of 1 mm squares lying in between, with the perspexes screwed together. The 10 mm divisions were in slightly bolder ink. Each hand was placed flat, horizontal and with the fingers closed on top of the perspex with the crease at the base of the palm in line with the 0 cm mark. The index and ring fingers were measured from this crease to the tip of the finger.

The raters sat in front of a computer screen and on each trial had to decide by key press how masculine or feminine a sample of handwriting looked on a scale of 1 (very masculine) to 5 (very feminine). Altogether they were shown 120 samples of handwriting. The order of presentation was random for each participant. Each participant made a response in their own time. Once a key was pressed, the sample of handwriting would disappear. This was followed by the screen showing information on the correct gender of the writer of the handwriting. After the experiment was over they were asked ''What characteristics did you use to decide if the handwriting was masculine or feminine?''

2.3. Psychometric predictor

The handwriters were given Bem's Sex Role Inventory (BSRI, Bem, 1974) minus two items that contained the words "feminine" and "masculine". The BSRI contains scales for masculinity, femininity and social desirability (this last scale was not used for analysis). Each scale has 19 characteristics (e.g. "forceful") thought to be representative of that dimension, which are rated on a 7-point scale. One extreme is "Never or almost never true", whereas the other was "Always or almost always true". The test has a test-retest reliability of .90 for both the masculinity and femininity scales.

2.4. Test of handwriting

The BSRI was followed by the handwriting part. The questionnaire had the following statement followed by the passage that had to be copied followed by six dotted lines extending from one side of the margin to the other:

> We want to take a sample of your normal handwriting. Please copy the following passage, writing it as you would normally. Make sure that you use a biro, preferably a **black** biro. Please write along the dotted lines:
> Four score and seven years ago our fathers brought forth on this continent a new nation, conceived in liberty, and dedicated to the proposition that all men are created equal.

2.5. Results and discussion

The sex of participant, the masculinity and femininity scales from the BSRI questionnaire, the 2D:4D ratios for the left and right hands and the ratings of handwriting for gender were intercorrelated for all 120 participants, as shown in Table 1. As found in other studies there was a strong correlation of 0.67 between the sex of the participant and the rating of the gender of their handwriting. Further analysis revealed that 65.67% and 66.08%, respectively, of the handwriting samples of the males and females were correctly identified. This is a level similar to Hamid and Loewenthal (1996) who also had a middle category. The high ratio of female to male raters in the present experiment does not seem to have had a confounding influence on these ratings, whereby female raters may have been better at identifying female handwriting than male hand-

Table 1
Intercorrelations among the principal variables for all participants

Variable	Sex rating	Masculine	Feminine	LH	RH	Mean	SD
Sex	.667***	−.146	.406***	.655***	.634***	–	–
Sex rating of writing		−.039	.281**	.457***	.491***	3.02	.97
Masculine BSRI scale			.138	−.235	−.197*	4.558	.701
Feminine BSRI scale				.437***	.381***	4.832	.518
Left hand (LH) fingers					.855***	1.006	.021
Right hand (RH) fingers						1.007	.020

Note: $N = 120$ in all cells, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

writing. Instead, there is no difference in identification rates of male and female handwriters. Also, Hayes (1996) found that there was no difference between male and female raters in accuracy at rating the sex of handwriting. Our rating was undertaken on a 5-point scale and the middle rating of "3" was given for males and females for 10.41% and 10.83% of the samples, respectively. If one compares these percentages with experiments using a slightly different procedure where a forced response was required (i.e. no middle rating), one might assume (perhaps conservatively) that the present participants would have given 50% of their ratings in each direction, instead of giving a "3" rating. This would adjust the ratings to 70.88% and 71.50%, respectively, similar to the levels found by Hayes (1996), who did not have a middle category.

Table 1 also shows that the judged gender of handwriting was significantly related to digit ratios on both hands, thus on average when the ratio was below one in the male direction (whereby the second finger of males relative to their fourth finger is relatively lower) handwriting was judged to be more masculine and vice versa in the female direction. Similarly the mean ratings on the BSRI femininity scale correlated positively and significantly with digit ratio in both hands and the ratings on the BSRI masculinity scale correlated negatively and significantly. Other aspects about Table 1 to note are that the sex of the participant correlates with 2D:4D ratio for both hands, indicating that for males the ratio is in the male direction and for the females it is in the opposite direction, concurring with previous research. The ratios of the left and right hands correlated well with each other indicating both a satisfactory level of precision in measurement and a consistency in the measure.

A remaining aspect of this table is that the validity of the BSRI appears to be upheld for females, but not for males. This might be partly connected with a study by Choi and Fuqua (2003) examining 23 factor analysis studies of the BSRI. They found that whereas most studies report that the F scale has one clean factor that may be described as "expressive or communal" (e.g. sympathetic, compassionate); by contrast, the M scale had only 6 out of 23 studies that reported one clean factor—most reported 2 or 3 factors. There were nine studies reporting an instrumental factor (e.g. "willing to take a stand") and an autonomous factor. In the present study the validity of the M scale of the BSRI similarly appears to be challenged as the correlation between the BSRI masculine scale and gender although in the correct direction failed to reach significance, compared to a significant correlation for the feminine, also in the correct direction. Further comparison can be made with the original sample at Stanford University (Ns: 444 males and 279 females, Bem, 1974) whereby males had mean (and SD) ratings of 4.97 (.67) and 4.44 (.55) for the M and F scales, respectively, compared with 4.66 (.736) and 4.455 (.654) in the present study. The two male samples are comparable on the femininity scale, but the present cohort appears to be lower in masculinity. In terms of Cohen's d this is an effect size difference on the masculinity scale of .441 comparing the Bem (1974) sample with the present cohort, which is slightly below a "medium" effect size in Cohen's terms. This reduced effect for masculinity might be because the male attributes on the scale were considered as socially more undesirable in the present era of the beginning of the 21st century. In the present experiment the reliabilities on the BSRI (Cronbach's α) were reasonably high at .756 and .706 on the M and F scales, respectively, for the females and .863 and .705 on the M and F scales, respectively for the males.

The fact that handwriting style correlates with a number of variables associated with gender does not necessarily mean that digit ratio (or for that matter sexual preferences) actually affects handwriting in a causal way. Handwriting might be related to gender and these two aspects—digit

ratio and sexual preferences—happen to be linked to gender as well. A more useful comparison would be to see if there are any relationships within each sex. For example, could there be a tendency for men with particularly low digit ratios (and therefore prenatally influenced by testosterone to a greater degree than normal) also to have more masculine writing?

Table 2 shows these two correlation matrices with the females above the diagonal and the males below. This is a more conservative test as the Ns are halved in each matrix (relative to the sexes combined) and furthermore, in virtually all cases (the males on the masculine scale being an exception) the variance is slightly reduced when looking at the sexes separately compared to the pooled variance, which further reduces the correlation. This analysis shows that the rating of the gender of the handwriter is still significantly correlated with digit ratio in the right hand for females ($p = .127$ for the .199 correlation in the other hand). In other words, those women with higher digit ratios in their right hand tend to have more feminine handwriting. The BSRI masculinity and femininity scales were correlated significantly with each other for the females, which had not been the case with the pooled data. Finally, the feminine BSRI scale correlated with digit ratio in both hands. Those who were more feminine according to the BSRI also had higher digit ratios in both hands indicating a biological determinant of the extent of feminisation of sex role identification. For the males there were no corresponding correlations between digit ratios and the scales of the BSRI. One correlation approached significance ($p = .092$) for the left hand ratio and the femininity scale. Finally the males also had an expected correlation between digit ratios in the two hands.

To examine whether there were differences in the extent of sex differences between the hands a 2×2 (sex by hand) mixed repeated measures ANOVA was computed with sex as a between-subjects factor and left and right hand digit ratio as within subjects. (Means and SDs for this analysis are available in Table 3). There was the expected highly significant main effect for sex, $F(1, 118) = 95.87$, $p = .000$, $\eta^2 = .448$. However, the difference between the hands just failed to reach significance, $F(1, 118) = 2.95$, $p = .088$, $\eta^2 = .024$. The interaction was not significant, $F(1, 118) = 1.70$, $p = .195$, $\eta^2 = .014$. Although the interaction and the main effect for hands was not significant, eta squared was much larger than for Lippa (2003) computing an identical ANOVA but with a sample of over 2000 adults. With such power both main effects and the interaction were significant; however it seems that apart from the main effect of sex, effect sizes are small.

Differences between males and females were compared by two-tailed *t*-tests and the differences are shown in Table 3. Only one test failed to reach significance, which was on the masculinity scale of the BSRI, $t(118) = 1.61$, $p = .110$. Cohen's *d* statistic showed an effect size in rating of gender of

Table 2
Intercorrelations among the principal variables with females above the diagonal and males below

Variable	Sex rating	Masculine	Feminine	LH	RH
Sex rating of writing		−.015	.018	.199	.261*
Masculine BSRI scale	.165		.260*	−.186	−.079
Feminine BSRI scale	.014	.184		.290*	.274*
Left hand (LH) fingers	−.089	−.187	.219		.608***
Right hand (RH) fingers	−.012	−.182	.090	.859***	

Note: $N = 60$ in all cells, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 3
Means (and SDs) for males and females among the principal variables

Variable	Males				Diff.	Females			
	Mean	SD	Min.	Max.		Mean	SD	Min.	Max.
Sex rating of writing	2.38	.72	1.30	4.00	***	3.67	.73	2.00	4.65
Masculine scale	4.660	.736	3.16	6.74	ns	4.455	.654	3.11	5.84
Feminine scale	4.620	.491	3.21	5.63	***	5.041	.458	4.00	6.00
Left hand (LH) fingers	.9918	.018	.949	1.045	***	1.01925	.014	.974	1.047
Right hand (RH) fingers	.9948	.016	.957	1.044	***	1.01967	.015	.981	1.070

Note: $N = 60$ in all cells, ***$p < 0.001$ by t test.

handwriting of 0.75, which is close to Cohen's classification of "large". These t-test analyses do not bring out the potential interaction between gender and the BSRI. Accordingly a 2×2 (sex by BSRI) mixed repeated measures ANOVA was computed. This examined each participant's masculine and feminine scale performance in relation to gender. A significant interaction was found, $F(1, 118) = 20.552$, $p = .000$, $\eta^2 = .148$. Males were relatively undifferentiated by the male and female scales, compared with the females. Inspection of the data showed that this was not produced by isolated outliers, as only 23.3% of females had higher masculinity than femininity scores, but 55% of males had higher femininity scores than masculinity scores. Examination of the main effects is not particularly informative, but for completeness, the BSRI main effect was significant, $F(1, 118) = 15.98$, $p = .000$, $\eta^2 = .119$, whereas the main effect for sex was not, $F(1, 118) = 1.61$, $p = .207$, $\eta^2 = .013$.

After making their judgments the 20 raters were asked to describe the distinctive characteristics of male and female handwriting and the frequencies of these descriptions are summarised in Table 4. There is some measure of agreement that while male handwriting tends to be messy, slanted and spiky, female handwriting is by contrast more rounded, tidier and more legible and yet is more ornate. Certain letters in female handwriting, especially 'i' and 'd' appear to have embellishments. There were however contradictions, particularly on the dimension of size of handwriting. These dimensions shown in Table 4 broadly agree with those in a study by Burr (2002) using samples of 17- to 25-year-old British sixth form and undergraduate students.

3. General discussion

The relationships between the triumvirate of handwriting, sex roles and hormones indicate that in women, at least, prenatal hormones influence both sex role identification and the femininity of their handwriting. To qualify this briefly, the sex role in question is on the dimension of love, and the prenatal hormonal influence is in the right hand, connected to the left hemisphere. The other side of the coin is that although sometimes in the appropriate direction, these relationships do not reach significance for the men. This is not to say that they would not within a much more powerful design. The lack of significant association with the BSRI on the masculinity scale may be due to changes in cultural attitudes since 1974 concerning male dominance. The males in the present study who were more masculinised according to their digit ratios may have changed (perhaps by

Table 4
Frequencies of descriptions of the 20 raters on the characteristics of male and female handwriting

Males	Females
Messier, scruffy (13)	More rounded (10)
Smaller handwriting (4)	Tidier, neater (8)
More slanted (3)	Circles instead of dots (4)
More scribbling out, mistakes (2)	Bubbly (3)
More spiky, angular (2)	More swishy bits, curlier, curvier (3)
Just everywhere, all over the place (2)	Much easier to read, clearer (2)
Stalks larger (1)	Very uniform, more regular (2)
Bits of the letter were small (1)	Smaller (2)
Rushed (1)	Bigger (1)
More straight lines (1)	Letters bigger and spaced apart (1)
More italic (1)	More slanted (1)
Either really large or really tiny (1)	More fancy (1)
Bad handwriting (1)	More spread out (1)
Like children's (1)	More details (e.g. on 's') (1)
Unevenness of the letters (1)	More organized (1)
More spelling mistakes (1)	Lower case 'd' distinctive (1)[a]
Unsymmetrical (1)	
More spread out (1)	
Bigger handwriting (1)	

[a] *To elaborate:* the upward tail could be marked or slanted away from the norm. Note that all raters were given feedback after each piece of writing they rated.

sublimating) their attitudes within this masculine dimension, which we have seen may have at least two sub-dimensions (Choi & Fuqua, 2003). More importantly there is a lack of relationship between male digit ratio and handwriting style; in particular, the relationship between the sex of their handwriting and the digit ratio in their right hand is very low at −.012. We can rule out a difference in variance between the sexes in rated sex of handwriting (SDs were .72 and .73 for males and females, respectively) and for the measures of finger ratio (see Table 3) for a possible source of the lack of association. This implies that there could be some other source accounting for variability in the sex of male handwriting not studied here. The similarity in the variances puts doubt on an explanation for the lack of male effects being due to an abnormal male sample. If this male sample had been overall more feminised than normal this would surely have been revealed by their digit ratios.

Returning to the results found for the women, it is interesting that the connection between sex of handwriting and digit ratio occurred significantly only in the right hand. This might tentatively suggest that those women with hypothesised higher levels of progesterone when in uterus, which produced higher digit ratios, were also affected in their subsequent left hemisphere development and later developed a more feminine handwriting style, assuming specialisation in the left hemisphere. This result raises further questions about why this biological determinant should affect writing style in this specific manner. There are several possibilities. One is that these hormones induce specific differences in style of motor performance; for instance, if handwriting is less rushed then it might take on more of the appearance of female handwriting. Feingold (1994) proposed that men are high in assertiveness, whereas women are high in nurturance.

Although perhaps not closely linked, increased assertiveness may also be connected with a more masculine style of handwriting. Another explanation is that the differences in handwriting may instead be due to the underlying differences that develop in motor structures. Hayes (1996) considering the evidence of Kozlowski and Cutting (1977) that males and females are consistently different in their body movement when walking, suggested that there is a similar manifestation in handwriting. Another possibility is that female hormones promote (or do not inhibit to the same extent) verbal development and also greater sociability to increase the frequency of such communication. More communication leads to greater practice both orally and in writing—the so-called Matthew effect coined by Stanovich (1986) in the context of reading development. This leads to female handwriting appearing to be more mature and by contrast male handwriting less mature. A slightly different manifestation could be that female hormones promote an inclination to express oneself in a more female way. As Hayes (1996) suggests, handwriting might be considered to be a form of expression of gender identity. Hayes (1996, Experiment 3) found that accuracy judgement for the sex of handwriting for the nonpreferred hand was much lower (but nevertheless significant) than from the preferred hand. This might suggest both an underlying motor effect *and* a cumulative developmental/practice effect. Whatever the underlying explanation, we might conclude that the factors behind the prenatal development of high digit ratios also contribute to causally influencing femininity in the handwriting in women, and probably gender identification preferences. By contrast, in men there were no corresponding significant associations.

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