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## Second to fourth digit ratio and the ‘big five’ personality factors

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### Abstract

Several studies have demonstrated that the ratio between the lengths of the second and fourth digits (2D:4D) is sexually dimorphic. On average males demonstrate lower digit ratios than do females. There is accumulating evidence that 2D:4D is established early in development and is negatively related to prenatal testosterone and positively with prenatal estrogen. In this present study, we investigated associations between digit ratio and the ‘big-five’ personality factors (extraversion, neuroticism, openness, conscientiousness and agreeableness). Only agreeableness showed a significant sex difference with females scoring higher. Neuroticism showed a significant positive correlation with right hand digit ratio for the whole sample, and in females only for right hand 2D:4D. Further, a significant negative association was found between females’ right hand digit ratio and agreeableness. Male 2D:4D did not correlate significantly with any of the personality factors. The results follow previous studies reporting that 2D:4D was a stronger correlate of personality traits in females than in males. In summary, the associations between digit ratio and personality factors are weak but provide some further support for the claim that gender-related behaviour is affected by the amount of steroid hormones present during critical periods of prenatal development.

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## 1. Introduction

The ratio between second and fourth finger lengths (2D:4D) is known to be sexually dimorphic, with mean values being lower for males than for females (George, 1930; Manning, Barley, et al., 2000; Manning, Scutt, Wilson, & Lewis-Jones, 1998; Phelps, 1952). Digit ratio is thought to be stable between childhood and adulthood and is determined in utero by about the 14th week (Garn, Burdi, Babler, & Stinson, 1975; Manning et al., 1998; Phelps, 1952). There is evidence in both males and females that digit ratio acts as a negative correlate of prenatal testosterone and a positive correlate of prenatal estrogen. These findings include (i) the waist-to-hip ratio of women (a positive correlate of testosterone and a negative correlate of estrogen) is negatively related to their 2D:4D ratio (ii) the waist-to-hip ratio of mothers is negatively associated with the 2D:4D ratio of their children (iii) the 2D:4D ratio of mothers is similar to that of their children, and fetuses of mothers with low 2D:4D have high levels of testosterone in their amniotic fluid (iv) children with congenital adrenal hyperplasia, a trait associated with high prenatal androgen, have lower 2D:4D than controls (Manning, 2002; Manning, Trivers, Singh, & Thornhill, 1999; Manning, Trivers, Thornhill, & Singh, 2000; Okten, Kalyoncu, & Yaris, 2002). Manning et al. (1998) have suggested that the underlying mechanism for such correlations are via the action of the Homeobox genes, which control the differentiation of digits, testes and ovaries. This common control of the differentiation of digits and gonads may allow aspects of gonadal function such as the production of testosterone and estrogen to affect the development of the digits.

A primary role of the steroid hormones during early development is the establishment of morphological sex differences, which provide the foundation for the subsequent observed sex differences in behaviour. Sex differentiation of the brain appears to follow a similar pattern to that of morphological features in the way that tissue is masculinized by the presence of testosterone or feminized by its absence (e.g. Collaer & Hines, 1995). These effects of prenatal testosterone levels feature in Geschwind and Galaburda's (1987) influential theory concerning brain lateralization. These authors suggested that high levels of fetal testosterone may compromise the development of the left cerebral hemisphere (leading to left-hand preference, language impairments and autism) and facilitate that of the right hemisphere (leading to enhanced musical, spatial, and mathematical abilities). Some evidence linking this theory to digit ratio has been put forward. For example, left-hand preference in a peg moving task in children has been shown to be related to low digit ratios (Manning, Trivers, et al., 2000), autistic children have lower digit ratio values than the general population (Manning, Baron-Cohen, Wheelwright, & Sanders, 2001), whilst a study of male musicians in a British symphony orchestra showed that members had lower digit ratios than controls, with high-ranking players having lower values than their low-ranking colleagues (Sluming & Manning, 2000). These studies show effects in the direction that would be consistent with the Geschwind–Galaburda theory if low values of 2D:4D were a marker for high prenatal testosterone.

There are known to be a number of replicable male–female differences in personality. The above review suggests that it may be of interest to investigate possible associations between digit ratio and those personality traits for which mean scores differ between the sexes, especially for those where theoretical or empirical links to sex hormone have been established. In personality, males demonstrate higher scores than females on psychoticism (Eysenck & Eysenck, 1976) and on various aggression scales (Buss & Perry, 1992; Harris, Rushton, Hampson, & Jackson, 1996). Males also score higher than females on sensation seeking and on the impulsive unsocialized sensation-seeking

(P-ImpUSS) dimension derived by Zuckerman (1991). Females have been found to score higher than males on 'neuroticism' and on various measures of depression (Eysenck & Eysenck, 1976; Hawkins, McDermott, Shields, & Harvey, 1989; Sowa & Lustman, 1984) and to have a higher incidence of diagnosis of clinical depression (Brems, 1995). In the case of aggression, associations between aggression scores and testosterone levels have been found for both sexes (Harris, 1999; Harris et al., 1996), though such associations are not always reported (Archer, 1991). Stronger associations have been reported for testosterone and dominance in males (for review see Mazur & Booth, 1998 and peer reviews following this article for critical comments). Similarly, positive associations between sensation seeking scores and testosterone levels have also been reported for males (Gerra et al., 1999). Negative associations between testosterone levels and neuroticism have been found in males (Dabbs, Hopper, & Jurkovic, 1990). In summary, there is evidence that exposure to androgens during critical periods of development is essential for masculinization of behaviour, resulting in more self-sufficient and independent behaviour. Exposure to prenatal estrogen points to a feminizing or demasculinizing effect causing males and females to express more group-dependent and less individualistic behaviours (Reinisch & Sanders, 1984).

A number of different tests have been used in the investigation of sex differences in personality (see Pervin & John, 1999). This makes it difficult to make comparisons across studies especially when studying hormonal contributions to sexually dimorphic behaviour in humans (for review see Reinisch, Ziemba-Davis, & Sanders, 1991). Although there is no consensus on a single personality model, it appears that researchers have recently reached some agreement on the number and nature of personality dimensions (Budaev, 1999). It has been proposed that human personality variation may be summarized by five major dimensions (McCrae & Costa, 1997). These are known as the 'big-five' factors, i.e. extraversion, openness, agreeableness, neuroticism, and conscientiousness (Digman, 1990; Wiggins, 1996). The five dimensions are held to be a complete description of personality (McCrae & Costa, 1997). Extraversion reflects preference for, and behaviour in, social situations. People high in extraversion are energetic and seek out the company of others. Low scorers tend to be more quiet and reserved. Agreeableness reflects how we tend to interact with others. People high in agreeableness tend to be trusting and cooperative. Low scorers tend to be more aggressive and less cooperative. Conscientiousness reflects how organized and persistent a person is in pursuing goals. High scorers are methodical, well organized and dutiful. Low scorers are less careful, less focussed and more likely to be distracted from tasks. Neuroticism reflects the tendency to experience negative thoughts and feelings. High scorers are prone to insecurity and emotional distress. Low scorers tend to be more relaxed, less emotional and less prone to distress. Openness reflects "open-mindedness" and interest in culture of a person. High scorers tend to be imaginative, creative, and to seek out cultural and educational experiences. Low scorers are more down-to-earth, less interested in art and more practical in nature.

There are no clear sex-differences among the five factors but it seems that neuroticism and agreeableness differ more clearly between the sexes than the other factors. This is consistent with the above-mentioned findings of studies using other personality models (e.g., Dabbs et al., 1990). Budaev (1999) has suggested that these two factors represent basic dimensions of dominance-related aggressiveness, which might be mediated to some extent by testosterone levels. Again, we may suppose that low neuroticism and agreeableness should be more strongly expressed in males than females. Within the five-factor model of personality males are also thought to score higher for openness and extraversion, which can be related to the findings from the sensation-seeking

dimension (see Zuckerman, 1991). In contrast, women show higher scores for conscientiousness and neuroticism (Wiggins, 1996).

Up to now, there has been only one reported study on the relationship between personality and 2D:4D. In a preliminary report Austin, Manning, McInroy, and Mathews (2002) considered associations between 2D:4D and various personality traits, and they reported significant negative associations between 2D:4D and sensation seeking, thrill seeking and disinhibition in females only. They also found that 2D:4D was positively related to neuroticism for males and females combined and close to significance ( $p = 0.06$ ) for females only. The work of Wilson (1983) is also relevant in the context of 2D:4D and personality as he reported that women with low self-measured 2D:4D ratio were more likely to describe themselves as assertive and competitive than women with high 2D:4D.

From the above information it seems possible to some degree to formulate hypotheses about the expected signs of the correlations between digit ratio and the 'big-five' personality factors. Given that prenatal testosterone levels affect aspects of personality in males and females differently, we predict that androgenized forms of 2D:4D (i.e., lower values) will correlate negatively with factors, which have been reported to be higher in males (extraversion, openness). Positive correlations between 2D:4D and personality scores are expected for traits where female scores have been found to be higher (neuroticism, agreeableness, conscientiousness).

## 2. Methods

### 2.1. Participants

Our sample comprised 50 males (mean age = 22.47,  $SD = 4.88$ ) and 70 females (mean age = 22.90,  $SD = 4.25$ ) recruited from the University of Vienna, Austria ( $n = 58$ ) and Northumbria University, UK ( $n = 62$ ).

### 2.2. Materials

We used the NEO Five-Factor Inventory (NEO-FFI—Costa & McCrae, 1985, 1992). The NEO Five-Factor Inventory is a shortened version of the NEO-PI, designed to give quick, reliable and valid measures of the five dimensions of adult personality. The NEO-FFI yields scores for extraversion, neuroticism, openness, conscientiousness and agreeableness. The 60 items are rated on a five-point scale. The NEO-FFI scales show correlations of 0.75–0.89 with the NEO-PI validimax factors. Internal consistency values range from 0.74 to 0.89. The NEO-FFI takes 10–15 min to complete. For the personality assessment of the Austrian sample we used the German version of the NEO-FFI, translated by Borkenau and Ostendorf (1993).

### 2.3. Procedure

Participants were asked to fill out the personality inventory. We then measured the lengths of the 2nd and 4th digits of the left and right hands from the ventral proximal crease of the digit to the tip from photocopies. Where there was a band of creases at the base of the digit, we measured

from the most proximal of these. For 120 right and left hands, the 2nd and 4th digits were measured directly from the hand and from the photocopies in order to establish repeatabilities. All measurements were made with digital Vernier calipers measuring to 0.01 mm. Those participants who reported injuries to the 2nd or 4th digits were discarded from the analyses, as were participants who identified themselves as homosexual or bisexual so that our final sample comprised 30 males and 50 females.

We used repeated measures analysis of variance (ANOVA) to calculate the intra-class correlation coefficient ( $r_1$ ) and the ratio ( $F$ ) between measurement error (the differences between successive measures of 2D:4D) and between-subject differences. If not reported otherwise unpaired two-tailed  $t$ -tests for determining possible sex-differences in 2D:4D. Pearson correlation coefficients were used for assessing the relationship between 2D:4D and personality scores. All  $p$  values for correlations were two-tailed at  $p = 0.05$ .

### 3. Results

#### 3.1. Repeatabilities

The intra-class correlation coefficient from the first and second measurements of right hand 2D:4D was  $r_1 = 0.67$  and for the left hand 2D:4D  $r_1 = 0.60$ . For both hands we found that the within-subject differences in 2D:4D (measurement error) was significantly lower than between-subject differences in 2D:4D (right  $F = 5.14$ ,  $p = 0.0001$ ; left  $F = 4.00$ ,  $p = 0.0001$ ). We concluded that our measurements of 2D:4D reflected real differences between subjects.

#### 3.2. Sex differences

A series of  $t$ -tests were performed to investigate sex differences between the measured variables (see Table 1). Male 2D:4D ratio was significantly lower in both hands than the female ratio. Females scored significantly higher than males on agreeableness. No sex-differences were found on neuroticism, extraversion, openness and conscientiousness. As personality scores were assessed from two different ethnicities we controlled whether ethnicity has a significant influence on

Table 1  
Sex differences for digit ratio and personality scores

	Mean (SD)		$t$	$p$
	Males	Females		
2D:4D left hand	0.96 (0.03)	0.98 (0.03)	-3.451	0.001*
2D:4D right hand	0.95 (0.03)	0.98 (0.03)	-4.102	0.000*
Neuroticism	17.20 (7.17)	19.06 (7.89)	-1.056	0.294
Extraversion	31.23 (7.56)	31.66 (4.79)	-0.309	0.758
Openness	33.33 (5.16)	33.24 (5.40)	0.076	0.940
Agreeableness	29.33 (6.11)	32.50 (4.99)	-2.521	0.014*
Conscientiousness	30.47 (5.52)	32.46 (6.26)	-1.440	0.154

Note: SD = standard deviation.

\*  $p < 0.05$ , two-tailed.

Table 2  
Correlations of digit ratios with personality scores

	Whole sample (left)	Whole sample (right)	Males (left)	Males (right)	Females (left)	Females (right)
Neuroticism	0.092	0.249*	0.010	0.120	0.118	0.292*
Extraversion	0.067	−0.043	0.127	0.166	0.006	−0.265
Openness	−0.201	−0.160	−0.209	−0.161	−0.198	−0.163
Agreeableness	−0.099	−0.089	−0.172	0.110	−0.114	−0.359*
Conscientiousness	−0.009	−0.023	0.017	−0.048	−0.052	−0.066

\*  $p < 0.05$ , two-tailed.

personality assessments. This was only found to be the case for openness ( $t$ -test,  $T = -2.553$ ,  $p = 0.013$ , two-tailed; Austria: mean = 35.66, UK: mean = 30.77) and extraversion ( $t$ -test,  $T = 4.469$ ,  $p = 0.000$ , two-tailed; Austria: mean = 29.90, UK: mean = 33.18). Due to the sample size these differences were not considered in the further analyses.

### 3.3. Correlations with digit ratio

In Table 2 we present correlations between digit ratio and personality test scores. We found a positive significant correlation between neuroticism and right hand digit ratio for the whole sample, and also for females only with right hand 2D:4D. No significant association was found for males. Furthermore, females' right hand digit ratio and agreeableness were significantly negatively related. A near significant negative correlation was found between females' right hand 2D:4D and extraversion ( $p = 0.063$ ). Male 2D:4D did not correlate significantly with personality scores. The strongest association for males was found between right and left hand 2D:4D and openness, with a tendency for low 2D:4D to be associated with higher scores of openness (see Table 2).

## 4. Discussion

The data presented here extend previous findings of possible associations between digit ratio and certain personality traits (Austin et al., 2002; Wilson, 1983). As in earlier studies our significant findings were with female 2D:4D. Our results provide some additional evidence for the hypothesis that prenatal exposure to high testosterone levels may affect personality traits as well as physical features. In the present study, associations between digit ratio and the 'big-five' factors of personality were however weak. In discussing the results for personality, since the expected effect directions were predicted, it seems reasonable to consider near significant as well as significant correlations.

Among the traits that were predicted to correlate positively we found neuroticism to be significantly positively related to digit ratio for the whole sample and for females only, but not for males. This result is in accord with previous studies where females have been shown to score higher on neuroticism than males, and that 2D:4D was positively related to neuroticism in males and females combined and most strongly related in females (Austin et al., 2002). We found that

only right hand 2D:4D showed this significant association. The Austin et al. (2002) study found the strongest associations for the left hand. Many earlier reports on digit ratio, have reported that right hand 2D:4D show a stronger association with a range of index traits, and it has been suggested that right hand ratio may be more sensitive to prenatal testosterone than left 2D:4D (Manning, 2002). Thus far the studies which indicate a positive association between 2D:4D and neuroticism have shown significant relationships with both left and right 2D:4D. Conscientiousness, which was also predicted to correlate positively with 2D:4D, showed no significant association either for males or females. Interestingly, the association between 2D:4D and agreeableness did not follow our prediction (for a positive relationship), as it was found to correlate significantly negatively with female right hand 2D:4D. In males, the association was also negative but not significant. There is no strong evidence for predicting a positive or negative slope between agreeableness and 2D:4D but on balance a positive slope seems to be the most probable relationship. The negative association we found is puzzling. It may be a Type I error and further data will make this clear.

For the remaining personality factors we hypothesised a negative relationship with digit ratio. No significant association was found between digit ratio and extraversion, either for the total sample or for the male and female sub-samples, though a negative association between female's right hand 2D:4D and extraversion was near significance. As predicted, openness was related negatively (but not significantly) for both right and left 2D:4D ratio in males, females and the total sample. In summary, apart from conscientiousness and agreeableness, the associations followed our predictions but were stronger for females than for males. Less androgenized forms of the digit ratios in right hands were significantly related to neuroticism scores in females and higher androgenized forms of right hand 2D:4D were related significantly negatively to conscientiousness and agreeableness scores in females.

Gonadal steroid hormones, active during fetal life, continue after birth to influence the central nervous system and affect behaviour. The characteristically different circulating concentrations of male and female steroid hormones in men and women appear to be partial determinants of certain sexually dimorphic behaviours, interacting in a complex way with psychological and socio-cultural factors as well as with other biological factors (Reinisch et al., 1991). Although personality factors should be seen to vary continuously between the sexes and cannot be strictly categorized, it is thought that males generally exhibit a more assertive and competitive behaviour while females possess greater caring attitudes and sociability. These personality characters have been extensively studied in males, especially in their involvement in aggressive competition (e.g. Elias, 1981; Gouzalez-Bono, Salvador, Serrano, & Ricart, 1998). Baucom, Besch, and Callahan (1985) found that females with high levels of masculinity had somewhat higher testosterone levels than did feminine-sex-typed females. While females with higher level of testosterone perceived themselves as self-directed, action-oriented and resourceful individuals, the women with lower level of testosterone viewed themselves as conventional and socialized individuals (Collaer & Hines, 1995).

As Austin et al. (2002) noted, it seems that the relationship between digit ratio and personality variables is rather weak. Therefore, the results of the present study should be interpreted with caution. It may also be that hormonal contributions to behavioural sex differences are not clearly expressed when using a personality model that is based on a principal components model as differences may be more clearly expressed on single sub-scales of personality traits. However, in general the patterns reported here follow the assumption that males and females differ in their

personality to some extent, and this may be in part caused by the fact that they experience different in utero testosterone to estrogen ratios. Because the associations between 2D:4D and personality are weak further work is needed to establish the real nature of these relationships. At present the pattern, which appears to be emerging, is that of significant associations between 2D:4D and personality scores in females but not males.

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