

Digit Ratio (2D:4D) and Cattell's Personality Traits

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Abstract

The ratio between second and fourth finger (2D:4D) is sexually dimorphic; it is lower in men than in women. Studies using broad personality domains yielded correlations of 2D:4D with neuroticism, extraversion or agreeableness, but the obtained results have been inconsistent. We correlated 2D:4D of 184 women and 101 men with their scores in Cattell's 16 Personality Factor (16PF) Questionnaire. We found women with a higher (more 'feminine') right hand 2D:4D to score lower in emotional stability and social boldness and higher in privateness. Mediator analysis showed emotional stability to be probably primarily correlated with 2D:4D and to act as a mediator between 2D:4D and social boldness. privateness appears to be mediated by an even more complex path. We discuss the usefulness of primary-level personality questionnaires and mediator analyses in the investigation of psycho-morphological associations. Copyright © 2007 John Wiley & Sons, Ltd.

Key words: testosterone; sex differences; personality; digit ratio; 2D:4D; Cattell; 16PF

INTRODUCTION

There is growing evidence for specific associations of psychological traits with morphological features in humans. The existence of such associations is rather surprising in the human species where personality is expected to be distinctly shaped by an immense array of social, genetic and environmental factors. Recently, attention has been drawn to the relationship between the ratio of the second and fourth finger (2D:4D) and personality. Wilson (1983) found women with a lower (i.e. more 'masculine', see below) self-reported 2D:4D to describe themselves as more assertive and competitive. This older study has been followed by research in the 21st century, measuring 2D:4D directly: Austin, Manning,

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McInroy, and Mathews (2002) reported stronger 2D:4D-personality associations for women than for men; they found a negative correlation of left-hand 2D:4D with sensation seeking, thrill seeking and disinhibition, and a nearly significant positive correlation with neuroticism measured by the Eysenck Personality Inventory (EPI) in women, but not in men. Fink, Manning, and Neave (2004) replicated the finding of a positive association between 2D:4D and neuroticism in women using the NEO—Five Factor Inventory (NEO-FFI), observed a negative correlation of 2D:4D with agreeableness, and a marginally significant negative correlation with extraversion in women, always only for the right hand. Bailey and Hurd (2005a) found lower right-hand 2D:4D in more aggressive men and in men with lower scores of depression measured as a trait (Bailey & Hurd, 2005b), but did not obtain the same correlations for women. Luxen and Buunk (2005) reported higher levels of agreeableness in both men and women with higher right-hand 2D:4D. Lippa (2006) having the largest sample size revealed only a weak negative association between mean (from both hands) 2D:4D and extraversion, a weak positive association between mean 2D:4D and Openness to experience and a non-significant trend towards a negative association with agreeableness for men and women together. Finally, Fink, Neave, Laughton, and Manning (2006) found both right- and left-hand 2D:4D in males to be significantly negatively associated with sensation seeking.

The usual explanation of these associations is that they are caused by steroid hormones, and especially prenatal testosterone levels, assumed to be negatively correlated with 2D:4D (Fink et al., 2004; Neave, Laing, Fink, & Manning, 2003). This assumption is based mostly on indirect evidence spanning from the finding of the sex difference in the ratio, with females having higher 2D:4D than males (George, 1930; Manning, Scutt, Wilson, & Lewis-Jones, 1998; Manning, Trivers, Thornhill, & Singh, 2000; Phelps, 1952), through studies of subjects with congenital adrenal hyperplasia (CAH) who suffer from prenatal elevated androgen production and have a lower 2D:4D (Brown, Hines, Fane, & Breedlove, 2002; Ökten, Kalyoncu, & Yaris, 2002) to studies of the relationship between 2D:4D and number of CAG elements in the androgen receptor (Manning, Bundred, Newton, & Flanigan, 2003) previously reported to be inversely correlated with masculinising effects (Callewaert, Cristiaens, Haelens, Verrijdt, Verhoeven, & Claessens, 2003; Ding, Xu, Menon, Reddy, & Barrack, 2004). The strongest evidence for the role of the testosterone/oestradiol ratio (but no significant relationship was found for the concentration of either hormone alone) seems to come from the study of Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer, and Manning (2004) where 2D:4D at the age of 2 years was correlated with hormone levels in amniotic fluid. As observed by McIntyre, Chapman, Lipson, and Ellison (2007), higher levels of oestradiol correlate with higher 2D:4D in adult women. Both findings were reported for the right hand. There is also reference to the association of other female hormones with 2D:4D. In a sample of men and women, Manning et al. (1998) determined the strongest (and positive) correlation of 2D:4D with oestrogen and luteinising hormone (LH) for the right hand; somewhat weaker but still significant were also the correlations with prolactin for the right hand and LH for the left hand.

As 2D:4D is sexually dimorphic, supposedly as a consequence of difference in prenatal hormone levels between men and women, Austin et al. (2002) hypothesised that also differences in personality between participants with higher and lower 2D:4D would be most apparent in traits that are sexually dimorphic, expecting a positive correlation of 2D:4D with more feminine traits. This presumption is in relatively good concordance with some findings—for example positive correlation of 2D:4D with neuroticism (Austin et al., 2002; Fink et al., 2004), with women tending to be more anxious (Feingold, 1994; Hall,

1984; Maccoby & Jacklin, 1974; no correlation was, however, observed in the largest study by Lipa, 2006)—but other findings are inconsistent: agreeableness where women usually score higher than men (e.g. Costa, Terraciano, & McCrae, 2001) showed positive correlation with 2D:4D as reported by Luxen and Buunk (2005) while the opposite (a negative correlation) was observed by Fink et al. (2004). Extraversion, which is not consistently sexually dimorphic (Hyde, 1984), also appears rather inconsistently associated with 2D:4D (marginally significant negative correlation reported by Fink et al., 2004, significant negative, although very low, correlation observed by Lipa, 2006, a trend in the opposite direction reported by Luxen & Buunk, 2005).

It is important to remark that most previous studies used either one-dimensional personality questionnaires or multi-dimensional questionnaires consisting of a small number of broad personality traits (EPI or NEO-FFI), often labelled 'super-traits'. These factors are supposed to correspond to the second-order factors of Cattell's 16 Personality Factor (16PF) Questionnaire (Eysenck & Eysenck, 1985). Cattell's primary first-order factors are independent 'source traits' that are the generic causes of behaviour (Cattell, Eber, & Tatsuoka, 1970). We can therefore expect at least some of them to be more directly influenced by specific biological factors (see also Fink et al., 2004). In contrast, the broader second-order traits are generally not conceptualised to reflect a single biological precursor. Therefore, we suggest that when looking for associations of the biologically based trait 2D:4D with personality, it is more legitimate to search among the first-order factors. Moreover, the same greater compactness of at least some first-order factors enables us to make clearer and more specific predictions about sex differences in the average scores. This, as we will argue further on, could help to better understand some previous inconsistencies and 'reversed' outcomes.

In this study, we used first-order factors from 16PF and compared the results to those of previous studies. Following the overlaps between the personality questionnaires EPI, NEO-FFI and 16PF, and in particular, based upon gender differences in personality reported by the literature, we were able to make predictions regarding the factors expected to correlate with 2D:4D:

The Five Factor Model trait neuroticism with the facets anxiety, angry hostility, depression, self-consciousness, impulsiveness and vulnerability (Costa & McCrae, 1992) is related to the 16PF second-order factor anxiety, which is loaded mainly by the first-order factors Q4 (tension), C (emotional stability) and O (guilt proneness). Higher anxiety (i.e. anxiety, neuroticism or emotional lability) in women than in men was found in the meta-analysis of Hall (1984), and Feingold (1994) replicated his finding for general anxiety, but not for social anxiety. Factor C (emotional stability) is similar to Eysenck's neuroticism, and measures dynamic integration and maturity and the strength of ego in the psychoanalytic terms (Cattell et al., 1970). It seems that out of the three first-order factors loading on anxiety, emotional stability is closest to the general anxiety concept, and therefore we expected it to negatively correlate with 2D:4D.

The Five Factor Model domain extraversion corresponds to the 16PF second-order factor extraversion. It is loaded by factors A (warmth), F (liveliness), H (social boldness) and Q2 (self-deficiency) which substantially correspond to the Five Factor Model extraversion facets warmth, gregariousness, assertiveness, activity, excitement seeking and positive emotions. For individual facets of extraversion, different patterns of sex differences were reported. For instance, men scored higher in assertiveness, whilst women achieved higher scores in gregariousness in the meta-analysis of Feingold (1994). Similarly, Costa et al. (2001) reported higher scores in warmth for women, with men

scoring higher in assertiveness. As the latter corresponds well to factor H (social boldness) and both scales of warmth are greatly related, we can expect factor A (warmth) to be positively and factor H (social boldness) to be negatively correlated with 2D:4D.

Agreeableness with the facets trust, straightforwardness, altruism, compliance, modesty and tender-mindedness (Costa & McCrae, 1992) can be expected to most strongly relate to the opposites of factors L (vigilance vs. trust) and N (privateness vs. straightforwardness). Feingold (1994) found women to reach higher scores in trust than men, therefore we expect factor L (vigilance) to be negatively correlated with 2D:4D. Privateness (or the opposite straightforwardness) does not appear among sexually dimorphic factors in the analyses of Feingold or Hall, but women typically reach higher scores in this factor than men both according to Cattell et al. (1970) and the Czech norms (Říčan, 1975). Thus we expect this trait to be positively correlated with 2D:4D.

In line with the previous studies (e.g. Fink et al., 2004; Luxen & Buunk, 2005) we also expect to find stronger correlations for the right hand than for the left hand.

METHODS

Participants

The study subjects included of 194 female and 107 male Czech or Slovak biology students from Charles University in Prague who participated voluntarily and without any compensation in the experiment. Their average age was 20.9 years ($SD = 1.87$; range 19–29) for men and 21.0 years for women ($SD = 1.77$; range 19–29). Ten women and six men who failed to submit personality questionnaires were excluded from the study: the final numbers of participants were 184 women and 101 men. The rather unbalanced proportion of men to women in this study reflects the actual male to female ratio of biology students at the university.

Materials and procedure

We used the Czech version (Říčan, 1975) of the 16 Personality Factor Questionnaire, form A (Cattell et al., 1970). For the list of 16 personality factors, see Supplement—Table 1. Cohorts of biology students have been tested with this questionnaire since 1992 as a part of an unrelated long-term study. Single measures of the lengths of the 2nd and 4th digits from the finger tip to the ventral proximal crease of the left and right hand were collected using a digital sliding caliper calibrated to 0.05 cm. The measurements were performed in 2003 through 2005 by two anthropologists trained in somatic measurement.

At the first time of contact, the participants signed an informed consent form and obtained the 16PF questionnaire to fill out at home. In the following half-year term, they were invited for anthropometrical measurement.

Statistical analyses were performed using the SPSS, separately for men and women. As scores in personality factors are correlated with age, we used residuals computed from the regressions of 16PF raw scores with age in our analyses. To estimate direct and mediated relations, we computed the inverse correlation matrix which comprised calculating inverse correlation scores and scaling them to have unit entries on the diagonal. According to Whittaker (1990), values of the inverse correlation matrix closed to zero can be interpreted as conditionally independent given the remaining variables. To consequently create the

most probable model of mediations, we tested several models by mediator analyses following the procedures outlined by Baron and Kenny (1986). Including the effect of experimenter (on measuring the digit length) into the model did not change the basic pattern of the results; therefore we only present results of analyses without controlling for this potential confounding factor only. To determine sex differences in the digit ratio and Cattell's factors, we used unpaired *t*-tests.

RESULTS

We found a significant sex difference in the 2D:4D ratio for the right hand, but not for the left hand (see Table 1). Women scored higher in factors A (warmth), I (sensitivity), O (apprehension) and Q4 (tension), while men did so in factors E (dominance), H (social boldness), M (abstractedness) and Q1 (openness to change) (see Table 1).

For women, we found a significant negative correlation of 2D:4D with factors C (emotional stability, $r = -0.20$, $p = 0.007$), H (social boldness, $r = -0.18$, $p = 0.016$) and a positive correlation with factor N (privateness, $r = 0.15$, $p = 0.048$) for the right hand only. For men, there was no significant correlation with any of the 16PF factors (see Table 2).

Relations of the right-hand 2D:4D, emotional stability, social boldness and privateness were further analysed for women. The inverse correlation matrix (Table 3) shows that the associations of right-hand 2D:4D with emotional stability, of emotional stability with social boldness and of social boldness with privateness are likely to be direct correlations. In contrast, associations of right-hand 2D:4D with social boldness, of right-hand 2D:4D with privateness and of emotional stability with privateness seem to be rather mediated by

Table 1. Reliabilities of Cattell's factors and sex differences for the digit ratio and personality factor scores for this sample

	Cronbach α	Mean (SD)		<i>t</i>	<i>p</i>	Cohen <i>d</i>
		Women	Men			
2D:4D right hand		0.985 (0.032)	0.972 (0.031)	3.44	<0.001	0.40
2D:4D left hand		0.985 (0.032)	0.980 (0.035)	1.34	0.181	0.15
Warmth (A)	0.42	10.63 (3.28)	9.49 (3.24)	-2.84	0.005	-0.34
Reasoning (B)	0.41	10.36 (1.64)	10.20 (1.73)	-0.78	0.439	-0.09
Emotional stability (C)	0.58	12.88 (3.82)	13.58 (4.11)	1.46	0.145	0.17
Dominance (E)	0.59	12.89 (4.30)	14.81 (4.39)	3.60	<0.001	0.43
Liveliness (F)	0.68	13.06 (4.65)	13.11 (5.35)	0.07	0.941	0.01
Rule-consciousness (G)	0.50	9.74 (3.70)	9.38 (3.56)	-0.81	0.416	-0.10
Social boldness (H)	0.83	9.88 (5.92)	11.57 (6.70)	2.21	0.028	0.26
Sensitivity (I)	0.51	13.07 (3.31)	10.50 (4.04)	-5.82	<0.001	-0.69
Vigilance (L)	0.39	10.19 (3.49)	10.46 (3.27)	0.64	0.525	0.08
Abstractedness (M)	0.24	12.78 (3.29)	14.14 (3.40)	3.32	0.001	0.39
Privateness (N)	0.15	8.04 (2.56)	8.23 (2.72)	0.57	0.568	0.07
Apprehension (O)	0.55	12.23 (3.79)	10.45 (3.95)	-3.76	<0.001	-0.45
Openness to change (Q1)	0.46	6.90 (3.08)	7.94 (3.16)	2.72	0.007	0.32
Self-reliance (Q2)	0.34	12.70 (3.21)	12.76 (3.16)	0.16	0.876	0.02
Perfectionism (Q3)	0.33	10.04 (3.16)	10.41 (3.47)	0.91	0.362	0.11
Tension (Q4)	0.66	15.60 (4.44)	13.73 (4.90)	-3.28	0.001	-0.39

Table 2. Pearson correlations of right- and left-hand 2D:4D with residuals of regressions of Cattell's first-order factors with age in women and men

	Women		Men	
	Right	Left	Right	Left
Warmth (A)	-0.07	0.02	0.16	Null
Reasoning (B)	Null	0.01	0.11	0.17
Emotional stability (C)	-0.20**	-0.06	-0.10	-0.06
Dominance (E)	-0.03	0.05	-0.03	0.02
Liveliness (F)	-0.13	Null	Null	-0.08
Rule-consciousness (G)	0.03	-0.01	Null	0.04
Social boldness (H)	-0.18*	-0.06	-0.04	-0.07
Sensitivity (I)	-0.03	-0.02	0.08	0.05
Vigilance (L)	Null	0.06	0.03	0.07
Abstractedness (M)	-0.07	-0.05	0.14	Null
Privateness (N)	0.15*	0.01	0.16	0.03
Apprehension (O)	0.01	0.01	-0.05	0.04
Openness to change (Q1)	-0.06	0.02	-0.07	-0.11
Self-reliance (Q2)	0.05	-0.04	0.01	0.10
Perfectionism (Q3)	-0.02	0.03	-0.07	-0.09
Tension (Q4)	0.10	0.01	-0.04	-0.02

Null ... (-0.01;0.01).

* $p < 0.05$ (two-tailed).

** $p < 0.01$ (two-tailed).

other factors. To test for this we performed mediator analyses for all relevant variable combinations with the presumption about the direction of causality leading from the digit ratio to the personality factors. We found that emotional stability mediated at least partially the right-hand 2D:4D-social boldness link and that social boldness mediated the emotional stability-privateness link. The results are displayed in Figure 1.

The Sobel test (Sobel, 1982) revealed that including emotional stability as a mediator significantly reduced the beta for the linear effect of the digit ratio on social boldness, $z = 2.37$, $p = 0.018$. Similarly, the Sobel test revealed that including social boldness as a mediator significantly reduced the beta for the linear effect of emotional stability on privateness, $z = -3.07$, $p = 0.002$. (The Sobel test conducted on the mediation of the digit ratio-privateness link by social boldness was also significant, $z = 2.01$, $p = 0.037$, but at a lower level compared to the two above mentioned results; our resulting model represents the most probable option.)

Table 3. Inverse correlation matrix of right-hand 2D:4D and Cattell's emotional stability, social boldness and privateness

	Right 2D:4D	Emotional stability (C)	Social boldness (H)	Privateness (N)
Right-2D:4D	1			
Emotional stability (C)	0.14	1		
Social boldness (H)	0.09	-0.30	1	
Privateness (N)	0.09	0.04	0.26	1

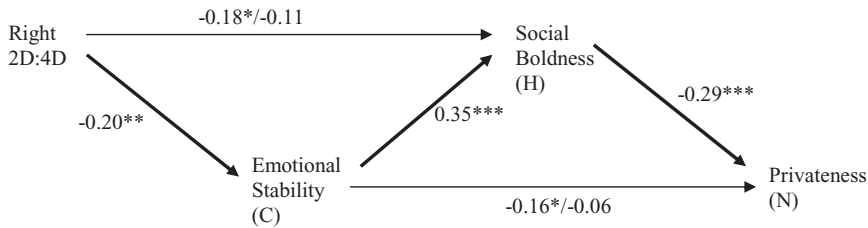


Figure 1. Emotional stability at least partially mediates the relations between the right-hand 2D:4D and social boldness, and social boldness fully mediates the relationship between emotional stability and privateness (performed for women). Bold arrows indicate the resulting model. Values before slashes represent results before including the mediator in the model; values after slashes represent results after including the respective mediator in the model. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Coefficients are standardised.

DISCUSSION

In our study, we found the morphological trait 2D:4D to significantly (though not very strongly) correlate with three Cattell's first-order factors in women, namely with lower emotional stability, lower social boldness and higher privateness. Primarily, this shows that we can observe associations of 2D:4D with personality even at the lower level of Cattell's source traits. Previous studies mostly demonstrated associations with global personality domains (e.g. neuroticism, extraversion and agreeableness) which correspond to Cattell's second-order factors. We consider the correlations with the first-order factors to be more informative as some of them might be especially bound to the hormone influence or depend on other biological factors more directly than any higher-order factor. Moreover, mediator analysis revealed that emotional stability is probably the factor primarily correlated with the morphological trait 2D:4D (and with the hypothetical biological factor responsible for differences in 2D:4D), whereas the significant correlations of the other two personality traits with 2D:4D seem to be merely due to correlations among the personality traits.

Importantly, the pattern of our results fits the hypothesis of Austin et al. (2002) which says that the associations between 2D:4D and personality traits within sexes will reflect differences between sexes. We confirmed three (for emotional stability, social boldness and privateness) out of five correlations with the digit ratio predicted on the basis of this hypothesis. (We were not able to find a significant correlation with warmth and trust.) This has not always been the case for the higher-order factors, of which, for example agreeableness and extraversion showed inconsistent associations with 2D:4D. Actually, these previous inconsistencies might have been caused by the fact that some first-level factors (facets) loading on these second-order domains are differently (oppositely) related to sex. More specifically, our results indicate that straightforwardness (reversed factor N), in which women typically score higher than men (Cattell et al., 1970) in contrast to agreeableness as a whole (Costa et al., 2001), and which correlates negatively with the digit ratio, could have been responsible for the previous unexpected results of a negative association of agreeableness with 2D:4D (see Fink et al., 2004). Similarly, a negative association of 2D:4D with social boldness (assertiveness) could have been responsible for findings of a negative correlation of the digit ratio with extraversion (Fink et al., 2004; Lippa 2006); however, an opposite (positive) association of 2D:4D with some other facet (e.g. warmth) could have caused the absence of correlation and a trend in the opposite direction of 2D:4D with extraversion in the study by Luxen and Buunk (2005).

The unexpected lack of association of 2D:4D with factor L (vigilance vs. trust) could reflect a specific property of the Czech population or a slight shift in the Czech meaning of this factor in relation to other trust scales. The typical sex difference (with women trusting more) for trust scales and related traits is absent for factor L both in our sample (see Table 1) and in the norms for the Czech population (Říčan, 1975). Contrary to predictions, we have not found any correlation of warmth (factor A) with 2D:4D either. We suggest that this might be a type II error and future research can reveal a positive association.

As in most previous studies, we have found stronger associations of the personality profiles with the right hand than with the left hand, and in concordance with the study of Fink et al. (2004), we have also observed stronger associations for women than for men. The right-hand precedence is usually explained by the right hand being a stronger marker of prenatal steroid hormones than the left hand (Fink et al., 2004; Luxen & Buunk, 2005). However, this phenomenon still remains the subject of speculation.

Our mediator analysis has shown emotional stability to be primarily influenced by a hypothetical factor (probably steroid hormones) which also affects 2D:4D whereas correlations with social boldness and privateness seem to be mediated by intercorrelations among these personality factors. Anxiety (the reverse of emotional stability) is strongly influenced by oestrogens and progesterone in females (e.g. Frye, Petralia, & Rhodes, 2000; Walf & Frye, 2006), indicating that female sex hormones could act as the neuroendocrinological factor causing the 2D:4D-personality association. Also the fact that most correlations were obtained for women draws attention to the role of female, in addition to male, hormones in the association between 2D:4D and personality. Female steroid hormones were previously found to correlate with 2D:4D in adulthood (Manning et al., 1998; McIntyre et al., 2007). Moreover, McIntyre, Ellison, Lieberman, Demerath, and Towne (2005) showed that 2D:4D increases in childhood in both sexes, but faster in early pubescent females, who show a rise in sex hormones. Seemingly contradictory results were obtained by Trivers, Manning, and Jacobson (2006). However, this longitudinal study first recruited the subjects at the average age of almost 10 years, thus the first rise of female hormones might not have been reflected. If we accept this notion of a link between pubescent rise of sex hormone levels and 2D:4D, the previously mentioned explanation of the stronger associations of personality with 2D:4D in the right hand than in the left hand would not hold up since based on postnatal stability of 2D:4D.

It is important to note that our results only indicate weak associations between personality and 2D:4D. This might have been partly caused by the relatively low reliability of several factors from the Czech translation of Cattell's questionnaire (see Table 1). Nevertheless, although the pattern of results, mostly confirming our predictions, can be considered as evidence for the validity of this association indicative of an interesting effect of hormones (or other factors), it must be kept in mind that the psychological meaning is rather imperceptible. Also, the effect found in our sample of undergraduate biology students cannot be generalised to the whole population. The specificity of our sample has probably also caused the lack of accord between the pattern of personality sex differences obtained in our sample, pattern of personality sex differences obtained by meta-analytical studies and pattern of our 2D:4D correlations. This, however, should not reduce the validity of our results based on intra- and not intersex variability.

In conclusion, we consider it very useful to look for more specific personality traits correlated with the morphological feature 2D:4D. Moreover, we propose that in addition to analysing separately both men and women and the right and left hand, which is crucial for the obtained pattern of results, it is important to always combine more differentiated

psychometric measures with more sophisticated correlation analyses to identify associations mediated by intercorrelations between personality traits. As intercorrelations of personality factors are frequent, results of correlation analyses of 2D:4D with personality (not only here, but also in previous studies) are likely to have been influenced by both direct effects of hormones and interactions among psychological factors. Such an approach can shed more light on the structure of the psychological correlates with the morphological trait, and thus also contribute to the debate about the underlying neuroendocrinological mechanisms.

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