Direct versus image-based digit ratio (2D:4D) measurement compared:

Performance indicators and associations with candidate traits ¹

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[This manuscript version: March 12, 2010](#)

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Summary.--Direct vs computer-assisted image-based measurements of the second-to-fourth digit ratio (2D:4D), a widely studied assumed negative correlate of prenatal testosterone, were compared in a sample of 96 men. Both methods yielded comparable associations of 2D:4D with a range of sexually differentiated personality measures, including the Big Five, aggression, hypermasculinity, and self-esteem (partly additionally assessed with implicit tasks and peer-ratings complementing the self-report measures). Directly ascertained 2D:4D was significantly less precisely measurable and significantly higher than 2D:4D ascertained from images by the same observers. In particular, measurement method impacted fingers differentially: directly measured index vs ring fingers were 1% vs 2% shorter, thereby yielding higher 2D:4D than when measured from images. Finger differences in fingertip size have been hypothesized to account for such discrepancies. However, fingertip size is unrelated to 2D:4D. Alternatively, diminished finger extensibility in supinated hand position (when taking direct measurements), as compared with finger extensibility in pronated hand position (when taking palmar-view hand images), might account for these observations. For anatomical reasons, this effect should be stronger for ring fingers than for index fingers and moreover should increase with age. The present data supported this novel hypothesis for explaining measurement-dependent differences in 2D:4D.

There is considerable interest in research into possible retrospective markers of prenatal male sex hormones (i.e., androgens, especially testosterone). This is mainly motivated by two interrelated facts.

First, animal experiments as well as natural experiments in humans (as provided by androgen-related endocrine disorders) suggest that prenatal androgen action has far-reaching effects beyond those leading to anatomical sexual differentiation. These effects are called organizational (or organizing) hormone effects, in that they operate early, during prenatal life, and appear to modify brain tissues and circuitry permanently. As such, prenatal androgen action appears to be a prime candidate responsible for early emerging human psychological sex differences, and respective investigations may shed light on the origin and developmental trajectory of individual difference variables characterized by sex differences.

Second, however, the prenatal sex-hormonal milieu is generally difficult to study directly and, for obvious reasons, this is untenable to experimentation in humans. It is for these two facts combined that retrospective markers of prenatal androgen action are a much sought-after desideratum of research (for reviews of these research lines, see Cohen-Bendahan, van de Beek, & Berenbaum, 2005; Neave, 2008). Of these candidate markers, the second-to-fourth digit ratio (2D:4D) has become the most popular one over the past few years (for a bibliography of 2D:4D research, see Voracek & Loibl, 2009).

2D:4D, as measured postnatally, is assumed to be a negative correlate of prenatal testosterone (Manning, Scutt, Wilson, & Lewis-Jones, 1998; Manning, 2002) for a variety of reasons. First, 2D:4D on average is lower in men than in women, and this sex difference is already established prenatally and appears to be developmentally fairly stable. Second, diverse validation studies have suggested that lower (i.e., more masculine) 2D:4D corresponds to a higher testosterone-to-estradiol ratio in the amniotic fluid as well as to higher genetically based sensitivity to testosterone and its cellular actions. Third, there is various evidence that 2D:4D is meaningfully

altered in androgen-related human endocrine disorders and in animals is modifiable by prenatally administered exogenous testosterone or through known endocrine disruptors (for background references of 2D:4D validation studies, see McIntyre, 2006; Neave, 2008; Voracek & Loibl, 2009).

To calculate 2D:4D, researchers have measured finger lengths via different methods. These may aptly be summarized under image-based methods (i.e., when finger length is ascertained from palmar-view images of the hand, such as photocopies or flatbed scans) vs the direct method (i.e., when caliper-based measures are directly taken from the fingers). Of note, there currently is a debate in 2D:4D research regarding the equivalence of these different methods for ascertaining finger length. Evidence mainly stemming from one group of researchers (Manning, Fink, Neave, & Caswell, 2005; Fink, Thanzami, Seydel, & Manning, 2006; Caswell & Manning, 2009) suggests that image-based methods yield lower 2D:4D than direct measurements. This finding has been replicated by other researchers (Burriss, Little, & Nelson, 2007; Allaway, Bloski, Pierson, & Lujan, 2009), but not consistently so (see Voracek & Dressler, 2006; Voracek & Offenmüller, 2007).

In this context, it has been conjectured (Manning, et al., 2005; see also Wallen, 2009) that sex differences and finger differences in the curvature and size of the fingertips could account for the lower 2D:4D obtained via image-based methods. Subtle differences in these features could be relevant, as fingertip fat pads may be differentially deformed when taking images of the palm, whereas they are not deformed with direct finger-length measurements. However, other data (Voracek, Pietschnig, & Oeckher, 2008) suggest that fingertip size, although it shows large finger differences, is only negligibly sexually differentiated and, in fact, is unrelated to 2D:4D, thus weakening the plausibility of this conjecture. Of importance, in the context of the ongoing discussion on measurement matters in the 2D:4D literature, it has also been noted (e.g., Manning & Fink, 2008; Manning, Baron-Cohen, Wheelwright, & Fink, 2010) that direct finger-length measurements are superior to image-based methods, whilst the latter ones, in contrast, are in some way distorted, and that therefore the direct method should be preferred over image-based methods

in 2D:4D studies, wherein expectable effect sizes are small.

It is worth noting that there still is a lack of comprehensive studies on the equivalence or non-equivalence of these two 2D:4D measurement methods with regards to the effect sizes obtained, when correlations between 2D:4D, measured differently, and external variables (i.e., sexually differentiated target traits) are calculated. Relatedly, although there is some evidence that directly ascertained 2D:4D is less precisely measurable than 2D:4D from images (e.g., Voracek & Offenmüller, 2007), this evidence should beneficially be replicated. Hence, the present study was designed as a systematic comparison of 2D:4D measurement methods (direct vs image-based), specifically pertaining to the performance indicators of these and to the associations of differently measured 2D:4D obtained with external candidate variables.

METHOD

Participants

The all-male sample comprised 96 individuals from rural areas in Lower Austria (the country's most northeasterly state), who volunteered to participate in a broader-scoped investigation (personality assessment among rural occupations). The sample was notably more mature and heterogeneous in age than typical college samples are (age M = 44.3, SD = 12.5 yrs., age range: 19-74 yrs.).

Instruments

A range of personality measures was available for this research. Explicit assessments (i.e., self-report scales) were partly accompanied by implicit assessments or peer-ratings of the same trait. To begin with, Macho components of personality were assessed explicitly with the Hypermasculinity Inventory (Mosher, 1998), consisting of 30 forced-choice items (with 10 items each forming its three subscales Callous sexual attitudes, Violence as manly, and Danger as exciting). A German version of this instrument was developed for this research, using the parallel blind technique (Behling & Law, 2000).

Self-esteem was explicitly assessed with the German form (von Collani & Herzberg, 2003) of Rosenberg's Self-Esteem Scale (RSES; 10 items with 4-point response format) and implicitly with the Initial Preference Task (IPT; Kitayama & Karasawa, 1997). The IPT is a widely used implicit measure of self-esteem and is based on the name-letter effect (i.e., individuals rate letters appearing in their forename and surname, especially their initials, more favorable than the remainder of the alphabet). Specifically, participants rated the likeability of all letters of the alphabet on 7-point scales.

For assessing the Big Five dimensions of personality, i.e., agreeableness, conscientiousness, emotional stability (reverse-coded neuroticism), extraversion, and openness, the Ten-Item Personality Inventory (TIPI; Gosling, Rentfrow, & Swann, 2003) was used. The TIPI is a very brief and thus economic measure of the Big Five, which are represented with two items each therein, to be answered on 7-point scales. For measuring aggression explicitly, the German form (Herzberg, 2003) of the most frequently used self-report measure of aggression, the Buss-Perry Aggression Questionnaire, was administered. This instrument gauges four distinct facets of the trait (physical aggression, verbal aggression, anger, and hostility) with 9, 5, 7, and 8 items, respectively, on 5-point scales. For the Big Five measure as well as for the aggression questionnaire, complementing the self-ratings of the participants, independent peer-ratings were also available (see Vazire, 2006, for the advantages of this approach in the field of personality assessment). The latter ones were made by same-sex, same-generation individuals, who usually were participants' longstanding friends or neighbors and furthermore were matched with regard to age and educational level to them.

Aggression was measured implicitly with a standard task, namely an Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998), furnished to probe aggression (target categories: me vs others; attribute categories: peace vs aggression). Finally, social desirability was assessed with the Social Desirability Scale SDS-17 (Stöber, 2001), comprising 17 items with true-false response format.

The communality of the above personality measures was that all of them show sex differences. For instance, men on average score higher on aggression and self-esteem scales, which sex effect generalizes to implicit assessments of the same dimensions (e.g., Voracek & Stieger, 2009). Regarding the Big Five, it is well-known that men report higher emotional stability and openness than women, whereas lower extraversion, agreeableness, and conscientiousness (e.g., Schmitt, Realo, Voracek, & Allik, 2008). Also, there is evidence for higher social desirability levels in women than in men (Stöber, 2001). Finally, the Hypermasculinity Inventory was specifically devised to assess an unwelcome personality constellation that is genuinely male-typical.

Procedure

Participants were recruited individually in rural areas by personal referral and nominated their peer-raters. Participants reported basic demographic information, completed a survey form comprising the self-report (i.e., explicit) measures, and the two implicit tasks (IPT and IAT). Finally, finger lengths were measured directly and images of participants' hands were taken.

For calculating the IPT effect (whereby higher values represent higher implicit self-esteem) for the forename and surname initials combined, the I algorithm (for details, see LeBel & Gawronski, 2009) was employed. For calculating the IAT effect (whereby higher values stand for higher implicit aggression), the D measure (Greenwald, Nosek, & Banaji, 2003) was utilized.

Two trained investigators independently measured participants' index and ring fingers (2D and 4D) of both hands, using digital vernier calipers measuring to 0.01 mm (Mitutoyo Ltd., Andover, Hampshire, U.K.; Model 500-191U). The same two investigators independently measured finger lengths from 300 dpi flatbed-scanned images of the ventral side of participants' right and left hands, using a freeware program specifically designed for image-based measurement of 2D:4D (AutoMetric 2.2; available from www.facelab.org/debruine/Programs/autometric). There is evidence that such computer-assisted 2D:4D measurements have higher precision than other image-based methods (caliper-based measurement from photocopies or from laser printouts of

scanned images; Allaway, *et al.*, 2009; Kemper & Schwerdtfeger, 2009). For obtaining the scanned images, participants placed their hands on the scanner surface, with fingers held parallel, in a relaxed position and without exerting pressure. The lower and upper measurement landmarks for the direct and image-based finger-length measurements were the midpoint of the flexion crease most proximal to the palm and the fingertip, respectively.

For each 2D:4D measurement method, individual finger-length measurements of the two investigators were averaged prior to calculating right-hand and left-hand digit ratios (R2D:4D and L2D:4D). AutoMetric 2.2 yields length measurements in pixels. To compare these imaged-based finger-length measurements with those measured directly, the obtained pixel values were converted to mm, according to the formula: finger length (mm) = [finger length (pixels) / 300 (dpi)] * 25.4 (mm). From this calculation, it also becomes clear that, although the measurement resolution of both methods was very high, it still was by nearly one decimal power better for direct measurements (0.01 mm) than for image-based measurements (1 pixel = 25.4 mm / 300 dpi = 0.085 mm).

The right-minus-left difference (D_{R-L}) in digit ratios is generally lower as well as more frequently below zero in men than in women and thus is considered as an additional pointer to high prenatal androgen levels (for background and reviews, see Manning, 2002, pp. 21-22; Bescós, Esteve, Porta, Mateu, Irurtia, & Voracek, 2009; Hönekopp & Schuster, 2010). This measure of directional asymmetry in digit ratios, also considered here, was calculated as $D_{R-L} = R2D:4D - L2D:4D$. Absolute finger length (FL) is a putative marker of postnatal androgen levels, possibly reflecting pubertal-adolescent androgen action, because sex differences in finger length are negligible before, but very large after, puberty, and correlations of finger length and height among adults are far below unity (only in the .50s), thus suggesting finger length is not merely a proxy for body height (Lippa, 2006). Mean finger length, additionally considered here, was calculated as $FL = (R2D + R4D + L2D + L4D) / 4$. Interobserver repeatabilities of the finger-length measurements were

quantified with single-score intraclass correlation coefficients (ICC, two-way mixed-effects model with absolute-agreement definition; see Voracek, Manning, & Dressler, 2007).

RESULTS

Performance indicators of direct vs image-based 2D:4D measurements

The results of the 2D:4D measurement method comparisons are set out in Table 1. To enable precise and thus informative method comparisons, key statistics are reported up to the third decimal place therein.

Numerical comparisons of the ICC values indicated that direct measurements were throughout less repeatable than those from images. Comparisons of the 95% confidence intervals associated with these ICC values showed that in 6 out of 8 tests (except for L2D:4D and L4D) direct measurements had significantly lower repeatability than image-based ones. These method differences were less pronounced for individual finger-length measurements (R2D, R4D, L2D, and L4D) or those combined (FL), but sizable for digit ratios (R2D:4D and L2D:4D; with ICCs in the mid .80s for direct vs still in the high .90s for image-based measurements), and, even more so, for D_{R-L} (about .65 vs still in the .90s, respectively).

On average, digit ratios were invariably higher and finger lengths invariably shorter when measured directly rather than from images. As indicated by paired t tests, these method differences were significant (p s < .001), although effect sizes (Cohen d values) generally were small. The exception from this pattern was D_{R-L} , which was lower, but not significantly so (paired t = -1.93, two-tailed p = .057), when measured directly vs from images. In addition, evidently larger method effects emerged regarding the length of ring fingers than regarding the length of index fingers. This was consistently seen for both hands.

Sample variability (SD values) of digit ratios and finger lengths was slightly smaller (6 out of 8 comparison, except for D_{R-L} and L2D) for direct than for image-based measurements. Skewness of the distributions of measurements was mostly positive (12 out of 16 tests), but never significant, as

would be indicated by values larger than twice the standard error (SE) of the skewness statistic (SE = 0.25 with this sample size). Further, skewness was numerically larger for direct than for image-based measurements in 4 out of 8 comparisons, whereas smaller in the other half of comparisons. Kurtosis of the distributions of measurements was positive in 9 out of 16 tests. Of the 7 negative kurtosis values, 6 pertained to the distributions of absolute finger-length measurements. In only one case (D_{R-L} , measured from images), the respective kurtosis value was larger than twice its SE (0.49 with this sample size). Further, kurtosis was numerically larger for direct than for image-based measurements in 3 out of 8 comparisons. As expected from these findings pertaining to skewness and kurtosis, tests for normality of the measured traits were never significant (all Kolmogorov-Smirnov $\underline{z} < 0.9$). The direct measurement method yielded smaller $\underline{z}$ values than image-based measurements in 6 out of 8 comparisons.

Linear association tests for the differently measured traits (based on Pearson r) attested that directly vs image-based measured traits correlated with about .95 for finger lengths, .85 for digit ratios, and .70 for D_{R-L} (see bottom of Table 1). Relatedly, when the traits measured from images were regressed on the same traits measured directly, the intercepts in these linear regression models invariably were significant (details omitted), thus indicating location shift (i.e., different mean trait values) across measurement methods, as noted above (fingers measured directly were shorter and digit ratios measured directly were higher than those obtained from image-based measurements). Consequently, exact agreement tests for the differently measured traits (using absolute-agreement definition ICCs) yielded correspondingly lower figures than those from the linear association tests, namely in the low .90s for finger lengths, about .80 for digit ratios, and below .70 for D_{R-L} .

As indicated by tests for curvilinearity (details omitted), the relationships between the traits measured directly vs from images was fully linear over the whole range. Specifically, squared trait values, as obtained with one measurement method (direct), did never significantly predict the same

trait measured with the other method (image-based), over and above the predictive power of the simple values of the former trait (i.e., measured directly), and vice versa. For completeness (not shown in Table 1), the correlation of R2D:4D and L2D:4D, i.e., the right-left-hand correspondence of digit ratios, was somewhat lower for the direct than for the image-based method ($r = .62$ vs $.70$, respectively; both $ps < .001$).

Associations of direct vs image-based 2D:4D measurements with candidate traits

The associations of finger-length measurements with the external variables (i.e., candidate traits) are displayed in Table 2. As above, to enable precise comparisons of the measurement methods, the correlation coefficients are reported up to the third decimal place therein.

Altogether, 224 correlations were calculated (the relationships of the 4 finger-length measures R2D:4D, L2D:4D, D_{R-L} , and FL, each measured via the two methods, with 28 personality variables, assessed explicitly or additionally implicitly, and via self-reports or additional peer-ratings). The distributions of the correlation coefficients with the personality variables, obtained with direct vs image-based finger-length measurements (112 correlations for each method), had both inconspicuous skewness (in above order, 0.07 vs -0.37 , with $SE = 0.23$) and kurtosis (-0.30 vs 0.10 , with $SE = 0.45$) and thus did not deviate from normality (Kolmogorov-Smirnov $z = 0.52$ vs 0.51 , ns). For both methods, the obtained correlations on average amounted to $r = .03$, meaning that they typically were tiny and, of note, not more substantial with one or the other measurement method.

Of all correlations shown in Table 2 (see bottom), 17% (38/224) were significant. Specifically, with the direct method 18.8% (21/112) of the correlations were significant, whilst with the image-based method 15.2% (17/112). A difference of proportions test showed this difference between methods to be far from significance ($z = 0.71$, two-tailed $p = .48$). More precisely, out of 28 comparisons per finger-length measure (R2D:4D, L2D:4D, D_{R-L} , and FL), the r value obtained with direct measurements was numerically larger than the corresponding r value

obtained with image-based measurements in 20, 14, 21, and 14 cases, respectively. Wilcoxon tests showed that these method differences in the r values obtained were only significant for D_{R-L} (in 21 out of 28 comparisons numerically larger for direct measurements, two-tailed $p = .02$; see bottom of Table 2).

Overall, for both methods the proportion of significant correlations ($p < .05$) observed exceeded the Type I error rate (5%). However, it has to be taken into account that, apart from the correlated traits R2D:4D and L2D:4D, a great many of the personality variables tested here were similarly mutually interrelated and thus neither conceptually nor empirically independent from each other. This pertained foremost to the 4 subscales and the total score of the Buss-Perry Aggression Questionnaire, for which both self-reports and peer-ratings were available. It is also emphasized that, given the multitude of tests conducted, none of the significant correlations would have survived corrections for multiple statistical testing.

What is even more, almost no theory compliant correlations between finger-length measures and personality variables emerged. To explain, for candidate variables wherein men on average exceed women (e.g., aggression, hypermasculinity, or self-esteem), meaningful within-sex associations would be as follows: more masculine (i.e., lower) digit ratios (including the D_{R-L} measure) and more masculine (i.e., longer) fingers should correspond to a more masculine (i.e., higher) expression of the trait under scrutiny. Briefly, theory compliant correlations for aggression, hypermasculinity, self-esteem, and similar traits, wherein men exceed women, would be expected to be negative for digit ratios whilst positive for absolute finger length. With the present data (Table 2), there was a single correlation (out of 224 calculated) that was theory compliant: scores of the Callous sexual attitudes subscale from the Hypermasculinity Inventory were significantly negatively related to R2D:4D (measured from images). This finding did neither generalize to L2D:4D nor to direct digit ratio measurements, the other two subscales of this instrument, or its total score. Since this finding was isolated and would not survive adjustment for the multitude of

statistical tests conducted overall, it should not be regarded as credible.

On the other hand, it was also obvious (see Table 2 entries) that quite a number of significant correlations emerged from the data which were directionally opposite than expected. In particular, a number of significant, but directionally erroneous, correlations clustered on the explicit aggression measure (for both self-report and peer-rating data), in that these were positive (instead of negative) for digit ratios and negative (instead of positive) for absolute finger length. Since the direction of these associations are hard to reconcile with theory and expectation, they should be best regarded as having arisen due to sampling variability.

DISCUSSION

Direct measurements of finger length, including digit ratios calculated from these, are significantly less precise than image-based, computer-assisted measurements of the same traits made by the same trained observers. This loss of measurement repeatability is least conspicuous for finger lengths, more substantial for digit ratios, and most pronounced for D_{R-L} , the directional asymmetry measure of digit ratios.

Such a pattern is unsurprising and, in fact, expected by measurement theory (see Voracek, et al., 2007). Sources of random measurement error mutually cancel out, when averages of single measurements are taken (such as when individual finger-length measures are averaged across observers). Summing up individual observations is equivalent to averaging these. However, measurement errors do not cancel out, when differences between observations are calculated; rather, they accumulate. Even worse, errors multiply when ratios are calculated (such as digit ratios from finger lengths). For this reason, measurement precision is highest for finger length, lower for digit ratios, and lowest for D_{R-L} (because this is the difference of two ratio variables). Since study effects are inevitably attenuated by measurement error, directly measured digit ratios conceivably will yield smaller group effects (e.g., diminished sex differences) than digit ratios ascertained with higher precision (such as image-based, computer-assisted measurements).

Replicating various prior evidence (e.g., Manning, *et al.*, 2005), the present data showed that directly measured 2D:4D is significantly higher, whilst directly measured fingers are significantly shorter than the same traits measured from images. Of note, there was a simple relationship between 2D:4D ascertained directly *vs* from images, in that it was fully linear over the whole range of values. Hence, directly measured 2D:4D can practically be considered as merely being higher than image-based 2D:4D, whereas not complexly or nonlinearly related to the latter one. Furthermore, as expected, both methods yielded approximately normally distributed traits, with no practically relevant distributional peculiarities.

However, the current data also show that the two measurement methods impact fingers differentially. Whereas directly measured index fingers were on average less than 1 mm (or 1%) shorter than their image-based measurements, directly measured ring fingers were about 1.5 mm (or 2%) shorter (see Table 1). This differential effect explains why direct measurements yield higher 2D:4D values than image-based measurements, but the question remains what causes this discrepancy. It has previously been suspected that finger differences in fingertip size and shape might account for such observations (Manning, *et al.*, 2005; cf. Wallen, 2009). Indeed, there are substantial differences between index and ring fingers regarding this anatomical detail. But then again, fingertip size is unrelated to 2D:4D (Voracek, *et al.*, 2008); hence, this hypothesis is unsupported. In what follows, a novel hypothesis for the above findings of length discrepancies is presented and tested.

There might be a simple reason for the observed discrepancies between 2D:4D ascertained directly *vs* image-based. One important, obvious difference between these measurement methods, not previously discussed in the 2D:4D literature, is the posture of the hand. With direct measurement, the hand is in supinated position (i.e., the palm points upwards), whereas it is pronated (i.e., the palm points downwards), when palmar-view images (photocopies or flatbed scans) are taken. Hand supination clearly is an uncomfortable position. In particular, fingers are

less easily fully extended than in the more comfortable pronated position. This effect of diminished finger mobility in supination should be more notable among elder individuals, as the tendon apparatus of their hand is less flexible.

What is more, this hypothesis can also account for the differential impact of the measurement methods compared on index vs ring fingers seen here. It is well-known that the ring finger is the least movable finger. This is most clearly demonstrated by observing that one can rather easily extend any finger, except the ring finger, from one's clenched fist. The reason for this difference is that of all fingers the ring finger has the most tendon connections (namely two tendons each originating from the musculus extensor digitorum and the musculus extensor digiti minimi). These numerous tendinous attachments markedly impede mobility, making the extension of the ring finger dependent on its two adjacent fingers. These subtleties of finger anatomy explain why in supinated hand position the ring finger is less extensible than the index finger. Consequently, when fingers are measured directly, ring fingers are apparently more shortened in length than index fingers are (by 2% vs 1%).

As a corollary of the above reasoning, discrepancies between 2D:4D measured in supinated vs pronated hand position (i.e., directly vs image-based) should increase with age. The large age range in the present sample (19-74 yrs.) was beneficial for such a test. This additional analysis supported the above hypothesis: the difference between digit ratios measured directly minus digit ratios measured from images was slightly positively associated with age (for R2D:4D and L2D:4D, Spearman r_s , calculated for robustness, was .16 and .18, one-tailed $p = .06$ and .04).

As for the associations of finger-length measures obtained with a suite of sexually differentiated and thus candidate personality variables for 2D:4D research, there were no indications for one measurement method yielding more substantial correlations than the other. In fact, the pattern was essentially one of null findings, since not a single significant and theory compliant association would have survived Bonferroni correction. This lack of associations

consorts well with prior evidence of no effects of 2D:4D on the Big Five (Lippa, 2006) or aggression, either measured explicitly or with the Implicit Association Test (Voracek & Stieger, 2009). A number of significant correlations emerged which were directionally opposite as expected and thus difficult to reconcile. The most likely reason for these observations is that these were chance findings, due to sampling variability, and thus erroneous. This was the first 2D:4D study considering the traits hypermasculinity, social desirability, self-esteem (measured with a self-report measure as well as with a task based on the name-letter effect), and peer-ratings of aggression and the Big Five. Similar to the remainder, these tests were also barren of results, thus suggesting that 2D:4D is unlikely to be reliably related to major sexually differentiated aspects of personality (for discussion, see Voracek, 2009; Voracek, Tran, & Dressler, 2010).

Study limitations include the all-male sample available for analysis, which moreover was of limited size. Hence, sex and other group differences could not be assessed within this design. A priori power calculations suggested that, for the association tests with personality variables, the sample ($N = 96$) had 98%, 69%, and 16% power to detect large, medium, or small effects (i.e., population r values of .40, .25, or .10) with $\alpha = .05$ and two-tailed testing. Were the direction of the effects clearly established by prior research and indeed as expected in the current data, thus allowing for one-tailed testing, corresponding power figures would have been >99%, 79%, and 24%. In other words, power was excellent for detecting large effects, satisfactory for medium, but insufficient for small effects. It would thus be beneficial to follow up the present findings in investigations of larger, mixed-sex samples.

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TABLE 1

PERFORMANCE INDICATORS OF FINGER-LENGTH MEASURES ASCERTAINED DIRECTLY VERSUS FROM IMAGES

Statistic for comparison	Method	R2D:4D	L2D:4D	D _{R-L}	R2D	R4D	L2D	L4D	FL
<u>ICC</u>	D	.851	.844	.658	.951	.989	.952	.993	.988
	I	.977	.971	.937	.995	.998	.994	.998	.999
<u>ICC</u> [95% <u>CI</u>]	D	[.784-.898]	[.775-.893]	[.528-.758]	[.927-.967]	[.984-.993]	[.929-.968]	[.990-.995]	[.983-.992]
	I	[.966-.985]	[.892-.988]	[.845-.968]	[.992-.997]	[.996-.999]	[.991-.996]	[.974-.999]	[.997-.999]
<u>M</u>	D	0.960	0.961	-0.001	74.37	77.55	74.88	77.97	76.19
	I	0.952	0.949	0.003	75.30	79.20	75.28	79.42	77.30
<u>SD</u>	D	0.032	0.032	0.028	4.63	5.31	4.61	5.37	4.75
	I	0.033	0.033	0.026	4.65	5.68	4.47	5.75	4.93
<u>t</u> (paired test)	D – I	4.27	6.37	-1.93	-6.40	-9.21	-2.61	-8.79	-8.47
Cohen <u>d</u>	D – I	0.246	0.364	-0.148	-0.200	-0.300	-0.088	-0.261	-0.229
Skewness	D	0.037	-0.294	0.154	0.196	0.055	0.227	0.470	0.237
	I	-0.247	-0.311	0.149	0.222	-0.070	0.160	0.381	0.095
Kurtosis	D	0.379	0.266	0.531	0.135	0.073	-0.426	-0.064	-0.146
	I	-0.435	0.027	1.256	0.023	0.094	-0.504	-0.001	-0.219
Kolmogorov-Smirnov <u>z</u>	D	0.729	0.454	0.725	0.648	0.724	0.559	0.748	0.581
	I	0.878	0.538	0.763	0.694	0.738	0.611	0.712	0.483
<u>r</u>	D to I	.847	.840	.705	.953	.951	.946	.960	.966
<u>ICC</u>	D to I	.824	.787	.696	.934	.909	.942	.927	.941

Note.—D, I = direct vs image-based finger-length measurements. D – I (and D to I) = difference between (and comparisons of) these measurement methods. See text for details.

TABLE 2

ASSOCIATIONS OF FINGER-LENGTH MEASURES (ASCERTAINED DIRECTLY VERSUS FROM IMAGES)

WITH PERSONALITY VARIABLES

Candidate variable	R2D:4D		L2D:4D		D _{R-L}		FL	
	D	I	D	I	D	I	D	I
Hypermasculinity (total)	.022	-.005	-.089	-.026	.126	.027	-.077	-.076
Hypermasculinity (Callous sexual attitudes)	-.177‡	-.206*	-.140	-.191‡	-.043	-.020	-.045	-.023
Hypermasculinity (Violence as manly)	.048	.123	.042	.163	.007	-.051	-.028	-.026
Hypermasculinity (Danger as exciting)	.144	.046	-.094	-.046	.272**	.118	-.084	-.103
Self-esteem (RSES)	.033	.026	-.006	-.062	.045	.113	.090	.078
Implicit self-esteem (IPT)	.024	.016	-.042	-.049	.075	.083	-.115	-.106
Agreeableness (self-rated)	.122	.084	.164	.120	-.048	-.046	.114	.067
Conscientiousness (self-rated)	-.049	.013	-.045	.011	-.004	.003	.109	.117
Emotional stability (self-rated)	.207*	.175	.072	.132	.154	.055	-.065	-.068
Extraversion (self-rated)	.120	.094	.062	.166	.067	-.092	-.071	-.068
Openness (self-rated)	-.003	.067	.093	.092	-.110	-.032	.015	-.045
Agreeableness (peer-rated)	.125	.056	.140	.067	-.017	-.014	.098	.034
Conscientiousness (peer-rated)	-.028	-.023	.039	.095	-.075	-.152	.100	.110
Emotional stability (peer-rated)	.065	.052	.071	.128	-.006	-.096	.075	.101
Extraversion (peer-rated)	-.022	.002	-.080	.037	.065	-.045	.039	.013
Openness (peer-rated)	.020	.006	.076	.033	-.062	-.035	.143	.082
Aggression (total, self-rated)	.252*	.254*	-.033	.092	.325**	.210*	-.273**	-.289**
Physical aggression (self-rated)	.162	.165	-.068	.067	.262*	.128	-.250*	-.252*
Verbal aggression (self-rated)	.303**	.292**	.001	.094	.346**	.256*	-.251*	-.295**
Anger (self-rated)	.241*	.261*	.018	.115	.255*	.189‡	-.273**	-.305**
Hostility (self-rated)	.158	.149	-.033	.035	.218*	.147	-.120	-.113
Aggression (total, peer-rated)	.168	.160	-.062	-.015	.266*	.227*	-.240*	-.234*
Physical aggression (peer-rated)	.177‡	.169	-.044	.038	.253*	.169‡	-.221*	-.224*
Verbal aggression (peer-rated)	.098	.056	-.168	-.136	.307**	.249*	-.157	-.155
Anger (peer-rated)	.126	.123	-.103	-.066	.261*	.244*	-.177‡	-.178‡
Hostility (peer-rated)	.155	.153	-.057	-.010	.242*	.210*	-.134	-.129
Implicit aggression (IAT)	.006	.043	.045	.060	-.045	-.021	-.111	-.160
Social desirability	-.014	-.107	-.019	-.143	.006	.045	.170‡	.232*
r values with $p < .05$ (per column, 28 tests)	4	4	0	0	11	6	6	7
r based on D numerically larger than r based on I (two-column comparisons, 28 tests)	20		14		21		14	
Difference test (Wilcoxon z , with two-tailed p) for the above row	$z = -1.51$ ($p = .13$)		$z = -1.18$ ($p = .24$)		$z = -2.39$ ($p = .02$)		$z = -0.30$ ($p = .77$)	

Note.— D and I = direct vs image-based finger-length measurements. See text for details.

‡ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$ (two-tailed).