DEVELOPMENTAL INSTABILITY AND PSYCHOLOGICAL FITNESS: CAN MORPHOLOGICAL ASYMMETRY PREDICT PSYCHOPATHOLOGY?

by

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Abstract

Developmental instability (DI) refers to an organism's failure to realize its ideal phenotype in a given environment. The most popular metric of DI is *fluctuating asymmetry* (FA), i.e., the degree to which bilateral morphological traits deviate from perfect symmetry when those traits are bilaterally symmetric per the ideal species phenotype. Numerous studies have shown that FA is inversely related to physical and reproductive fitness in myriad species of plants and animals. More recently, researchers have begun to assess correlations between FA and psychological variables in humans. Research has revealed negative relationships between FA and intelligence, neurological functioning, and typical brain structure. Positive relationships have also been found between FA and severe mental illness, such as schizophrenia. However, few studies have addressed the relationship between FA and symptomology of more prevalent forms of psychopathology, such as depression, anxiety, and alcohol abuse. The aim of this study is to address this void. Accordingly, FA was assessed in 204 college students across 12 morphological and dermatoglyphic traits. Current Axis I symptomology related to 13 diagnostic categories was assessed via the Psychiatric Diagnostic Screening Questionnaire (PDSQ). Depressive symptom severity was also assessed via the Beck Depression Inventory (BDI) in an attempt to replicate the previous finding of a positive relationship between FA and BDI in men (Martin et al., 1999). Finally, the SCID Axis II Screening Questionnaire (SCID-II-SQ) was administered to provide exploratory data regarding FA and personality disorders. Study analyses indicated

two significant effects. In men, positive associations were identified between self-reported alcohol abuse and asymmetry in both dermatoglyphic constructs. However, Martin et al.'s (1999) observed positive association between FA and BDI score was not replicated. The multiple null findings are defended as valid, and consistent with evolutionary-based theories of psychopathology as stemming, in part, from adaptive ancestral mechanisms being expressed in novel, modern environments (e.g., Tooby & Cosmides, 2000). Criticisms of the existing FA literature are also presented.

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Background and terminology

Developmental instability (DI) generally refers to an individual organism's failure to realize its ideal phenotype as defined by the population of its species in a given environment. The most common and widely accepted method for quantifying DI in bilaterally symmetric organisms involves the assessment of *fluctuating asymmetry* (FA; e.g., Clarke, 2003; Palmer, 1994; Polak, 2003). Indeed, these two constructs are so tightly linked that they often appear as synonyms in the literature. Specifically, however, FA is the degree to which an organism's bilateral morphological traits deviate from perfect symmetry when those traits are bilaterally symmetric according to that organism's ideal phenotype. For example, to assess FA in plants, one procedure is to subtract the left and right widths of leaves at the midpoint of the longitudinal mid-vein (Lempa et al., 2000). Common bilateral traits compared in humans include ear lengths, wrist widths, dermatoglyphics[1], and sophisticated assessments of facial asymmetries using digital photography and image-analyzing software (e.g., Martin, Manning, & Dowrick, 1999; Rosa et al., 2000; Grammer & Thornhill, 1994). Although many studies have relied on single traits to assess FA, indexes of FA in humans typically include multiple traits.

[1] I.e., finger and palm prints.

Multiple-trait indexes have been shown to provide more predictive power than individual traits alone (e.g., Wilson & Manning, 1996).

FA is distinguished from *directional asymmetry* (DA) in which the mean right-left magnitude for the population is a signed, non-zero value. Examples of DA include ear positioning in some owls (to allow sound localization along the sagital plane without tilting the head) and arm length in humans (due to load-bearing differences, the right typically being longer; e.g., Steele & Mays, 1995). Both FA and DA are distinct from a*nti-symmetry* (AS), the state in which the distribution of right-left magnitudes of a given trait in a population is bimodal yet centered on zero. Excluding internal organs, AS is apparently rare in nature, the often-cited example being the size discrepancy of male fiddler crab claws. The smaller claw is determined by the effectively random nature of autotomization through injury (Neville, 1976). A less well-known but perhaps more interesting example is that of the sail orientation in certain coelenterates, such as the Portuguese man-o'-war (Neville, 1976). These sails are equally likely to occur in one of two opposite orientations, functioning to prevent all offspring from being blown ashore in the event of catastrophic winds.

Although we have "almost no understanding of the [specific] underlying processes that control developmental stability" (Clarke, 2003; p. 188), there appears to be a consensus that both genetic and environmental forces are involved. Often-cited genetic processes conducive to stability include co-adaptation and heterozygosity. *Co-adaptation* refers to the notion that the genes of a genome are not

independent but have been associated through natural selection because their collaborative effects are adaptive. Evidence of its role in DI comes from studies showing increased FA in both natural and experimental hybrids of plants, fish, and mammals (reviewed in Alibert & Auffray, 2003). Heterozygosity is believed to contribute to stability because of the decreased likelihood of deleterious recessive alleles being expressed. Despite the popularity of these ideas, Alibert and Auffray (2003) explain that there is debate regarding the relative roles of each of these mechanisms in developmental stability, largely because they are interrelated and it is difficult to modify one without affecting the other. The authors add that several negative findings further complicate interpretations, concluding that this research is "still in an exploratory phase" (p. 130). Assuming they hold up, though, these ideas suggest that genetic diversity is stabilizing up to a point (i.e., heterozygosity) but can be excessive (i.e., hybridization).

Zakharov (2003) reviewed empirically established environmental causes of FA which tend to fall within the general category of *stress*. Such environmental stressors include non-optimal incubation temperature, environmental pollution, and social and nutritional stress. As an aside, it's interesting to note that such influences may work not only on the level of the individual but on segments of populations, such as those related to population density or location within a habitat. Another commonly cited cause of FA is infection. Moller (1996) reviews research involving organisms ranging from flies to reindeer showing that parasitism may contribute to FA. Such research is not always merely correlational. For example, one cited study showed

that experimentally imposing nematode infestations on fly larvae increased the amount of bristle asymmetry exhibited as adults.

It is important to note that FA corresponding to different traits may indicate the impact of stressors at different critical periods of development. For example, dermatoglyphic asymmetries in humans are established between 11 and 17 weeks post-fertilization (Babler, 1991), while FA indexes based on skeletal and facial proportions have been shown to vary post-natally and into puberty (Wilson & Manning, 1996).

The discussion of FA, DA, and AS above implies that only FA is *exclusively* associated with genetic or developmental error. Both DA and AS, while also subject to noise, may result predominantly from preferential use or genetic specifications. Also implied is the commonly held notion that while DA and AS are often associated with adaptive functioning, increased FA is typically associated with *compromised* fitness. Indeed, many researchers have reported inverse relationships between FA and various fitness and reproductive variables across a wide range of taxa. For example, Zakharov (2003) and Moller (1996) review a large number of studies showing, for example, that FA predicts impaired photosynthesis in plants and increased susceptibility to parasites in animals. In a particularly exhaustive review, Moller (1997) cites ten (of 12 relevant) studies indicating a positive correlation between symmetry and *growth rate* in plants, insects, snakes, birds, and rodents. Another 16 (of 17 relevant) citations document inverse relationships between FA and

reproductive success[2] in plants, insects, fish, reptiles, birds, and mammals, including humans. Finally, Moller (1997) cites 19 (of 21 relevant) studies reporting positive correlations between symmetry and *survival* across similar species as already mentioned, including humans.

It must be recognized that not all of the aforementioned research has been correlational: Fourteen studies reviewed by Moller (1997) actually involved experimental manipulations of FA. For example, Gest, Siegel, and Anistranski (1986) assigned pregnant rats to heat stress, cold stress, noise stress, or control groups. At birth, the rats in all three of the stress group litters showed increased femur FA compared to the control group litter.

The *parasite theory of sexual selection* is based on such notions that developmental fitness (namely, resistance to parasites[3]) is reflected in morphological symmetry and leads to greater mating success. This theory asserts that FA provides for impromptu "medical examinations" of other individuals within one's species (Grammer & Thornhill, 1994, p. 233), allowing one to shop for symmetrical mates who exhibit superior parasite resistance and hence are more capable of producing viable offspring. The theory is supported by research showing that animals ranging from *Drosophila* to humans prefer more symmetric mates (e.g., Markow & Ricker, 1992). In humans, Grammer and Thornhill (1994) have shown that both males and females rate symmetric faces of the opposite sex as more attractive than asymmetric faces. In a particularly interesting extension of this research, Thornhill and

[2] I.e., in terms of either number of seeds, litters, litter size, or offspring quality.
[3] I.e., both macroparasites, such as nematodes, and microparasites, such as bacteria.

Gangestad (1999) replicated a previous study in which the authors showed that human females prefer the *scent* of men with relatively symmetrical features *without having seen them*, consistent with the notion that human males secrete pheromones that corroborate such "medical examinations" based on symmetry. Other studies have suggested that dancing ability (Brown, Cronk, Grochow, Jacobson, Liu, Popovic, & Trivers, 2005) and voice quality (Hughes, Harrison, & Gallup, Jr., 2002) also correlate negatively with FA in humans. These complementary findings suggest that judgments of DI may actually be based on multiple converging cues.

It is only fair to note that not all of the aforementioned findings have received ubiquitous support. For example, Furlow, Gangestad, and Armijo-Prewitt (1998), while finding other FA effects in humans (discussed later), failed to detect the previously mentioned FA-attractiveness relationship. FA Critics contend that quality experiments in the area are difficult and rare, that counterexamples are often ignored, and that many studies are too simplistic (e.g., Tracy et al., 2003). However, despite such criticisms, it is still the case that literally scores of studies have identified positive relationships between external morphological symmetry and developmental and/or reproductive fitness.

Fluctuating asymmetry and the human brain

A considerable amount of research has addressed the relationship between FA and human neurological functioning and structure. Furlow, Armijo-Prewitt, Gangestad, and Thornhill (1997) assessed FA in 112 undergraduates by measuring

foot, ankle, wrist, elbow, and ear breadth and middle finger, ring finger, pinky finger, and ear length[4]. They reported that FA significantly predicted scores on one scale of Cattell's Culture-Fair Intelligence Test (CFIT; r = -.21). In a second study presented in the same paper, the researchers replicated this finding on a *different* sample of 128 undergraduates, this time using two scales of the CFIT (r = -.24). Although both age and sex also predicted performance, neither affected the aforementioned correlations when controlled for statistically. The authors proposed two non-exclusive hypotheses to account for these findings: (a) that morphological FA may correlate with compromised neurological integrity; and (b) FA imposes increased metabolic demands on the body for which neurological functioning must compete. Consistent with the latter idea, they cited a study by Manning, Koukourakis, and Brodie (1997) showing that resting metabolic rate indeed correlates with FA in men (r = 0.27; the effect was *ns* in women). However, whether resting metabolic rate correlates with intelligence measures has apparently never been assessed.

Using a sample of college students, Prokosch, Yeo, and Miller (2005) investigated the relationship between body FA and various intelligence tests believed to differ in their *g*-loadings, i.e., their ability to assess overall cognitive ability. Table 1 lists the intelligence tests in descending order of purported *g*-loading, along with each respective correlation with FA in their sample:

[4] These traits, or some subset of them, are the most commonly assessed traits in human FA studies. FA index traits will not be listed hereafter unless they deviate significantly from this convention.

Test	*r*	*p*
Ravens Advanced Progressive Matrices	-.39	<.01
WAIS III Vocabulary [recall]	-.27	<.05
Shipley Vocabulary [recognition]	-.24	<.05
WAIS III Digit Span Forward	-.07	ns
WAIS III Digit Span Backward	.04	ns

Table 1. From Prokosch et al. (2005). Cognitive tasks and their correlations with body FA in a college student sample.

The authors reported that the monotonic trend relating the above correlations with *g*-loading ranking was significant at $p < 0.0003$ and concluded that DI, as measured by FA, indicates both general physical *and* intellectual fitness.

Thoma et al. (2005) sought to determine whether the relationship between FA and intelligence is reflected in brain structure. These researchers used MRI to measure cortical and total hemispheric volume, overall atypical brain asymmetry, and the sizes of various specific structures, such as the corpus callosum and the planum temporale. They assessed intelligence using a battery of tests comprised of Raven's Advanced Progressive Matrices, three WAIS-III subscales, Trails Test A and B, the Vandenberg and Kuse Mental Rotation Test, and the Controlled Oral Word Association Test. These investigators replicated previous findings by detecting a positive correlation between cortical volume and intelligence ($r = .50$) and between FA and atypical brain asymmetry (also $r = .50$; Thoma et al, 2002), and by observing a negative correlation between FA and intelligence ($r = -.49$). They extended these

findings by showing that FA is *not* significantly related to cortical volume, which suggests that DI and cortical volume exert independent influences on intelligence. The researchers speculate that DI may affect intelligence through other mechanisms independent of volume, such as brain organization (i.e., neural connections) or metabolic effects (e.g., axonal processing speed).

FA has also been linked to brain function in the domain of laterality. Yeo, Gangestad, Thoma, Shaw, and Repa (1997) assessed FA in 149 undergraduates to whom they also administered a battery of laterality measures: the Annett Handedness Questionnaire, and peg moving, dichotic listening, line bisection, and chimeric face discrimination tasks. The first two instruments are intended to assess handedness, while the latter three are designed to assess laterality of cognitive function. Participants relatively high in FA exhibited significantly atypical lateralization relative to the entire sample in regards to both handedness *and* cognitive function.

Other work has shown that FA may predict the negative side effects of drugs. Specifically, Jung, Yeo, and Gangestad (2000) reported that FA moderates the deleterious effects of caffeine ingestion on memory. For 100 undergraduates in whom FA had been assessed, these researchers tested memory for word lists using two versions of the Rey Auditory Verbal Learning Test, one before administration of 3 mg/kg caffeine and one after. FA did not predict performance at baseline, but it significantly moderated the effects of caffeine on memory such that those high in FA suffered more memory decrements.

Developmental instability and psychopathology

The research linking FA with physical fitness, combined with that linking FA and neural structure and functioning, justifies the question: *Is FA related to psychological/emotional fitness?*

FA has actually already been associated with severe mental illness, i.e. schizophrenia. Markow and Wandler (1986) assessed FA via two dermatoglyphic constructs in schizophrenic patients, mood disordered patients, and controls. First, they measured the *a-b ridge count*, which is the number of dermatoglyphic ridges between the tri-radii[5] at the base of the pointer and ring fingers. Second, they counted how many corresponding fingers did not have matching print types (i.e., with respect to arches, loops, and whorls). For *both* measures, schizophrenics showed significantly more asymmetry between the two hands compared to controls. Remarkably, among schizophrenic patients, the a-b ridge count asymmetry significantly predicted *age at first hospitalization* (r = -.28). It is also interesting to note that the mood disordered patients scored between the controls and the schizophrenic patients on both FA measures, although they did not differ significantly from either group.

Dermatoglyphic FA may not only predict a diagnosis of schizophrenia but also schizotypal symptoms in sub-clinical populations. Rosa et al. (2000) measured the a-

[5] On the palm of each hand, there are five points where dermatoglyphic ridges form triangular patterns (tri-radii), one at the base of each finger excluding the thumb and one at the base of the hand near the wrist.

b ridge count asymmetry in 260 "healthy" (p. 125) [6] adolescent students in Barcelona and assessed their schizotypy symptoms using the Perceptual Aberration Scale (PAS), the Social Anhedonia Scale (SAS), and the Physical Anhedonia Scale (PhAS). They found that a-b ridge count asymmetry significantly predicted negative schizotypy traits (i.e., SAS & PhAs composite score) in boys but not in girls. This finding is particularly interesting because it suggests that assessing FA in just one trait may be sensitive enough to discriminate amongst functioning individuals along one dimension of pathology.

Despite the need, little research has addressed whether FA predicts more prevalent psychiatric symptoms such as depression and anxiety. Martin, Manning, and Dowrick (1999) did report that the regression of body FA against Beck Depression Inventory (BDI) score was significant in 52 British men ($F = 4.67$, $p = .04$) but not in the corresponding sample of 50 women.

Shackelford and Larsen (1997) had actually documented a significant positive correlation between BDI score and FA previously. However, the results of this study are difficult to interpret for two reasons. First, the researchers evaluated literally hundreds of correlations on an enormous data set; it's impossible to tell which findings are valid and which are attributable to inflated experiment-wise type-I errors. Second, the study method suffered from a serious limitation, as FA was assessed from digital photographs of the participants' faces, yet "participants were not given any special instructions about facial expression, head orientation, or, for

[6] Half of the sample had been screened for ADD risk as part of another study using the Continuous Performance Test (CPT). All analyses were conducted while statistically controlling for CPT score.

example, whether glasses should be worn…" (Shackelford & Larsen, 1997, p. 458). Other studies that have utilized digital photographs of the face to asses FA have been much more meticulous about these issues (e.g., Grammer & Thornhill, 1994). In any event, the authors reported a correlation of 0.51 between BDI score and vertical facial asymmetry (i.e., relative vertical shift of bilateral traits) in men ($p < .05$; that with horizontal facial asymmetry was non-significant, as were all BDI/asymmetry correlations with women).

Bogle, Reed, and Rose (1994) investigated whether individual dermatoglyphic symmetry predicts similar psychological symptom profiles across monozygotic (MZ) twin pairs. For each individual in over 100 MZ twin pairs, they measured the a-b ridge count and administered an abridged version of the Minnesota Multi-phasic Personality Inventory. The researchers defined "symmetric pairs" as those pairs in which *neither* twin had a ridge count asymmetry greater than three ridges; they defined "asymmetric pairs" as those pairs in which *either* twin had a ridge count asymmetry greater than seven. So-defined symmetric pairs were more strongly correlated on every one of the 19 different scales assessed, with the difference for four scales significant at the Bonferroni-corrected .003 level (13 were significant at the .05 level): one depression scale, two anxiety scales, and two psychosis scales. Unfortunately, the researchers did not report data regarding symmetry *between individuals in each pair*,[7] nor did they report on the asymmetry/pathology

[7] Given their operational definitions, the twins in an "asymmetric pair" could actually have identical prints, while those in a "symmetric pair" could differ by several ridges.

relationship. Nevertheless, their findings do suggest that the a-b ridge count may co-vary with neurotic symptomology and/or personality variables.

As with depression and anxiety, very little research has directly addressed the relationship between FA and variables associated with *personality* pathology (i.e., DSM-IV "Axis II" pathology, whereas anxiety and depression are "Axis I" diagnoses). Perhaps surprisingly, two studies have shown that FA *negatively* predicts aggression, but only in males. Furlow et al. (1998) showed that body FA and number of fights in the previous three years were significantly negatively correlated in male undergraduates (r = -.25), but not in females (r = -.01). Furthermore, FA was associated with fight initiation in males (r = -.66), even after intelligence, ethnicity, and weight were statistically controlled. The authors argue that their findings contest the notion that human aggression is a compensatory behavior for genetic inferiority and instead support the notion of "alpha-male" dominance behavior.

Manning and Wood (1998) replicated this finding in boys aged 10-15 years. They found that their index of FA was significantly inversely correlated with scores on a self-report physical aggression questionnaire (r = -.28).

Weinstein, Diforio, Schiffman, Walker, and Bonsall (1999) assessed dermatoglyphic asymmetries in 20 adolescents with DSM-IV schizotypal personality disorder, 20 with "another Axis II disorder or conduct disorder" (p. 618), and 26 controls. They found that ridge count FA significantly distinguished the schizotypal group (17.6) from the control group (11.6). (The "other disorder" group (16.2) did not significantly differ from the schizotypal or control groups.) It should be noted

that schizotypal personality disorder is often conceptualized as a *schizophrenia-spectrum* disorder; Weinstein et al.'s (1999) significant finding could arguably be more relevant to the discussion earlier regarding schizophrenia.

Other research has linked dermatoglyphic asymmetries to non-pathological gender-related behaviors. Two independent studies have linked left vs. right *fingertip* ridge count asymmetries to sexual orientation in men (Hall & Kimura, 1994; Green & Young, 2000). Unlike the a-b ridge count, fingertip ridge counts are commonly reported as directionally asymmetric, the right hand typically having a higher ridge count. However, both Hall and Kimura (1994) and Green and Young (2000) have reported that male homosexual populations have significantly fewer right>left fingertip ridge counts (although the right hands still have higher ridge counts overall). Kimura and Carson (1995) extended these findings by showing that people with left>right fingertip ridge counts, *regardless of gender*, excel at "feminine" cognitive tasks (e.g., perceptual speed), while those with right>left fingertip ridge counts excel at "masculine" cognitive tasks (e.g., mental rotation). Taken together, the research on aggression and sexual behavior suggests that some aspects of personality may be predicted by morphological asymmetries.

Summary

A large body of research has indicated that DI, as measured by FA, inversely predicts physical and reproductive fitness across a wide range of plants and animals, including humans. More modest support exists for the contention that FA can also

predict psychological fitness variables in humans. Although the extant research addressing the relationship between FA and neurological functioning is somewhat compelling, there exists a paucity of high-quality studies addressing the relationship between FA and non-psychotic psychopathology. The present study represents an attempt to address this deficiency by means of an empirical examination of the FA-psychopathology relationship that incorporates: (a) a comprehensive assessment of FA comprised of 13 morphological and dermatoglyphic traits; (b) an assessment of symptomology associated with 25 DSM-IV disorders; and (c) a large sample size (N > 200).

Method

Participants

Two-hundred-four undergraduates attending The University of Kansas participated. One-hundred-ninety were introductory psychology students participating to fulfill a course requirement; the remaining 14 were volunteers recruited via flyers posted on campus or class announcements. Four participants' data were excluded from the final analysis (three reported recent traumatic events that were expected to have affected their symptom profiles; one exhibited marked inattention/amotivation).

The mean age of the sample was 19.6 years, the range being 18-25. Ethnicities were represented as follows: Caucasian, 85%; Asian, 4.5%; African-American, 3.5%; Hispanic, 2.5%; Indian, 2%; Middle Eastern, 1%; Native American, 0.5%; mixed, 1%.

Three additional participants, not counted above, completed the study protocol as pilot participants before formal data collection began.

Materials: Independent variable (asymmetry) assessment

Neiko 12" Extra Large Digital Calipers (model 01409A) were used to measure body traits. The instrument is accurate to 0.01 mm. Antiseptic wipes were used to clean the instrument between participants. Other cleaning materials, such as towels, water, and alcohol were provided for participants as needed.

A magnifying glass was used to examine fingerprints directly on the participants' hands so that they could be classified as loops, whorls, or arches (described below). A sponge and stamp pad inker were used to apply ink to participants' hands so that palm prints could be recorded to measure the a-b ridge count. These prints were recorded by rolling a blank index card over the inked palm with a short, padded PVC pipe.

A Savin photocopier (model 9922DP) was used to image participants' hands so that finger length measurements could be made. A protractor was used to measure the ATD angles[8] from the same images, the vertices of which were marked on each palm with a fine-tip marker prior to photocopying.

[8] The ATD angle is another popular dermatoglyphic construct. It is the angle formed by two lines drawn from the wrist tri-radius to the tri-radii at the bases of the pinky and pointer fingers.

Materials: Dependent variable (psychopathology) instruments

Three self-report instruments were used to assess current symptomology. The Psychiatric Diagnostic Screening Questionnaire (PDSQ; Zimmerman, 2002) was employed for the primary goal of investigating the relationship between DI and Axis I symptomology. The PDSQ is comprised of 125 yes/no questions regarding symptoms across 13 common DSM-IV diagnoses, such as Major Depressive Disorder, Social Phobia, and Generalized Anxiety Disorder. A primary motivation behind the PDSQ was to provide an efficient means to screen potential patients for DSM pathology. Therefore, the questions have been derived using DSM standards and nomenclature. The instrument has been under development for approximately 10 years; over 3,000 psychiatric patients have served as research participants. The PDSQ has been shown to be both reliable and valid, and to have excellent convergent and discriminant validity (Zimmerman, 2002). For each of the 13 disorders assessed, the probability of obtaining a formal diagnosis (i.e., via the Structured Clinical Interview for DSM-IV Axis I Disorders; First, Spitzer, Gibbon, & Williams, 1997) increases with the number of symptoms endorsed[9].

The Beck Depression Inventory (BDI; Beck, Rush, Shaw, and Emery, 1979) was employed primarily to provide a replication attempt of Martin et al. (1999), who reported a positive relationship between body FA and BDI score. The BDI is one of the most widely used instruments to assess severity of current depressive symptomology, and its reliability and validity for this purpose are well established

[9] Psychosis is the exception, in that the relationship holds from 0-4 symptoms endorsed, but then decreases dramatically when 5-6 symptoms are endorsed.

(Beck, Steer, & Garbin, 1988). It consists of 21 questions that address common problems associated with depression, such as depressed mood, feelings of worthlessness, and sleep and appetite disturbances. Each symptom is ranked according to severity on a three-point scale. Therefore, the range of possible scores is 0-63. Cut-off scores between approximately 12-16 are commonly used in research to identify participants as "depressed."

The Structured Clinical Interview for the DSM-IV Axis-II Screening Questionnaire (SCID-II-SQ; First, Gibbon, Spitzer, Williams, & Benjamin, 1997) was administered to collect exploratory data relating DI and Axis-II symptomology. The SCID-II-SQ is comprised of 119 yes/no questions regarding symptoms across 12 DSM-IV personality disorders, such as Avoidant, Narcissistic, and Schizotypal. Also included are proposed diagnoses that are not currently official, such as Depressive Personality Disorder and Passive-Aggressive Personality Disorder. The SCID-II-SQ was designed as an efficient screening instrument based on the DSM-IV.

Procedure

Participants completed the study protocol either one or two at a time, depending on how many could be scheduled. When participants were processed in pairs, one completed questionnaires while the other's physical traits were measured. When both participants were finished, they switched tasks.

Once a participant arrived at the laboratory, the primary investigator verbally explained the purpose and procedure in detail. The participant then completed the

three questionnaires sequentially. The BDI was always completed second, while the order of the PDSQ and the SCID-II-SQ was counterbalanced. The primary investigator never left the participant alone, so that he/she could be monitored and so that his/her questions could readily be addressed.

During the measurement phase, the participant sat in a comfortable chair. The calipers were used to measure the following traits directly on the participant's person, in accordance to the instructions detailed in Appendix A (provided by Steven W. Gangestad, personal communication): ear length; ear, wrist, elbow, ankle, and foot width[10]. All measurements were taken blindly, i.e., values were not read until after the calipers had been stabilized. After all 12 of these traits were measured once, the process was repeated. If any second measurement varied from the first by more than 1.0 mm, a third measurement was taken, and so on, until two measurements within 1.0 mm were obtained. If one measurement was within 1.0 mm to two different measurements, then all three were used. In rare instances, a criterion of 1.5 mm was necessary. During the measurement phase, participants were asked whether they had suffered a fracture to any of the relevant body parts; if so, that trait was omitted from that participant's FA index.

Next, fingerprint mismatches were assessed directly by visual inspection. Each of the 10 fingerprints of a participant's hands was classified as an arch, loop, or

[10] These traits, along with the four fingers excluding the thumb, were chosen because (a) they have previously been reported to conform to the definition of FA in humans (i.e., they tend to be symmetric and normal); (b) they have already produced significant findings in college student populations; and (c) they are accessible.

whorl using the method first described by Galton (1895) but still popular today. This involves counting the number of tri-radii, or "deltas," associated with each print (arches, zero; loops, one; whorls, two). Corresponding fingerprints across a participant's hands were compared so that a mismatch score could be tallied (i.e., 0-5). A magnifying glass was employed when necessary. Print classification as such was rarely ambiguous. When it was ambiguous, the prints were simply viewed simultaneously and their overall symmetry was judged without formal classification.

Next, partial palm prints were taken from each hand at the base of the index and middle fingers so that the a-b ridge count could be quantified at a later time. This was done by using a sponge to blot ink from an ink stamp refiller onto the palm and then rolling an index card over the palm using a small, padded PVC pipe. This was the most difficult measurement in the study. The most common problem was that for many participants, the ridges were simply indelible where they traversed a palmar crease. Also, callouses or peeling could mask ridges. (Indeed, this IV was eventually omitted from the study, once it was determined that only approximately 1/3 of palm prints could be assessed reliably.)

Next, hands were photocopied so that the finger lengths could be measured at a later time. Prior to photocopying, the three tri-radii used for measuring the ATD angle were marked with a fine-tip marker so that they could be measured later as well. Hands were photocopied one at a time. The primary investigator ensured that each hand was placed flat on the photocopying surface, and that the fingers were consistently in a slightly fanned shape.

Following data collection, each participant was debriefed privately by the primary investigator, a fourth-year clinical psychology graduate student. This included providing a qualitative summary of each participant's overall symptom profile for him or her, and answering any questions he or she had. When necessary, participants were provided with information on how to obtain psychological services at the university and in the community.

Results

Descriptive summary

The means and standard errors for all independent and dependent variables are reported in Tables 2 and 3, respectively. The tables reflect the final participant sample which resulted after an evaluation of outliers, described below. Four traits are not reported in Table 2 because they did not conform to formal definitions of FA (see below), and the corresponding trait variables were removed from study analyses.

	MALES				FEMALES		
	Max	Mean	se		Max	Mean	se
Morphological asymmetries (|right – left|), mm							
Ear length	4.01	1.19	0.09		3.32	1.13	0.09
Ear width	3.51	0.92	0.07		3.23	1.02	0.07
Elbow					3.55	1.11	0.08
Wrist					3.28	1.10	0.08
Fingers							
Index	3.19	1.08	0.08		3.51	0.96	0.08
Middle	4.15	1.01	0.09		3.19	1.12	0.09
Ring	3.33	1.10	0.08		3.38	1.02	0.08
Pinky	4.64	1.18	0.09		4.07	0.90	0.09
Ankle	4.56	1.32	0.10		4.85	1.08	0.09
Foot width							
Dermatoglyphic variables							
Fingerprint mismatches	5	1.20	0.11		4	0.99	0.10
|ATD angle asymmetry|, deg	12	2.43	0.24		9.5	2.31	0.23

Table 2. Means and standard errors (se) for all independent variables, by gender. Minimum values were zero or very near zero. Gray areas indicate variables removed from the analysis because they showed significant directional asymmetry (described below).

As reported elsewhere (Livshits & Kobyliansky, 1989; Wilson & Manning, 1996), the overall asymmetry difference between the genders was not significant (i.e., comparing mean absolute asymmetry across all traits; male $\bar{x}$ = 1.11; female $\bar{x}$ = 1.05; t = 1.33, two-tailed p = .19).

	MALES				FEMALES		
	Max	Mean	se		Max	Mean	se
PDSQ							
Depression (21)	13	3.06	0.28		15	3.29	0.36
PTSD (15)	8	1.31	0.19		14	1.57	0.32
Bulimia (10)	6	1.02	0.14		9	1.29	0.22
OCD (7)	5	0.65	0.11		3	0.46	0.08
Panic (8)	5	0.50	0.11		4	0.46	0.10
Psychosis (6)	1	0.13	0.03		2	0.10	0.04
Agoraphobia (11)	4	0.46	0.10		6	0.80	0.16
Social Phobia (15)	13	3.65	0.34		12	3.55	0.36
Alcohol (6)	6	0.86	0.13		5	0.70	0.12
Drugs (6)	6	0.59	0.13		3	0.21	0.07
GAD (10)	10	2.24	0.25		10	2.76	0.29
Somatization (5)	3	0.51	0.08		3	0.53	0.08
Hypochondriasis (5)	2	0.12	0.04		2	0.13	0.04
TOTAL (125)	68	15.27	1.21		60	15.92	1.34
BDI (63)	23	5.51	0.47		22	6.31	0.59
SCID-II-SQ							
Avoidant (7)	7	2.13	0.15		7	2.02	0.18
Dependent (8)	6	1.63	0.13		6	1.76	0.15
OCPD (9)	9	3.71	0.18		7	3.80	0.18
Passive-aggressive (8)	6	1.88	0.16		8	1.70	0.18
Depressive (8)	8	1.76	0.17		8	1.88	0.21
Paranoid (8)	8	1.80	0.18		7	1.42	0.18
Schizotypal (11)	7	2.12	0.17		8	1.67	0.19
Schizoid (6)	5	1.15	0.10		4	1.16	0.10
Histrionic (7)	7	2.59	0.16		7	2.45	0.17
Narcissistic (17)	14	4.87	0.25		12	4.09	0.26
Borderline (15)	13	3.27	0.24		12	3.51	0.32
Antisocial (15)	6	1.01	0.15		4	0.42	0.09
TOTAL (119)	71	27.96	1.17		70	25.87	1.43

Table 3. Means and standard errors (se) for all dependent variables, by gender. The column "Max" indicates the maximum value observed for that variable. Maximum possible for each variable is shown in parentheses.

Data integrity

The data were inspected carefully and appropriate adjustments were made prior to the final analysis. Those procedures are described next, and summarized at the end

of this section in Table 5.

Following convention, reliability of repeated measurements was assessed by calculating the intra-class correlation coefficient for the six traits that were measured twice. For all 12 of these measurements (i.e., six traits x two sides), ANOVAs indicated that the reliability was very good (mean ICC = .99; mean $F = 312.73$; all ps <.001). The results of this analysis are highly similar to those reported elsewhere (e.g., Martin et al., 1999).

Although fingers were only measured once, convergent evidence suggests that the finger measurements are valid. Specifically, it is well-established in the human anatomy literature that the ratio of index finger length to ring finger length differs across the genders, in that it approaches one in females and is slightly lower in males (Manning, 2002). This relationship was replicated in this sample, indicating that the relative lengths of fingers were assessed accurately (female $\bar{x} = 0.97$; male $\bar{x} = 0.95$; $t = 4.13$, $p < .00001$).

Dermatoglyphic measurements (i.e., fingerprint mismatches and ATD angle) were also only measured once. However, these measurements were typically unambiguous, and all were assessed by a single rater. (Indeed, inter-rater variability was not an issue with any of the measurements performed for this study, since the primary investigator made and processed all measurements.)

Following the repeatability tests, the histogram for each independent and dependent variable for each gender was inspected for outliers. A data point was identified as an outlier if it was greater than four standard deviations from the mean

and it was noncontiguous with the bulk of the data in the histogram. This resulted in the removal of only two independent variable data points, one male wrist difference and one male ATD angle difference. Scores identified as outliers among the DVs were not actually excluded from the dataset, but instead truncated so that they equaled the highest score that was not identified as an outlier. This adjustment affected 11 total data points. Finally, one female's extreme PDSQ Somatization score was completely removed because, during the debriefing period, she disclosed having a serious, legitimate health problem.

Calculating the FA index

Trait asymmetries were screened for whether they conformed to strict definitions of fluctuating asymmetry (Palmer, 1994). Namely, for each trait, the distribution of left-right differences was required to be normally distributed and centered on zero. Signed asymmetries for each trait within each gender were tested for normality using Kolmogorov-Smirnov tests and for directional asymmetry (i.e., mean deviation from zero) using one-sample *t*-tests. None of the 20 morphological variables (i.e., 10 traits x 2 genders), nor the ATD angle, deviated significantly from normal. However, four morphological variables did show directional asymmetry and were therefore excluded from FA indexes described below: female foot width and male foot, elbow, and wrist widths. (The fingerprint mismatch variable was not subjected to the normality and zero tests, as it is constrained to be a positive integer ranging from zero to five.)

As recommended by Palmer (1994), each of the traits comprising the FA index was scrutinized for size-asymmetry dependencies to determine whether size adjustments would be necessary. This was done by creating a scatterplot for each trait within each gender, plotting unsigned asymmetry against average trait size. None of the remaining 16 traits showed a significant size-dependence. However, differences in mean asymmetry were noticed among traits. Sample data are shown in Figure 1 (i.e., male ankles and middle fingers). As can be seen, neither trait shows a significant size-dependence relationship. However, the mean ankle asymmetry is greater than the mean middle finger asymmetry. Note that the larger trait in this case is the relatively symmetric trait. Although there was an overall tendency for larger traits in this study to show more asymmetry (e.g., mean ear length asymmetry > mean ear width asymmetry), there were several exceptions beyond the one depicted (e.g., the pinky was the most asymmetric male finger). Therefore, in order to control for differences among traits without changing the shape of each trait's distribution, each individual trait asymmetry score was *z*-transformed prior to calculating FA indices. Although it is more common to compute asymmetries relative to the size of the trait in question (unfortunately, without testing for size-asymmetry dependencies first), at least one previous study has employed the *z*-transform method utilized here and found significant relationships between FA and psychological variables (i.e., Yeo et al., 1997).

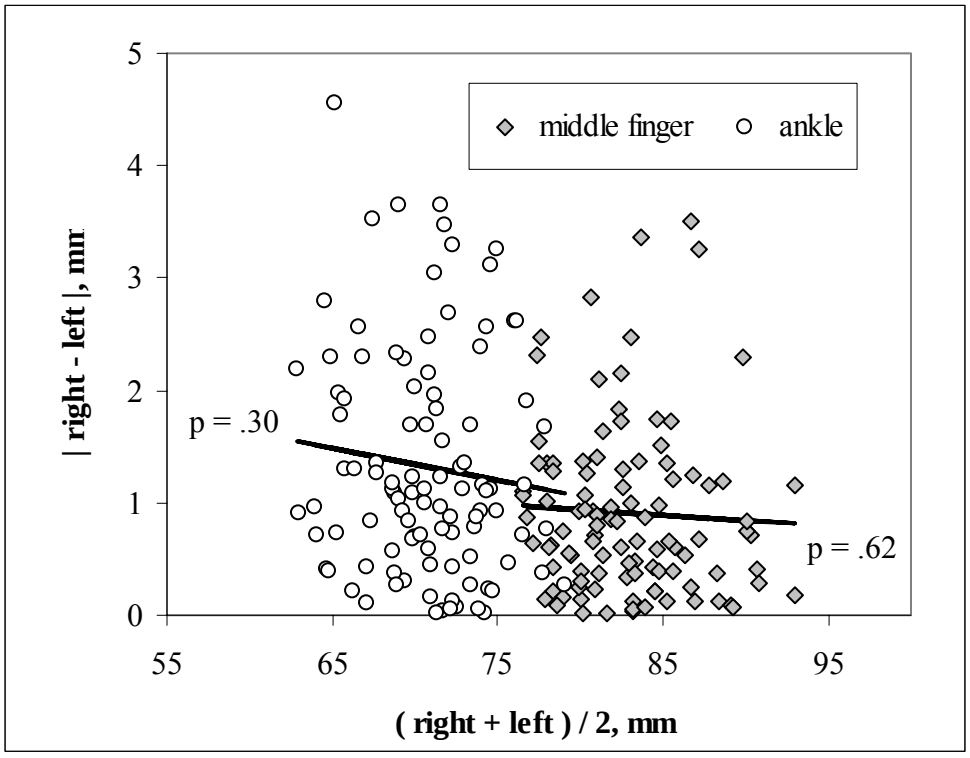

Figure 1. Sample (male) data showing no FA-size dependency within traits but a mean FA difference between traits. Note the larger mean ankle asymmetry indicated by the vertical difference between the regression lines.

It has often been reported that asymmetries of different traits from the same individual only correlate weakly, if at all (e.g., Livshits & Smouse, 1993). This raises the suspicion that not all traits are theoretically suited for an FA index, as those that are not correlated with the others would only be contributing noise. For this reason, each set of morphological asymmetries for each gender was subjected to a principal components factor analysis. Table 4 shows the first-factor weights of each trait within each gender. In males, the first factor accounted for 22% of the total variance; in females, 17%. Only traits with weights ≥ .3 were included in each FA index,

indicated by bold text and an asterisk in the table. Each trait asymmetry was multiplied by its associated weight before being summed into the index.

	Male	Female
Ear length	**.53***	- .04
Ear width	- .06	- .27
Elbow		**.48***
Wrist		**.42***
Ankle	**.29***	.00
Index finger	**.58***	**.63***
Middle finger	**.47***	**.71***
Ring finger	**.57***	**.38***
Pinky finger	**.54***	- .22

Table 4. First-factor weights obtained by principal components factor analysis of morphological asymmetries for each gender. Male elbows and wrists were not included in the analysis because they had already been shown to exhibit directional asymmetry. Those traits reported in bold and marked with asterisks were retained for the respective FA indices. Individual values were multiplied by their respective weights before summing into the index.

It should be noted that the different traits selected across the genders using this method is actually not unexpected, as Livshits and Smouse (1993) have shown that the correlation matrices of trait sizes are quantifiably different across the genders.

Finally, as many variables in the dataset exhibited significant skew, each variable was log-transformed according to $\log_{10}(x+1)$ and re-tested for normality using the Kolmogorov-Smirnov test. Only the ATD angle clearly benefited from the

transform, in that the transformed distribution was normal while the raw distribution was not. Because the DVs did not benefit from the transformation to the same degree, it was decided to leave them in their raw forms for the purpose of study analyses.

An analysis of the dependent variable values, although less formal than that for the independent variables as described above, suggests they are valid. First, overall expected symptom frequencies were observed. That is, the most commonly endorsed items were those associated with commonly observed disorders—social phobia, generalized anxiety, and depression—while the least commonly endorsed items were those associated with relatively rare disorders, e.g., psychosis. Second, symptom frequencies conformed to well known gender effects. For example, males typically endorsed more SCID-II-SQ Antisocial items ($\bar{x}$ = 1.06) than females ($\bar{x}$ = 0.42; t = 3.25, $p < .001$). Third, symptoms were interrelated as expected. For example, depression was assessed by two separate instruments, the BDI and the PDSQ, which were strongly positively related ($r = .78$, $p < .001$). Similarly, SCID-II-SQ Avoidant personality disorder co-varied with PDSQ social phobia ($r = .59$, $p < .001$), but it was inversely associated with SCID-II-SQ histrionic personality disorder, as would be expected ($r = -.25$, $p < .001$). Symptom profiles that were not expected to correlate did not, such as SCID-II-SQ narcissism and PDSQ agoraphobia ($r = .09$, $p = .20$). These examples are merely illustrative; many more followed the same patterns. In fact, none were noted to defy clinical sensibilities. Overall, these analyses are consistent with the primary investigator's anecdotal observation that the

vast majority of participants appeared attentive and motivated when completing the questionnaires.

Table 5 summarizes the assessments and adjustments applied to the dataset, as described above.

Issue	Data	Tests	Assessment	Adjustment
Repeatability	All repeated measures (i.e., 6 morphological traits x 2 sides)	Intra-class correlation coefficient	Repeatability of measurements was very good.	None.
Validity of finger measurements	Index and ring fingers	*t*-test comparing male vs. female index/ring length ratio	Replicated the "2D:4D" gender effect; finger measurements are valid.	None.
Outliers	All data (12 IVs; 26 DVs)	Histogram inspection and 4*sd criterion	Few outliers required attention.	IVs: 2 points removed. DVs: 11 points truncated.
"Ideal" FA (i.e., normality and 0 mean)	10 morphological traits comprising the FA index; ATD	Kolmogorov-Smirnov; *t*-tests	Most traits exhibited "ideal" FA.	4 traits show DA & removed from further analyses: female foot; male foot, wrist, and elbow.
Size dependence	Remaining morphological traits comprising the FA index	Scatterplot inspection: |left-right| vs. mean size; linear regression	No size dependency w/in traits; traits varied, but not always related to size.	All left–right differences converted to *z*-scores.
FA index noise	Remaining morphological traits comprising the FA index	Principal components factor analysis	Traits contribute differentially to FA; some not at all.	Trait differences weighted by factor 1 loading prior to summing into FA indices; other traits removed.
Skew	Dermatoglyphic variables and DVs	Histogram inspection; Kolmogorov-Smirnov	Many variables skewed, but only ATD reasonably improved by log-transform.	Log transform ATD angle.
DV validity (i.e., psychopathology reporting)	26 DVs	Pearson correlations and *t*-tests	Relationships among DVs conform to clinical fact and sensibility; DVs appear valid.	None.

Table 5. Summary of adjustments made to the dataset prior to the final analysis. All issues except repeatability were addressed separately for each gender.

Regressing psychopathology on asymmetry: PDSQ Axis I Disorders

The data for each gender were initially analyzed via 14 multiple regression models. That is, each of the 13 PDSQ subtest scores, and the total psychopathology score, were regressed onto the three asymmetry predictor variables: FA index, fingerprint mismatches, and $\log_{10}$(ATD angle+1) simultaneously. For the males (N = 107), only one overall model—that for Alcohol Abuse—was found to be significant at the $\alpha = .05$ level. The FA index was not a significant predictor of self-reported alcohol abuse in men, but both dermatoglyphic variables, fingerprint mismatches and log ATD angle asymmetry, were significant predictors. The summary statistics are reported below in Table 6 (male PDSQ Alcohol Abuse) and Tables 7a/7b (all others).

	Overall model fit				Standardized beta coefficients		
	F	*p*	r		FA index	fingerprints	Log ATD
Alcohol Abuse	3.55	.02	.32		-.09 (*p* = .35)	.25 (*p* = .02)	.23 (*p* = .02)

Table 6. Summary statistics for multiple regression of male PDSQ Alcohol Abuse onto three asymmetry predictor variables: FA index, fingerprint mismatches, and log ATD angle asymmetry.

	Overall model fit				Standardized beta coefficients		
MALE	F	*p*	r		FA index	fingerprints	Log ATD
Depression	1.03	.38	.18		.02 (*p* = .82)	-.15 (*p* = .15)	-.12 (*p* = .23)
PTSD	1.25	.30	.20		.03 (*p* = .77)	-.17 (*p* = .10)	-.13 (*p* = .21)
Bulimia	0.92	.43	.17		-.02 (*p* = .85)	-.10 (*p* = .30)	.11 (*p* = .30)
OCD	0.74	.53	.15		-.06 (*p* = .57)	-.14 (*p* = .17)	-.01 (*p* = .90)
Panic	1.05	.37	.18		-.03 (*p* = .78)	-.14 (*p* = .17)	-.14 (*p* = .18)
Psychosis	0.39	.76	.11		.04 (*p* = .73)	-.05 (*p* = .62)	.08 (*p* = .44)
Agoraphobia	1.27	.29	.20		-.04 (*p* = .69)	-.05 (*p* = .64)	-.20 (*p* = .06)
Social Phobia	0.27	.84	.09		.00 (*p* = .97)	-.07 (*p* = .50)	.05 (*p* = .66)
Drugs	0.21	.89	.08		.08 (*p* = .44)	.00 (*p* = .96)	.01 (*p* = .90)
GAD	1.17	.33	.19		-.13 (*p* = .19)	-.14 (*p* = .18)	-.06 (*p* = .57)
Somatization	0.66	.58	.14		.11 (*p* = .27)	-.02 (*p* = .86)	.09 (*p* = .40)
Hypochondriasis	0.12	.95	.06		.02 (*p* = .88)	-.06 (*p* = .56)	-.02 (*p* = .87)
TOTAL PDSQ	0.56	.65	.13		-.03 (*p* = .76)	-.13 (*p* = .21)	-.04 (*p* = .69)

Table 7a. Summary statistics for multiple regression of male PDSQ symptom categories onto three asymmetry predictor variables, FA index, fingerprint mismatches, and log ATD angle asymmetry.

	Overall model fit				Standardized beta coefficients		
FEMALE	F	*p*	r		FA index	fingerprints	Log ATD
Depression	0.86	.47	.18		.01 (*p* = .95)	-.13 (*p* = .27)	-.13 (*p* = .27)
PTSD	0.53	.66	.14		.09 (*p* = .41)	-.06 (*p* = .58)	-.09 (*p* = .45)
Bulimia	0.65	.58	.16		.06 (*p* = .60)	-.09 (*p* = .46)	.13 (*p* = .26)
OCD	0.82	.48	.18		.09 (*p* = .45)	-.10 (*p* = .37)	-.11 (*p* = .32)
Panic	0.71	.55	.17		.11 (*p* = .34)	.06 (*p* = .62)	-.10 (*p* = .40)
Psychosis	1.64	.19	.25		-.07 (*p* = .53)	-.18 (*p* = .12)	-.15 (*p* = .19)
Agoraphobia	1.51	.22	.24		.04 (*p* = .69)	.06 (*p* = .58)	-.22 (*p* = .05)
Social Phobia	0.42	.74	.13		.03 (*p* = .80)	.04 (*p* = .75)	-.12 (*p* = .31)
Alcohol	0.37	.78	.12		-.09 (*p* = .44)	-.01 (*p* = .91)	-.08 (*p* = .47)
Drugs	0.48	.70	.14		-.05 (*p* = .69)	-.09 (*p* = .42)	-.08 (*p* = .47)
GAD	0.46	.71	.13		.13 (*p* = .26)	.00 (*p* = .97)	-.02 (*p* = .84)
Somatization	1.38	.26	.23		.08 (*p* = .47)	-.14 (*p* = .21)	-.16 (*p* = .17)
Hypochondriasis	0.43	.73	.13		.10 (*p* = .37)	-.09 (*p* = .44)	.00 (*p* = .97)
TOTAL PDSQ	0.79	.50	.17		.09 (*p* = .45)	-.07 (*p* = .53)	-.13 (*p* = .26)

Table 7b. Summary statistics for multiple regression of female PDSQ symptom categories onto three asymmetry predictor variables, FA index, fingerprint mismatches, and log ATD angle asymmetry.

For the men, an inspection of the *p* values for individual predictors, regardless of overall model fit, identified no additional significant relationships. One predictor was marginally significant, log ATD angle for PDSQ Agoraphobia (standardized β = -.20, p = .06).

For the females (N = 93), none of the 14 overall model fits were significant. However, an inspection of the *p* values for individual predictors, regardless of overall model fit, identified the same marginally significant effect observed for the males, i.e., between Agoraphobia and log ATD angle (standardized β = -.22, p = .05; Spearman ρ = -.22, p = .05).

To investigate whether the two dermatoglyphic variables predicting male alcohol abuse were related themselves, their association was calculated using a two-tailed Spearman correlation coefficient. This analysis showed that the two dermatoglyphic variables are not significantly interrelated (r = -.14, p = .18), and are therefore independent predictors of self-reported alcohol abuse in men.

Figure 2 shows the mean male PDSQ Alcohol Abuse score versus fingerprint mismatches. As can be seen, those men with no fingerprint mismatches across the two hands endorsed the least number of the PDSQ Alcohol Abuse items. Those with one mismatch or greater endorsed more items. A trend is evident for those with three or more mismatches to endorse the most number of items. (For reference, Zimmerman (2002) recommends that respondents who score 1 on this scale should be regarded as at risk and assessed further.)

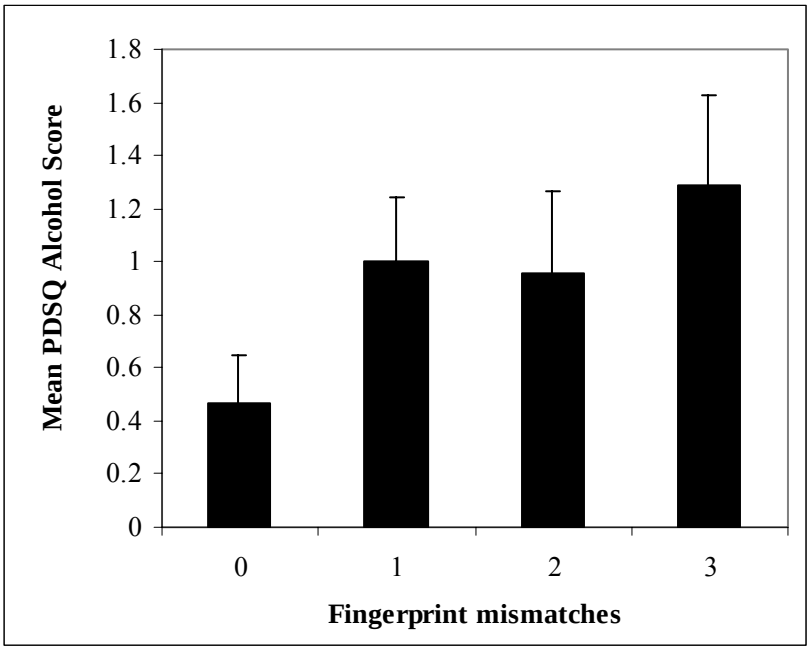

Figure 2. Mean male PDSQ Alcohol Abuse score for four fingerprint mismatches groups. Two men with four mismatches and one with five were included in the "≥3" group. Error bars are +1 se.

Figure 3 shows the mean male PDSQ Alcohol Abuse score for four groups of ATD angle asymmetry. (IV values were selected to maximize the equality of N across groups.) As can be seen, the number of PDSQ Alcohol Abuse items endorsed increases as does the ATD angle asymmetry across the two hands.

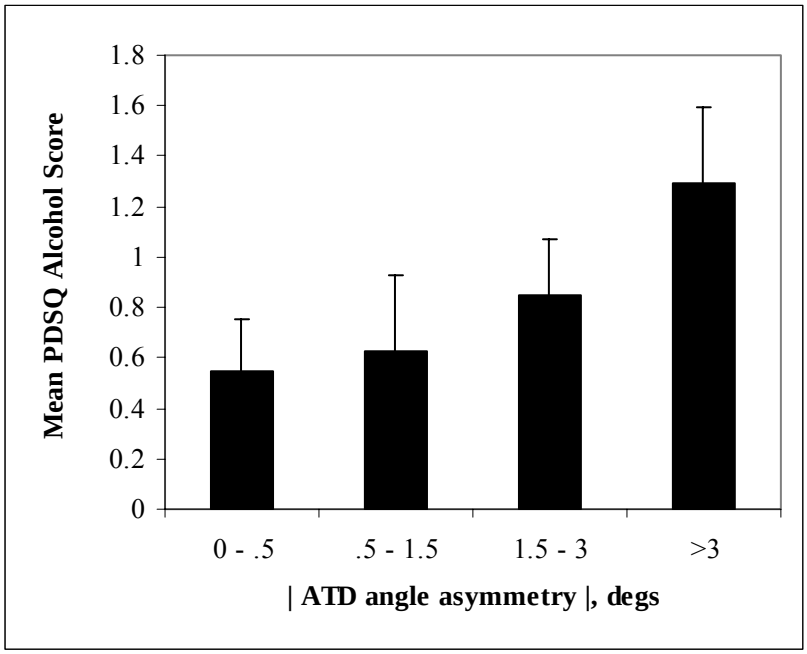

Figure 3. Mean male PDSQ Alcohol Abuse score for four ATD angle asymmetry categories. IV values were selected to maximize equality of N across the groups. Error bars are +1 se.

In order to ensure that the significant findings were not related to any violations of multiple regression assumptions (e.g., skew), two-tailed Spearman correlation coefficient matrices were calculated incorporating all of the IVs and DVs. This analysis confirmed the positive multiple regression findings (male Alcohol Abuse and fingerprint mismatches, $\rho = .25$, $p = .009$; male Alcohol Abuse and log ATD asymmetry, $\rho = .23$, $p = .02$), and provided no additional significant findings (e.g., agoraphobia – log ATD asymmetry, $\rho = -.19$, $p = .06$). Overall, the results of the Spearman analysis were highly congruent with the multiple regression and validates the use of the latter with this dataset.

Replication attempt regarding Martin et al., 1999 (BDI & body FA)

Martin et al. (1999) reported a significant linear relationship between body FA and BDI score in men ($F = 4.45$, $p = .04$). The data from this study indicated no significant relationship between these variables ($F = .17$, $p = .68$).

In order to test whether differences between the two studies could account for the replication failure, the data from this study were reanalyzed to create a more exact replication attempt of Martin et al. (1999). This included using the exact same FA index and BDI data transform (log[BDI+1]) as Martin et al. (1999). However, these adjustments also failed to detect a significant relationship ($F = .67$, $p = .42$).

Regressing psychopathology on FA: SCID-II-SQ Axis II Disorders

None of the overall models relating Axis II symptomology and asymmetry afforded statistically significant predictions for either gender. However, an inspection of the *p* values for individual Axis II independent variables, regardless of overall model fit, identified two significant relationships and two marginally significant relationships at the .05 level (Table 8). Of course, these results should be interpreted with caution, given the lack of any sensible pattern in them and the likelihood of type-I error. As with the PDSQ and BDI data, the FA index was not significantly related to any SCID-II-SQ dependent variable.

	FA index	Fingerprint mismatches	Log ATD asymmetry
Male Avoidant		β = -.23; *p* = .03	
Male Passive-Aggressive			β = .19; *p* = .07
Male Antisocial			β = .25; *p* = .02
Female Schizotypal			β = -.23; *p* = .05

Table 8. Individual significant and marginally significant individual predictors of SCID-II-SQ Axis II symptomology; standardized beta coefficients and associated *p* values are shown. Blank cells indicate no relationship.

Testing other FA indices

The relative absence of significant relationships between the FA index and study DVs was somewhat unexpected in light of prior published research. In order to explore the possibility that significant associations between these constructs had somehow been masked by our method of deriving the FA index or by the use of regression modeling, other FA indices were calculated and tested against the psychopathology DVs using Spearman correlation coefficients. Myriad FA indices were calculated and examined, including, but not limited to, the following:

- The traditional FA index in which all of the absolute differences from normally distributed traits centered on zero are size-scaled and summed; i.e.,

$$FA\ index = \sum_{i=1}^{x} \frac{|\ right_i - left_i\ |}{[1/2\ (right_i + left_i)]}\ ;$$

- FA indices calculated exactly as described in this study, except weighting trait asymmetries according to factor 2 or 3 (instead of factor 1);
- FA indices with no scaling whatsoever; i.e., absolute FA;
- FA indices using a more conservative definition of FA (i.e., omitting any traits showing any tendency toward DA);
- Separate FA indices for "soft" (i.e., ear) vs. "hard" (i.e., non-ear) traits;
- FA indices for apparently related traits (i.e., only the fingers).

None of these auxiliary investigations rendered any significant, meaningful findings that went beyond those expected merely on the basis of chance.

Discussion

The present study is arguably the most comprehensive investigation to date of the relationship between FA and psychopathology. It combines a relatively exhaustive assessment of FA, a large number of participants, and a wide range of dependent variables. Study data were analyzed more rigorously than is typical (a point elaborated below), and no problems with measurement of study constructs were evident. Despite these clear strengths, the observed results provide little support for the hypothesized relationship between asymmetry and psychopathology. The lone exception, previously unreported in the literature, concerns the finding that self-reported alcohol abuse in men was significantly associated with greater asymmetry on both dermatoglyphic constructs assessed.

Alcohol abuse findings

In a rather provocative finding, males with fingerprint pattern mismatches across hands were significantly more likely to report problems with alcohol abuse; moreover, the larger the number of such mismatches, the higher the (mean) reported level of alcohol abuse. Similarly, males with increasing ATD angle asymmetry across hands were more likely to report problems with alcohol abuse. It is important to note that these two asymmetries, fingerprint mismatches and ATD angle, were not themselves intercorrelated, which suggests that they reflect relatively distinct, independent constructs. As such, the two observed asymmetry-alcohol effects provide some degree of convergent validity for one another, and render it unlikely that both observed effects are due merely to type-I error.

A relatively obscure literature from the 1970s-80s, largely in Russian, has previously documented relationships between dermatoglyphic patterns (not asymmetry) and alcoholism. For example, Kojić, Dojčinova, Dojčinov, Stojanović, Jakulić, Susaković, and Gligorović (1977) reported that fingerprint whorls and arches were overrepresented in their sample of male alcoholics. Because dermatoglyphic ridge configurations are determined by both genetic and environmental factors (Babler, 1991), it is not clear whether such relationships reflect the known genetic predisposition to alcoholism (American Psychiatric Association, 1994) or other influences. On the contrary, dermatoglyphic asymmetries as reported in this study may actually serve as specific markers for early, non-genetic insults predisposing males to adult alcohol abuse.

It would be difficult to specify precisely what type of non-genetic insult might mediate the effect, but one speculation is particularly worth noting. Fetal alcohol syndrome, and its less severe counterpart, fetal alcohol effect, are known to include dermatoglyphic asymmetries (Wilber, Newell-Morris, & Streissguth, 1993). It has also been shown that prenatal exposure to alcohol increases the risk for adult alcohol abuse (Yates, Cadoret, Stroughton, Stewart, & Giunta, 1998). It is thus possible that dermatoglyphic asymmetry may link these two effects, in that it is influenced by prenatal exposure to alcohol and predicts adult alcohol abuse.

Although there is no ready explanation for why the effect was not observed in females, the gender difference was not completely unexpected. Many of the FA-psychological variable effects in humans have been limited to, or stronger in, males (e.g., Rosa et al., 2000). Testosterone has often been proposed as a mediating variable for this pattern (e.g., Martin et al., 1999). Regarding the particular findings here, the gender differences could simply be related to the fact that there are overall dermatoglyphic gender differences in normal populations (e.g., Plato, Cereghino, & Steinberg, 1975). For example, it could be that male-typical dermatoglyphic patterns are simply more sensitive to prenatal disturbances than female-typical patterns.

Because this study identified no relationships between psychological distress and FA, the alcohol abuse-FA relationship can not readily be explained as secondary to an FA-distress relationship. In other words, it is not simply the case that alcohol abuse is elevated due to self-medication of symptoms that are predicted by FA. This

is not to say that male alcohol abuse did not correlate with symptom variables; Table 9 shows the other DVs significantly related to PDSQ alcohol abuse score in men.

	Correlation with PDSQ Alcohol (ρ)
BDI	.18 (.030)
PDSQ	
Depression	.18 (.030)
Agoraphobia	.17 (.040)
Drug abuse	.19 (.030)
TOTAL PDSQ	.24 (.007)
SCID-II-SQ	
Dependent	.26 (.004)
Passive aggressive	.28 (.002)
Depressive	.26 (.003)
Histrionic	.42 (<.001)
Narcissistic	.37 (<.001)
Borderline	.30 (.001)
Antisocial	.28 (.002)
Cluster B total	.50 (<.001)
TOTAL SCID-II-SQ	.31 (.001)

Table 9. Symptom DVs significantly related to PDSQ alcohol abuse in males. Spearman correlation coefficients are shown, along with one-tailed *p* values in parentheses.

As would be expected, (male) alcohol abuse was related to many symptom domains[11]. However, none of these symptom variables are themselves related to FA. Because the alcohol abuse-asymmetry effect is not contingent on a more general psychopathology-FA relationship, it is probably more reasonable, and interesting, to interpret the relationship in light of the literature that has linked FA with atypical

[11] The clear relationship between alcohol abuse and Cluster B personality disorder scores (i.e., borderline, histrionic, narcissistic, and antisocial) replicates previous research (e.g., Cohen, Chen, Crawford, Brook, and Gordon, 2007) and again attests to the integrity of the DV measurements.

brain structure and function. Most relevant is Jung et al. (2000) who reported increased negative side-effects to caffeine with increasing FA. Findings such as these suggest that asymmetry may serve as a marker for neurological anomaly characterized by idiosyncratic reactions to ingested chemicals. Jung et al. (2000) indeed argue that FA probably has little to do with caffeine per se, but instead correlates with a general intolerance to foreign substances. However, the lack of a significant finding in males between FA and PDSQ Drug Abuse suggests some specificity.

Regardless of the mechanisms involved, assuming the alcohol abuse-FA relationship can be replicated (and refined), dermatoglyphic asymmetry could potentially have utility in helping to identify persons at risk. It is important to reiterate that the PDSQ Alcohol Abuse scores associated with dermatoglyphic asymmetries in this study (i.e., ~1.0) are clinically relevant (Zimmerman, 2002). Unlike a screening questionnaire, dermatoglyphic asymmetries, especially those of the fingerprint patterns which can easily be assessed, often with the naked eye, are completely objective and can be quantified at any time during one's lifetime. (Of course, the presence of an easily assessed morphological marker for alcohol abuse, or any other personality trait, presents a potential for misuse.)

Failure to replicate (male) depression & FA relationship

The failure to replicate the previously reported positive relationship between male BDI score and morphological FA (Martin et al., 1999) warrants further

discussion. First, it should be noted that the descriptive statistics of both BDI and FA variables across the two studies are highly similar, and therefore not responsible for the discrepancy.

Visually inspecting the scatterplot of BDI vs. FA in Martin et al. (1999; p. 207) raises the suspicion that a few extreme points may be responsible for the effect they reported. That is, the bulk of the data indeed appear somewhat disorganized, yet approximately three (of the 52) data points appear relatively extreme in regards to both high FA and high BDI. To investigate the potential impact of such points, an attempt was made to extract the data from Martin et al.'s (1999) figure. Because the graph is small and crowded, this proved difficult, but the resulting re-plotted figure appeared highly similar to the original. The regression of the extracted data actually showed a stronger relationship than the original ($F = 7.42$, $p = .009$ vs. $F = 4.67$, $p = .04$). Despite this fact, the removal of only the *two* most extreme scores was sufficient to render the relationship not significant ($F= 3.10$, $p = .08$). This investigation, albeit unorthodox, suggests that the previously reported male BDI-FA relationship is tenuous. Since the present study utilized a systematic method for treating extreme values and employed more than twice as many male participants ($N = 107$ vs. $N = 52$), it is much less likely that the results reported herein are due to statistical error or the presence of a small number of outliers.

Accounting for the null findings

It can be argued that the body FA indices reported in this study are actually more likely to be valid than many of those reported in the psychological literature (e.g., Martin et al. 1999; Shackleford & Larsen, 1997). Most traits were measured twice, and repeatability was very high. Those traits measured only once—i.e., the fingers—were essentially unambiguous; relative finger ratios for the sexes conformed to those reported elsewhere, indicating they were measured accurately. To conform to strict definitions of FA (Palmer, 1994), traits were screened for normality, DA, and asymmetry-size dependencies prior to summing into indices. A systematic, and somewhat conservative, method was employed for treating outliers. Principal components factor analysis was used to select and weight traits and therefore reduce additional noise in the FA indices. Finally, myriad other FA indices were computed and the data were reanalyzed. Despite these cautions, body FA did not predict any of the 26 psychological variables assessed in this study, for either gender.

Such care is rarely reported elsewhere. Many researchers do not check their own trait asymmetries for normality and DA, but instead assume they are normal and centered on zero because previous researchers have reported them to be. Also, it is common to weight trait asymmetries by the size of the associated trait without first checking for size-dependencies[12]. The data in this study did not show size

[12] In fairness, it should be mentioned that Martin et al. (1999) computed two FA indices, one relative (i.e., percent of trait size) and one absolute (i.e., no size scaling whatsoever), and found that the magnitude of the FA-BDI effect was virtually identical for each index.

dependencies within traits but did show dependencies across traits, yet these were not necessarily size-dependent.

It could also be argued that the identification of DAs in this study may be evidence that the body measurements were sensitive. It is probably not coincidental that all four traits shown to exhibit DA in this study (female foot width; male foot, male elbow, and male wrist widths) did so because the right sides tended to be larger than the left sides. Insofar as load-bearing differences are believed to produce DA (e.g., Steele & Mays, 1995), one would expect to find right-sided DAs in effectively random samples such as presented here. The fact that more male traits showed DA than female traits (three vs. one) is also consistent with this notion, assuming men, on average, bear more loads than women. The fact that several traits did not show DA (e.g., ear variables) suggests that the DAs reported in this study are not due to measurement error biases and reflect measurement precision.

Granting the integrity of the data reported here, the associated null findings deserve careful consideration. That is, it must be considered that they comprise an accurate description of the relationship between FA and psychopathology. That is, it may simply be the case that relatively common manifestations of psychopathology in functional young adults are not associated with DI.

This notion is consistent with evolutionary-based theory proposing that much psychopathology stems from adaptive, ancestral mechanisms being expressed in novel, modern environments (e.g., Tooby & Cosmides, 2000). Such theories assert that mechanisms of psychic pain, like those of physical pain, are normal and have

been selected because they have bestowed survival advantages to the organisms who have manifest them. For example, it is easy to see how a fear of heights could have been selected by preventing ancestral peoples from frivolously putting themselves in dangerous situations involving elevation. However, today's modern world offers many more, and much greater, heights than our ancestral environment did. Therefore, a fear-of-heights mechanism with normative sensitivity in the ancestral environment might find itself hyperstimulated in today's world (e.g., via buildings, bridges, airplanes, and the like), and could lead anyone with such a hyperstimulated mechanism to seeking psychiatric treatment.

Analogous arguments can readily be applied to other commonly treated psychiatric conditions. For example, ancestral peoples were probably served well by some innate repulsion to contaminated biological material, such as feces and rotten carcasses. Given the vast amount of awareness we now have about the countless (but typically innocuous) microorganisms living with, and literally on, us, it is not surprising that many people today find themselves obsessed with germs. A final illustration stems from the newfound solitude our modern luxuries permit. Ancestrally, depression (more specifically, loneliness) might have served as an aversive stimulus for social isolation. Social isolation during our evolutionary history not only would have decreased the likelihood of mating, it would also have decreased the probability of survival in the event of injury or illness. Today's world allows us, if not encourages us, to spend much less time physically interacting with

others, and hence any adaptive mechanism stimulated by isolation could be stimulated more today than intended by the early design.

Proponents of such ideas might not have been surprised if DI, as reflected in FA, had been *negatively* related to any of the DVs. Recall that PDSQ agoraphobia was (marginally) negatively related to ATD angle asymmetry in both genders (male standardized $\beta = -20$; $p = .06$; female standardized $\beta = -.22$; $p = .05$). The PDSQ agoraphobia questions inquire about anxiety associated with "crowded places," lines, "wide-open spaces," solitude, and products of technology, such as bridges, tunnels, cars, and public transportation. Given that these objects are indeed unnatural and/or potentially unsafe, it is easy to imagine how an agoraphobic mechanism would have been adaptive and might still be associated with developmental stability. Although the agoraphobia-ATD angle asymmetry relationship was the only one that was evident in both genders, the relationships are obviously weak and would need to be replicated and refined before being taken seriously.

Limitations

The greatest limitation of this study concerns the use of a convenience sample of participants drawn from an introductory psychology course participant pool. The participants of this study were obviously high-functioning to some degree, as they were each enrolled in coursework at a major university and took the initiative to participate in a research study. The obvious concern is that there may be more FA-psychopathology relationships than those reported herein, but that the study sample

employed simply did not provide the range of symptom severities necessary to identify them. In other words, there was a truncated range of scores across several study DVs. Indeed, the "outliers" described above in the critique of Martin et al. (1999) may represent the transition between functional psychopathology and non-functional psychopathology where identifiable effects begin to be realized. However, this issue should be regarded as more of a reservation than a criticism, as the data are still meaningful as they are. That is, they address the question "Can morphological asymmetry predict psychopathology?" by indicating "probably not, at least regarding *functional levels of psychopathology*."

A more pointed criticism is that self-report measures were used to assess psychopathological symptomology. Despite the acceptable psychometric properties of the instruments employed in this study, semi-structured clinical interviews typically provide a more rigorous diagnostic assessment (e.g., Field, Taylor, Celio, & Colditz, 2004). This is partially because it is considered acceptable for screening instruments, such as the PDSQ, to be somewhat overinclusive, since false positives are less problematic than misses in clinical settings (Zimmerman, 2002). To illustrate, even though relatively few psychotic symptoms were endorsed on the PDSQ, the numbers are higher than expected for this population. They certainly would have been even lower, and presumably more accurate, had interviews been conducted.

Again, the IVs in this study are arguably more valid than those in similar studies. However, the fingerprint mismatch variable was somewhat primitive; more

precise methods are available for quantifying dermatoglyphic asymmetry across the fingers. For example, a loop has directionality that can be quantified, i.e., as either "radial" or "ulnar" (e.g., Plato et al., 1975).

Despite the relatively large overall number of participants in this study, it is possible that more significant relationships would have been identified with an even larger participant pool, given the common subtlety of FA-fitness relationships reported in the literature. Also, the study may have benefited from an even more comprehensive assessment of FA; for example, by incorporating an assessment of facial asymmetry (e.g., Grammer & Thornhill, 1994).

FA: A cause for skepticism

As mentioned earlier, despite the large number of published studies showing positive relationships between FA and fitness, the issue continues to be passionately debated (Clarke, 2003). Critics (Palmer, 1999; Livshits & Smouse, 1993) have argued, for example, that publication bias and sloppy methods, namely, poor measurement and statistical techniques, can account for many of the published findings. Such critics will likely receive the null findings described here well.

It is interesting to note that Livshits and Smouse (1993) specifically cite inappropriate size scaling and across-gender pooling of data as examples of sloppy data management. Each of these were attended to carefully in this study, and no body FA-fitness relationships were noted. Furthermore, Livshits and Smouse (1993) suggest that dermatoglyphics may be a more appropriate IV than body FA in

asymmetry-fitness studies, arguing they are less indicative of truly random ontogenetic noise, due to the much shorter time period over which they are formed. This notion is supported by the fact that many studies have reported asymmetry-fitness relationships based on single dermatoglyphic traits (e.g., Weinstein et al., 1999), but FA indices comprised of multiple body traits are regarded as better predictors of fitness variables than single traits alone (e.g., Wilson & Manning, 1996).

Future directions

Assuming the alcohol abuse-asymmetry finding described here can be replicated, future research should attempt to explain the exact mechanisms underlying it. Other dermatoglyphic asymmetry-psychopathology relationships might be uncovered if more sensitive assessments of both the IVs and DVs were conducted on more diverse participant populations. If so, such findings would contribute to the understanding of the etiology of various psychopathologies, and could potentially provide useful means for helping to identify people at risk.

Continued examination of the relationship between FA and psychopathology is still warranted, as there is still much controversy regarding how FA should be assessed, and, moreover, what it represents. The field would be well served in this respect by adopting the recommendations of those such as Palmer (1994) and Livshits and Smouse (1993) for the use of much more stringent measurement and

data analytic strategies. The study described here, although certainly open to criticism, arguably represents an improvement over the status quo.

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Appendix A

Below are unpublished instructions for measuring FA using ten morphological traits, written by Steven W. Gangestad, University of New Mexico, provided in June 2005 (personal communication):

Description of FA Measures

We use metal calipers that digitally read out to an accuracy of .01 mm (although we can't really measure that accurately). They are available from biology or medical supply stores for about $150. Cheaper ones that don't read out quite that accurately are probably also available.

1. **Ear length**. We measure along the longest axis of ear length—i.e., we don't worry about figuring out what is the "true vertical" dimension. The ear is soft tissue so a delicate touch is needed. I use the subject's shoulder for support of my arms/wrists while measuring; that seems to help keep a steady hand. I then hold one point of the caliper as steady as possible at the bottom of the lobe of the ear (or point where is attaches if the ear lobe is attached). I move the top point slowly down to the point where is barely touches. I always have the "back" of the caliper (the long arm with a scale) at the rear side of the ear, despite the fact that I can't read the digital face when measuring one ear that way. In general, what's important is that the measurement is done the same way on the left and the right side and, hence, when possible I aim to have the caliper in the same orientation with respect to what I'm measuring on both sides.

2. **Ear width**. We measure from the "notch" (just above the small "protrusion" toward the ear hole) on the front side of the ear to the back of the ear. Frankly, this

is not an easy measure, relative to others, but good reliability is possible. Again, what's important is that you measure the R and L sides similarly. In general, it's often useful to "set" or "anchor" one point of the caliper, then move the other one in. For ear width, I gently press one point into the notch (front), and then try to hold that steady while I move the other toward the back of the ear, barely touching it to get my measurement. I always hold the long arm of the calipers below the points for both the left and right measurements.

3. **Elbow width**. I have the subject hold his or her arm in an "L" shape—the upper arm pointing toward me, the forearm held vertically, with the palm facing back toward the subject (i.e., toward his or her face). At the elbow, there is generally a fairly well-defined knob on both sides (the inner one generally somewhat more proximal [closer to the subject's shoulder). I try to measure from the top of one knob to the top of the other (i.e.. along the axis afforded by them, not worrying about whether it is truly parallel to the subject's chest). I find it useful to hold each point of the caliper between my thumb and forefinger. I then simultaneously "feel" for the knobs with these fingers while tightening the calipers around them. When the knobs are fairly well-defined, this is not a terribly difficult measure, as you often don't have to deal with thick soft tissue. Particularly for some men, however, the knob on the outside of the elbow is not well-defined and, if so, the measure is more difficult. Be careful on this one to measure the same character (and axis) on both the R and L sides; it's possible to subtly introduce directional bias here, in my experience.

4. **Wrist width**. I have the subject hold his or her arm out (somewhat relaxed—not stiff) with the palm of the hand facing downward. A knob on the outside of the wrist is generally very distinct. There is a smaller knob on the inside of the wrist, which you generally have to feel for. (It's usually slightly more distal [further from the elbow].) I measure along the axis going through the top of those two knobs (which, again, is typically an axis not perfectly perpendicular to the forearm). As with

elbows, I hold the calipers by the points with my thumbs and forefingers, so that I feel for the knobs I want the calipers to be on at the same time as I am pressing the calipers tighter. I find that for both the wrists and elbows, rocking the points gently back and forth a bit (*very* gently) can help locate the points right on the tops of the knobs you want to be on.

5-8. **Index, middle, ring, and pinky finger length**. I have the person hold their hand out with palm facing upward and fingers straight. For each finger, I try to measure from the crease at the bottom of the finger to the tip. To do so, I hold the distal point of the calipers somewhat firmly down in the middle of the crease (and here I do mean the very point—that is, the tip [though with the caliper point somewhat flat, that is, not sticking straight into the hand]). While holding that tip steady, I then move the other point until the very tip of that point barely touches the finger tip. (I often rock the tip back and forth a bit to see that it barely scrapes along the tip of the finger.) The bottom crease of the finger will not always be well-defined. The crease may be a bit "feathered" or there may be two creases. The important goal, again, is to measure the R and L sides comparably and so, when you see a crease that is not well-defined, it may help to look at the other hand to make a determination of how you can best measure the finger similarly on both sides.

9. **Ankle width**. Ankle width is often a tough one. We try to measure from the top of the two knobs on either side of the ankle—with the inside knob almost always somewhat anterior and proximal to the outer one. One thing that makes the measure tough is that, given the axis defined by those two knobs, it is not possible to read out the measurement with the calipers placed on one (the right) ankle (as the long arm of the caliper must be oriented inward, with the arm on the front of the ankle. The calipers must therefore be gently pulled off the ankle, turned, and read. When I must do that for the right ankle, I generally do the same on the left, even though I can read the digital face with the calipers on the ankle. I figure that this procedure might

better control for the fact that the readout will move a bit (hopefully, no more than a few hundredths) when the calipers are pulled off. I look at how much change there is in the readout when I pull them off the left ankle and will re-measure if I see a lot of movement (usually there is very little).

10. **Foot width**. Have the participant sit with his or her feet flat on the ground. Measure across the bones just proximal to the toes. It's not always easy to get just the right pressure here, as pressure will change the measurement. I usually push in the calipers kind of tight, then "release" them, which will result in them backing off just a bit. I read the calipers without pulling them off.

Advice on checking reliability:
We now always measure each trait twice—though not consecutively. Optimally, you'd measure all traits once, then go back and measure (independently) a second time. So long as you're not remembering the measurements from the first go round for a trait when measuring it again, however, I think you're fine.

We use a recorder separate from a measurer (that is, the recorder is not the measurer, but rather is a second person). I'd advise using a recorder if possible. We have the recorder track differences in measurements across the first and second measures and, when the first and second measures for a specific trait-side (e.g., the left pinky) differ by more than 1 mm, we obtain a third measure. If the third measurement is decidedly closer to one than another, we'll replace the outlier. If it's between the others, we 1) use it and the average of the other two as the two measures, or 2) simply use the original two measures (it shouldn't matter much if any which way you go here, as the two ways give about the same average measurement). You may find that you're having to do a lot of re-measures using this criterion (more than 1-2 per individual) and, if so, you might move the criterion up to 1.5 mm. (You simply want to eliminate the measures than are probably quite off through this procedure.)

You can track your repeatability of measurements during practice or in the early phase of data collection. To do so, 1) take the R minus the L (or, if you wish, L – R) for the first and second measurements of a character, keeping the sign of the difference; 2) take the absolute difference (unsigned difference) between these differences; 3) do so for all traits for an individual. If these differences average half a mm or less, you're doing extremely well and can pretty much be assured of getting a repeatability for the sum of the asymmetries in the .8-.85 range. If the absolute differences between the differences average .5-.8 mm, you are doing as well as all but a very few of the measurers we've ever had and will be just fine (repeatability greater than .7). If their mean is getting close to 1 mm, you want to improve. I'm assuming here that the first and second measures are blind to one another, in that you are unaware of what asymmetry you measured when you measure the second time.