

Fluctuating asymmetry and intelligence

Timothy C. Bates *

University of Edinburgh, 7 George Square, Edinburgh EH8 9JZ, United Kingdom

Received 18 June 2005; received in revised form 1 March 2006; accepted 30 March 2006

Available online 16 May 2006

Abstract

The general factor of mental ability (g) may reflect general biological fitness. If so, g -loaded measures such as Raven's progressive matrices should be related to morphological measures of fitness such as fluctuating asymmetry (FA: left–right asymmetry of a set of typically left–right symmetrical body traits such as finger lengths). This prediction of a negative correlation between FA and IQ was confirmed in two independent samples, with correlations of -0.41 and -0.29 , respectively. Head size also predicted Raven's scores but this relationship appeared to be mediated by FA. It is concluded that g along with correlated variables such as head size are in large part a reflection of a more general fitness factor influencing the growth and maintenance of all bodily systems, with brain function being an especially sensitive indicator of this fitness factor.

© 2006 Published by Elsevier Inc.

Keywords: FA; Fluctuating asymmetry; IQ; Intelligence; Evolution; Sexual selection; Sex

1. Introduction

In two recent papers, Furlow, Armijo-Prewitt, Gangestad, and Thornhill (1997) and Prokosch, Yeo, and Miller (2005) reported a surprising correlation between general mental ability (g : Spearman, 1927) and fluctuating asymmetry (FA). FA is a summary measure of random departures from symmetry in bodily traits such as finger length that are normally bilateral symmetrical, reflected in population mean size differences of zero.

The correlation of IQ and FA is important for two main reasons. Prokosch et al. (2005) showed that it is the g factor of ability that drives the correlation of ability tests with FA. Secondly, Furlow et al. (1997) argued that the correlation between FA and g is adjusted for the limited validity of a 9 or 10 measure FA composite as an index of the latent-trait of developmental instability

(around 0.17: Furlow et al., 1997), the potential latent correlation might lie between -0.5 and -0.7 . Given that g itself accounts for only half the variance in test scores, these two findings suggest that g is potentially identical with the fitness variance underlying FA.

Both Furlow et al. (1997) and Prokosch et al. (2005) hypothesize that variation in g is not related to a small set of "intelligence" genes, but rather that it reflects fitness-related variation distributed across the genome, expressed throughout the body as well as in the brain. In this model, g is viewed as a trait that, because of the complexity of the biological systems that implement it, functions as a fitness indicator (Miller, 2000). Miller goes further to suggest that humans have been under sexual selection to develop brain systems the complexity of which is so high that mutations in almost any gene compromise mental function and thus differences in mental performance come to signal evolutionary fitness. Such selection pressure could account for the high heritability of g (Posthuma et al., 2005), which is not

* Fax: +44 131 65 1945.

E-mail address: tim.bates@ed.ac.uk.

predicted for traits affecting survival-selection traits (which should become canalized or buffered against disturbance), as well as its positive correlations with general fitness indicators such as health and longevity (Whalley & Deary, 2001), as well as height and head size (Jensen & Sinha, 1993). This theory also predicts the apparently very low maximum variance accounted for by single genes related to normal variation in intelligence (Butcher et al., 2005), as the theory suggests that each gene and its variant alleles will contribute only a small fraction of population-wide phenotypic variance in fitness.

Because the relationship of body symmetry to intelligence has important implications for theories of intelligence, the present research set out to replicate and extend the FA–IQ result. The first hypothesis tested in the present report was that bodily FA should correlate with a *g*-loaded measure of ability. Because some studies on FA have reported greater relationships between FA and fitness in males than females, sex effects were also examined. Finally, the possibility that the relationship of other bodily correlates of IQ such as head size (Raz et al., 1993) might also be mediated by general fitness was examined in a second study, followed by a discussion of the implications of the research for models of ability.

2. Study I: Replicating the intelligence–FA correlation

In the first examination of the relation of intelligence to FA, Furlow et al. (1997) assessed FA in the breadth of the foot, ankle, wrist, and elbow, lengths of the third, fourth, and fifth fingers, ear breadth and ear length in independent samples of 111 and 123 students. They found correlations between FA and Cattell's Culture-Fair test of intelligence of -0.19 and -0.27 , respectively, and argued that bodily FA is indicative of reduced developmental integrity of the brain and/or low metabolic efficiency in high FA individuals and, therefore, that human intelligence differences reflect a high sensitivity of the brain to developmental integrity. This phenomenon of accurate development under stress is termed "developmental instability" (DI) by evolutionary biologists researching genomic fitness where it is defined as the imprecise expression of developmental design in development (Waddington, 1957). Because the genetic blueprint for symmetrical traits is identical, high FA indicates high DI. FA is therefore believed to assess the average efficiency of survival and reproductive adaptations, and thus serves as an indicator of fitness (Ludwig, 1932; Palmer & Strobeck, 1986; Van Valen, 1962).

Prokosch et al. (2005) extended Furlow et al. (1997) by testing whether the correlation of FA and ability was

proportional to the *g*-loading of the ability measure. Assessing a range of IQ measures in 78 male students, they found support for a correlated vectors analysis, reporting correlations of -0.39 , -0.27 , -0.25 , -0.07 , and $+0.05$ for Ravens Advanced Progressive Matrices, Wais III Vocabulary, Shipley Vocabulary, Backward Digit Span, and Forward Digit Span, respectively (nb: signs are reversed from the values in Prokosch et al. to reflect a negative relationship with asymmetry, rather than the symmetry-based sign adopted by Prokosch). This initial report, then, suggests that it is *g* (and not more specific components of intelligence such as spatial or verbal ability) that is related to fitness.

Although no reports have failed to find the negative FA–IQ correlation, with only two published studies, the first hypothesis tested in the present report was that this FA–IQ correlation would be replicable in an independent sample.

The second hypothesis tested followed from the finding in some research on FA of greater relationships to fitness in males than in females, in species where females exercise more choice than do males (Andersson, 1994). For this reason, Prokosch et al. (2005) used only male subjects, expecting a stronger effect. For this reason, their data do not speak to the issue of sex differences in the strength or nature of the FA–IQ relationship. Furlow et al. (1997), however, did use a mixed-sex sample and, while they did not report correlations separately for sex, they found no effect of sex on the relationship of FA to IQ. Hypothesis 2, therefore, was more speculative, but was that the FA–IQ correlation would be equal for both sexes, as found by Furlow et al. (1997).

2.1. Methods

2.1.1. Subjects

Ninety-eight subjects participated: 66 female (mean age 31.5 years, S.D. 14.0), 32 male (mean age 32.1 years, S.D. 11.1). The sample consisted of university students and their family members and friends.

2.1.2. Measures

2.1.2.1. *Psychometric tests.* Intelligence was assessed using the Raven Standard Progressive Matrices (Raven, 1992) in an untimed computerized version.

2.1.2.2. *Fluctuating asymmetry.* FA was assessed in the width of the palm, length of each of the four fingers excluding the thumb, ear height and width, and the widths of the ankle and elbow. All measures were made using digital calipers accurate to 0.1 mm. Each body part

was measured twice and averaged. Participants were asked if they had suffered a significant injury to any of the measured body parts. Injured body parts were excluded for that subject and the FA measure based on the measured parts. No other exclusion criteria were used.

The accepted standard for computing FA is to sum the absolute percent asymmetry for each body part, i.e., $\sum(|(\text{left} - \text{right})/(\text{left} + \text{right})/2|)$ (Palmer, 1994). Alternative methods might be considered, for instance taking the first unrotated principal component. The factor analytic structure of fluctuating asymmetry has not received much attention to date. In the present sample, a principal components analysis suggested four factors, both by Scree plot and by the criterion of eigenvalues greater than one. The retained factors had eigenvalues of 1.87, 1.37, 1.32, and 1.099. The first factor accounted for 20.8% of variance and had positive loadings on most body parts dominated by strong loadings of the finger lengths (0.35–0.73) with a lower loading for palm width (0.19) and a weak loading for ankle width (−0.085). The remaining factors were specific for a body part. Thus, the principal components analysis supported the idea that there is a meaningful general factor or positive manifold in the data, in addition to variance specific to a body part or parts, thus validating the use of a summed factor to assess FA. To remain consistent with the existing literature, the standard equal-weighted summed measure was used for all analyses, rather than rely on specific body-part weightings, which given a modest sample size are unlikely to be reliable.

2.1.3. Procedure

All subjects gave informed consent to participate prior to completing the Raven and FA assessments in a random order. Both FA and IQ were scored automatically on computer, and testers were blind to these results. Subjects completed the computerized Raven with no time limit, as well as self-report personality measures unrelated to the present report.

2.2. Results

Raw Raven's scores varied from 26 to 55 (mean 38.8, S.D. 6.49). The core hypothesis that FA would predict Raven scores was supported in a regression analysis [R^2 of 0.185, $F(1,96)=21.8$, $p<0.0001$, see scatter plot in Fig. 1], equivalent to an r of 0.43. Unpaired t -test comparisons revealed significant sex differences on FA [$t(96)=2.48$, $p=0.015$ —females greater than males] and on Raven scores [$t(96)=2.14$, $p=0.035$ male and female means (and S.D.s) 37.9 (5.9) 40.8 (7.2), respectively]. The effect of sex on the FA–Raven relationship was examined using univariate regressions for each sex, showing an R^2 of

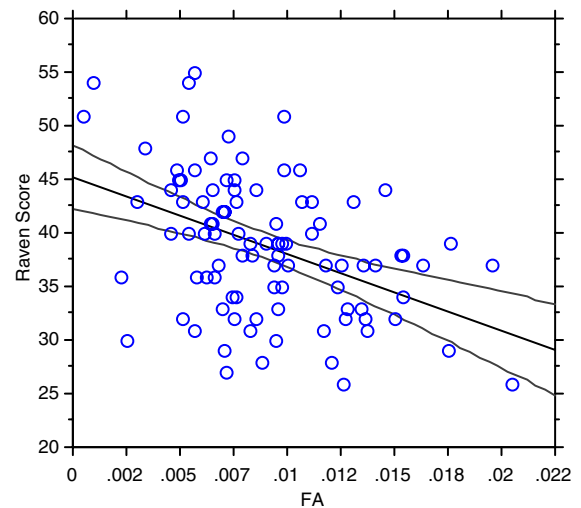


Fig. 1. Relationship of FA to Raven score (study I). Best-fit regression line representing the R^2 of 0.171 is plotted over the raw data. Note: Dotted lines are 95% confidence intervals for the means.

0.218 in males compared to 0.142 in females. However, this observed sex difference in the FA–Raven relationship was not supported by multivariate analyses where FA was the sole variable to enter a stepwise regression of Raven scores on age, sex, FA, and interaction variables FA*age and FA*sex. The power of this experiment to detect a sex difference in correlation of around 0.1 is, however, only 0.256.

2.3. Discussion

The overall magnitude of the relationship of Raven and FA reported in experiment one is similar to that reported by Prokosch et al. (2005) ($r=-0.39$ vs. -0.43 in the present study), and similar to, though larger than, the r of -0.21 reported by Furlow et al. (1997) using the Cattell's Culture-Fair measure of IQ. This consistent finding of a negative relationship between developmental instability and human intelligence supports the theory that variance in g is influenced by general fitness. While the univariate analyses appeared to show a sex effect in the FA–Raven relationship (stronger in males), the difference in correlation was not significant, as indicated by the null interaction effect of sex and FA, a finding also reported by Furlow et al. (1997). The experiment, however, has modest power to detect interactions.

In conclusion, study I demonstrated a link between Raven and FA, with little evidence that this was moderated by effects of sex or age. A second experiment was conducted to further testing the FA–IQ relationship and examine the relationship of a second physical variable

associated with intelligence and assessed by Furlow et al.—that of head size.

3. Study II: FA, IQ, and head size

While theories relating intelligence to developmental stability predict that intelligence will relate to body-wide asymmetry in non-neural systems, intelligence has been shown in many studies to relate to the physical volume of the brain, with correlations centering on 0.4 (cf.: Raz et al., 1993). Head size is correlated around 0.8 with brain volume and also correlates around 0.2 with IQ (cf.: Ivanovic et al., 2004). This relationship has usually been supposed to be direct: that the correlation of brain volume and IQ is explained by genes coding for greater numbers of neurons and/or increased neuronal connectivity. A related possibility, however, is that brain size–IQ relationship reflects differences in the ability to build a brain to a common blue print in the face of developmental stress. If the latter hypothesis is correct, then the head size–IQ correlation should be mediated by FA.

These hypotheses are testable in datasets that contain both FA and head size measures as well as an ability measure, though only one study has examined this to date (Furlow et al., 1997). These authors reported a significant correlation of 0.16 between head size and IQ. However, this relationship was rendered insignificant when FA was added to the analysis. Furlow et al. conservatively concluded that DI explains in part the covariation between brain size and IQ. The regression results are also compatible, however, with a stronger model in which head size makes no unique contribution to IQ once FA is accounted for. In order to explore this hypothesis in more detail, head size was assessed in study II. This second study, then tested four hypotheses: that the FA–IQ correlation would replicate, that sex effects would not be significant, that head size would correlate with IQ, and that FA would mediate all of this latter relationship.

3.1. Methods

3.1.1. Subjects

One hundred and sixty-four subjects participated (124 female (mean age 21.6 years, S.D. 7.34) and 40 male (mean age 21 years, S.D. 7.47) for course credit or for payment of \$10.

3.1.2. Procedure

All subjects completed the Raven Standard Progressive Matrices (Raven, 1992) in an untimed computerized version. FA was measured in 153 of these subjects in a session separate from the Raven measurement ses-

sion and blind to the Raven's scores. FA was assessed in the length of each of the four fingers of each hand excluding the thumb, with each finger measured twice using digital calipers accurate to 0.1 mm. FA was computed as in study I. Head circumference was measured with a flexible tape at a horizontal plane immediately above the eyebrow ridge and inion, with two measures taken and averaged.

3.2. Results

The mean raw Raven's Standard Matrices score was 22.06 (S.D. 5.28). Supporting Hypothesis 1, FA showed a significant negative correlation with Raven scores ($r = -0.29$, $p < 0.0003$). Regarding the hypothesized sex difference in FA–Raven relationship, a multiple regression with sex, age, FA, and the FA*sex interaction as DVs predicting Raven score was significant overall [$F(4,159) = 5.89$, $p < 0.0002$], but only the main effect of FA was significant individually. In contrast to study I, separate analyses by sex showed correlations of -0.33 in females compared to -0.13 in males, i.e., a *smaller* effect in males in this sample.

The third hypothesis, that head size would correlate positively with Raven score, was also supported ($r = 0.21$, $p = 0.009$). Head size and FA showed a weak negative correlation ($r = -0.12$, $p = 0.154$), supporting some common link between head size and FA. A stepwise regression of age, sex, head size, and FA against Raven score excluded age and sex as predictors of Raven, but retained both FA and head size [adjusted $R^2 = 0.102$, $F(2,150) = 9.82$, $p < 0.0001$].

3.3. Combined discussion

Study II replicated the correlation between FA and IQ in a clear-cut fashion. There are thus now five data samples from three separate laboratories reporting a significant correlation of between -0.2 (Furlow et al., 1997) and -0.4 (present report, study I, Prokosch et al., 2005).

Regarding the larger correlation in males than in females predicted by Prokosch et al. (2005), no interaction of sex*FA was found in either experiment I or II, and, while the correlation showed a trend for a larger effect in males than in females in study I, this was reversed in study II. Combined with the null finding of Furlow et al. (1997), this suggests that the FA–ability relationship does not involve sex-specific mechanisms. This suggests that human male sexual choice, perhaps because of significant post-coital investment in child rearing/family support, have exerted sexual selection

pressure on female mate quality. Given the modest power of the existing experiments, more work is required. Future research on FA should also explore the meaning of the greater female FA shown here: in particular controlling for female cycle (known to influence soft body tissue FA [Scutt & Manning, 1996](#)). As sexual selection theory suggests that males may be under pressure for lower canalization (i.e. greater trait variability) as a decrease in canalization increases the chance of displaying a high trait values, at the cost of increases in low trait values. Such effects would be revealed in larger standard deviations, which appears to be the case for IQ ([Deary et al., 2004](#)), including in this sample, but demonstrating this for FA in humans will require larger samples.

The study also aimed to address whether or not the correlation between head size and g is mediated by FA. The head size–Raven correlation itself was replicated with a magnitude estimate in line with other reports ([Ivanovic et al., 2004](#)), and in line with a range of research indicating that variables such as height and longevity co-vary with IQ ([Jensen & Sinha, 1993](#)). Developmental stability theory provides a rationale for this correlation: namely that biological fitness underlies both head size and IQ. In a pioneering paper identifying and discussing individual differences in vulnerability to environmental stress as a determinant of ability differences, [Jensen \(1969\)](#) hypothesized that vulnerability to stress may have evolved as an adaptation to low-resource environments in which fewer resources are invested in offspring during times when survival for a long period is unlikely. [Whalley and Deary \(2001\)](#) noted four related routes via which IQ might be associated with apparently unrelated traits such as longevity: IQ might be a record of prior stress or current bodily integrity and IQ might lead to pro-health behaviors: either by choice or greater opportunity to exercise these choices. Developmental instability can act influence each of these mechanisms and may therefore underlie the otherwise curious correlation of mental ability with longevity.

In the case of the head size–IQ relationship, developmental stability theory predicts that individuals with a low mutation load will be able to sustain the building of a larger brain, just as they can sustain life itself for a longer period. However, multiple regression analyses were ambiguous as to whether all the head size–IQ variance was absorbed by FA. A multiple regression of the type used by [Furlow et al. \(1997\)](#) including age, sex, head size, and FA as predictors of Raven scores indicated that head size was not a significant independent predictor of Raven scores. However, a stepwise regression on ability indicated that both head size and FA should be entered.

This latter result is probably capitalizing on chance, but research with a large sample is needed to provide a definitive answer.

To the extent that g can be assessed by non-neuronal features such as ear-length asymmetry, the data imply that the genes causing the high heritability of IQ do not code for different levels of psychometric intelligence per-sé but are pleiotropic—expressed in many systems, and acting on fitness in the same direction, positive or negative in all the systems in which they are expressed: be they in the brain, or in the fingers or ear lobe ([Miller, 2000](#)). It was noted in the introduction that the majority of g might be explained by developmental instability. An examination of [Fig. 1](#) comparing the ability range of individuals with the lowest FA to those at the highest levels of FA indicates that individuals exist whose FA is very low, but who nevertheless score poorly on the IQ test, while at the high-FA end, it is not possible to find individuals who score well on the ability measure. One explanation of this pattern is that FA forms an upper limit for ability, acting negatively to reduce an individual's potential, but that low FA alone is not sufficient to produce high ability. This would suggest the existence of both a general fitness/precision factor, related to FA, and additional IQ-specific genetic and environmental effects.

References

- Andersson, M. (1994). *Sexual selection*. Princeton: Princeton University Press.
- Butcher, L. M., Meaburn, E., Knight, J., Sham, P. C., Schalkwyk, L. C., Craig, I. W., et al. (2005). Snps, microarrays and pooled DNA: Identification of four loci associated with mild mental impairment in a sample of 6000 children. *Human Molecular Genetics*, *14*(10), 1315–1325.
- Deary, I. J., Wright, A. F., Harris, S. E., Whalley, L. J., & Starr, J. M. (2004). Searching for genetic influences on normal cognitive ageing. *Trends in Cognitive Sciences*, *8*(4), 178–184.
- Furlow, B., Armijo-Prewitt, T., Gangestad, S. W., & Thornhill, R. (1997). Fluctuating asymmetry and psychometric intelligence. *Proceedings of the Royal Society of London. Series B, Biological Sciences*, *264*(1383), 823–829.
- Ivanovic, D. M., Leiva, B. P., Pérez, H. T., Olivares, M. G., Díaz, N. S., Urrutia, M. S. C., et al. (2004). *Neuropsychologia*, *42*, 1118–1131.
- Jensen, A. R. (1969). How much can we boost IQ and scholastic achievement? *Harvard Educational Review*, *39*(1), 1–123.
- Jensen, A. R., & Sinha, S. N. (1993). Physical correlates of human intelligence. In P. Vernon (Ed.), *Biological approaches to the study of human intelligence*. Norwood NJ: Ablex.
- Ludwig, W. (1932). *Das rechts-links problem im tierreich und beim menschen*. Berlin: Springer.
- Miller, G. F. (2000). Sexual selection for indicators of intelligence. In G. Bock, J. Goode, & K. Webb (Eds.), *The nature of intelligence* (pp. 260–275). New York: John Wiley.

- Palmer, A. R. (1994). Fluctuating asymmetry analyses: A primer. In T. Markow (Ed.), *Developmental instability—Its origins and evolutionary implications* (pp. 335–364). Dordrecht: Kluwer.
- Palmer, A. R., & Strobeck, C. (1986). Fluctuating asymmetry: Measurement, analysis, patterns. *Annual Review of Ecological Systems*, 17, 391–421.
- Posthuma, D., Luciano, M., Geus, E. J., Wright, M. J., Slagboom, P. E., Montgomery, G. W., et al. (2005). A genome-wide scan for intelligence identifies quantitative trait loci on 2q and 6p. *American Journal of Human Genetics*, 77(2), 318–326.
- Prokosch, M. D., Yeo, R. A., & Miller, G. F. (2005). Intelligence tests with higher *g* loadings show higher correlations with body symmetry: Evidence for a general fitness factor mediated by developmental stability. *Intelligence*, 33, 203–213.
- Raven, J. C. (1992). *Standard progressive matrices*, 1992 edition. Windsor: NFER-Nelson.
- Raz, N., Torres, I. J., Spencer, W. D., Millman, D., Baertschi, J. C., & Sarpel, G. (1993). Neuroanatomical correlates of age-sensitive and age-invariant cognitive abilities: An in vivo MRI investigation. *Intelligence*, 17, 407–422.
- Scutt, D., & Manning, J. T. (1996). Symmetry and ovulation in women. *Human Reproduction*, 11(11), 2477–2480.
- Spearman, C. (1927). *The abilities of man*. New York NY: Macmillan.
- Van Valen, L. (1962). A study of fluctuating asymmetry. *Evolution*, 16, 125–142.
- Waddington, C. H. (1957). *The strategy of the genes*. London: George Allen and Unwin.
- Whalley, L. J., & Deary, I. J. (2001). Longitudinal cohort study of childhood IQ and survival up to age 76. *British Medical Journal*, 322, 1–5.