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Intelligence and semen quality are positively correlated

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ABSTRACT

Human cognitive abilities inter-correlate to form a positive matrix, from which a large first factor, called 'Spearman's *g*' or general intelligence, can be extracted. General intelligence itself is correlated with many important health outcomes including cardio-vascular function and longevity. However, the important evolutionary question of whether intelligence is a fitness-related trait has not been tested directly, let alone answered. If the correlations among cognitive abilities are part of a larger matrix of positive associations among fitness-related traits, then intelligence ought to correlate with seemingly unrelated traits that affect fitness—such as semen quality. We found significant positive correlations between intelligence and 3 key indices of semen quality: log sperm concentration (r=.15, p=.002), log sperm count (r=.19, p<.001), and sperm motility (r=.14, p=.002) in a large sample of US Army Veterans. None was mediated by age, body mass index, days of sexual abstinence, service in Vietnam, or use of alcohol, tobacco, marijuana, or hard drugs. These results suggest that a phenotype-wide fitness factor may contribute to the association between intelligence and health. Clarifying whether a fitness factor exists is important theoretically for understanding the genomic architecture of fitness-related traits, and practically for understanding patterns of human physical and psychological health.

1. Introduction

The new field of 'cognitive epidemiology' is emerging from the surprising discovery that intelligence correlates with many important health outcomes, even longevity (Batty, Deary, & Gottfredson, 2007). These correlations may be mediated by lifestyle factors such as eating well, exercising, avoiding cigarettes, working in safer, less stressful jobs, and having better access to health care. However, there is a further possibility, suggested by the nature of intelligence itself: all cognitive abilities, no matter how diverse, inter-correlate positively, forming a matrix (or 'manifold'). This commonality depends primarily on a single underlying factor called Spearman's *g*, named for its discoverer—the British psychologist Charles Spearman (1863–1945). Spearman's *g* usually accounts for around half the total variance in any broad battery of tests (Carroll, 1993). The term 'intelligence' is often used interchangeably with '*g*' (as here) because the behavioural manifestations of *g* fit well with popular conceptions of intelligence: "the faculty of understanding, quickness of mental apprehension" (Little, Fowler, & Coulson, 1984).

Could the positive manifold among cognitive abilities be part of a larger manifold among all fitness-related traits? (By 'fitness' we mean the statistical propensity to survival and reproductive success, given ancestrally typical conditions: fitness-related traits help or harm fitness). If so, the *g* factor may be a special case of a more general 'fitness factor' or *f* factor that captures individual differences in general phenotypic quality (Houle, 2000). To investigate this possibility, we analysed correlations between intelligence and a fitness-related trait that has little face-value association: semen quality (Bonde et al., 1998; World Health Organization, 1999). These two traits arise from distinct organ systems (brain

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versus testicles), composed of distinct cells types: neurons and glia in brains, spermatagonia and Sertoli cells in sperm (for a cytological comparison of neurons and sperm see Meizel, 2004).

2. Methods

2.1. Participants

Our sample consists of US Vietnam-era Army veterans enrolled in the Vietnam Experience Study (VES) by the US Centers for Disease Control. In 1985 4462 veterans underwent extensive medical and mental examinations; of these, 571 provided semen samples. Our analyses focused on the 425 men who had not been vasectomised, who collected their entire ejaculate without spillage, and for whom we had complete cognitive data for the measures listed below. These 425 men were aged 31 to 44 (mean 37.6, SD 2.5) at time of testing. 355 were White, 48 Black, 16 Hispanic, 4 Asian or Pacific Islanders and 2 Native American or Native Alaskan. The characteristics of the men who participated in the semen analysis were nearly identical to those of the larger group of 4462 medical examinees (The Centers for Disease Control, 1989 p.216). Comprehensive details of the sampling design are found in VES project reports (The Centers for Disease Control, 1989 pp.11–14 and also on the web Centers for Disease Control, 2007).

We ascertained representativeness further by examining the General Technical Test (GT) and Armed Forces Qualification Test scores obtained at induction (~age 18) for (a) the full sample of 18,313 veterans in the VES study, (b) the subsample of 4462 men who were given comprehensive examinations in 1985 (~age 37), and (c), of those, the 425 men in our analyses who provided semen samples. GT means (and SDs) at the three levels of sampling were very similar, respectively, 104.4 (20.1), 106.0 (20.3), and 106.5 (20.5).

2.2. Semen collection and measures

The men were asked to abstain from ejaculating for at least 48 h before semen collection. They were given plastic containers for collection and insulating cups to keep the semen warm. Following masturbation in their hotel rooms (without using lubricants or condoms), the men delivered their samples to the VES study receiving desk within 30 min of ejaculation. They noted the number of days since their most recent ejaculation. In the mid 1980s, objective, standardized computerised imaging had become available for measuring sperm concentration and motility. The Cellsoft computer-assisted semen analyzer system was used to video-record semen samples within 140 min of collection. For methodological details of the semen analysis protocols see (Centers for Disease Control, 1989 pp.197–199 and Centers for Disease Control, 2007, Supplement B pp.3–5).

We analysed three semen measures: sperm concentration (millions of sperm per ml of semen, $\log_{10}$ transformed to minimize skew), sperm count (millions of sperm in the total ejaculate, $\log_{10}$ transformed to minimize skew), and sperm motility (percentage of motile sperm). We selected these three measures because they are associated with fertility (World Health Organization, 1999). Sperm concentration and sperm motility are associated with the likelihood of fertilization (Guzick et al., 2001; van der Merwe, Kruger, Oehninger, & Lombard, 2005). Sperm morphology which is also associated in the andrology literature with the likelihood of conception was excluded from our analyses because there is ongoing debate among evolutionary researchers over whether different adaptive sperm morphs exist in humans as a response to sperm competition (see for review Shackelford & Pound, 2006). If there are sperm morphs that are adaptive under some conditions (such as sperm competition) then knowing the quantity of morphologically-typical sperm will be only partially useful, whereas even under sperm competition, concentration, count and motility would be useful indicators of fertility.

2.3. Cognitive tests and extraction of the g factor

The 4462 veterans studied in 1985 took 16 neuropsychological tests. Of these, we selected the 5 tests that provided the most psychometrically sound measures of the broad spatial, quantitative, and verbal abilities typically tapped by IQ test batteries. These were: the Verbal and Arithmetic tests of the Army Classification Battery (Montague, Williams, Gieseking, & Lubin, 1957), the Information and Block Design subtests of the Wechsler Adult Intelligence Scale—Revised (Wechsler, 1981); and the Reading subtest of the Wide Range Achievement Test (Jastak & Jastak, 1965). We used principal axis factoring on these five tests to extract a *g* factor (which explained >60% of the total variance among the test scores). We calculated *g* scores for all the men in the sample of 4462, which included the 425 men in this report, and used those *g* scores as the index of each man's intelligence.

2.4. Covariates

We assessed five key covariates that might confound any observed statistical relation between intelligence and semen quality. We focused on covariates that might confound our results by influencing both semen quality and intelligence since factors that influence only one trait would not explain the correlation between the two traits.

These covariates were: age (at time of testing in 1985), reported days of sexual abstinence before ejaculation ('days abstinence'), body mass index (BMI), alcohol use (self-reported alcoholic drinks per month currently), and smoking (self-reported cigarettes per day smoked currently). Intelligence and semen quality may both decline with age; days abstinence increases sperm concentration and count (Levitas et al., 2005); intelligence may predict compliance with VES instructions to abstain for at least 48 h before semen collection. Finally, less intelligent men might take poorer care of their health, resulting in more obesity, alcohol consumption, and smoking. Cigarette smoking is known to harm semen quality (Soares & Melo, 2008) as does higher BMI (Nguyen, Wilcox, Skjaerven, & Baird, 2007). Cigarette smoking, alcohol use and obesity have not been shown to harm intelligence, but since they are pervasively harmful to health in many epidemiological studies we included them as potential confounds.

We also examined service in Vietnam (because of possible exposure to toxins) and self-reported use of marijuana and

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Table 1
Descriptive statistics (n=425)

	Mean	SD	Skewness	Kurtosis
g factor	−0.02	0.98	−0.61	−0.45
Sperm concentration (mil/ml)	102.39	80.13	1.24	1.52
Sperm concentration (mil/ml) ($\log_{10}$)	1.86	0.40	−0.59	−0.11
Sperm count (mil/ejac)	263.23	246.17	1.93	4.81
Sperm count (mil/ejac) ($\log_{10}$)	2.23	0.46	−0.61	0.16
Sperm motility (% motile)	58.98	23.37	−0.42	−0.76
Abstinence (days)	3.15	1.78	2.42	8.40
Abstinence (days) ($\log_{10}$)	0.45	0.20	0.68	0.48
Alcohol (current drinks/mo)	25.85	40.86	2.38	5.80
Alcohol (current drinks/mo) ($\log_{10}$)	0.47	1.21	−0.19	−1.65
Smoking (current cig/day)	10.66	14.03	1.01	−0.06
Age at interview	37.62	2.55	0.11	−0.13
Body mass index	25.60	3.64	1.07	3.01
Body mass index ($\log_{10}$)	1.40	0.06	0.42	1.05

hard drugs (both past and current use for each) because all of these might undermine semen quality—and more intelligent men might more effectively avoid them. However, biserial correlations for these dichotomous variables showed that none of the five had a significant effect on any aspect of semen quality, so we did not include them in further analyses.

We considered the possibility that an unmeasured third variable might influence both intelligence and semen quality. Variables that influence only intelligence or semen quality would not explain any association between the two traits, although we would still like to know about them. We considered what factors (for which we have data) influence the intelligence of middle-aged men, to see whether they might also influence semen quality. The strongest influence on intelligence differences in adulthood is genetic. The heritability of intelligence in men of our sample age is around 70% (Plomin & Petrill, 1997). This does not rule out non genetic influences, but we could not identify any specific examples of environmental influences on intelligence in middle-aged men from published reports, other than those that would have led to the men being excluded from the Army (such as lead poisoning, iodine deficiency). Quantitative genetic analyses of intelligence find that the influence of shared family background of twins and adoptees is zero in adulthood (Plomin & Petrill, 1997; Scarr & Weinberg, 1978). The relatively small non genetic contribution to intelligence differences among middle-aged men may be non systematic, arising from idiopathic influences, random biological noise and measurement error (Jensen, 1997).

3. Results

3.1. Descriptive statistics

Table 1 provides basic descriptive statistics for intelligence (*g*), the three semen measures (sperm concentration, count, and motility), and the five key covariates (age, days abstinence, BMI, alcohol use, and smoking) for the 425 men. Sperm count, sperm concentration and alcohol use, were highly skewed, so we $\log_{10}$ transformed them for the analyses. We also $\log_{10}$ transformed BMI because its kurtosis deviated significantly from normal.

3.2. Correlations

Table 2 shows that intelligence correlates significantly and positively with all three measures of semen quality: sperm concentration (r=.15, p=.002), sperm count (r=.19, p<.001) and percentage of motile sperm (% motility) (r=.14, p=.005). The three semen measures also correlate substantially with each other (r=.56 to .82). The sample size here (425) affords above 80% power to detect a correlation of r=.14 at the p=.05 level (two tailed), which is the smallest of the three zero-order correlations between *g* and semen quality (SISA website).

3.3. Multiple regressions

Table 3 shows the results from the multiple regressions. In Model 1 we regressed each of the three semen quality measures, in turn, as the outcome variable on all five continuous covariates that might influence semen quality: age, day's abstinence, BMI, alcohol, and smoking. In Model 2 we included intelligence (the *g* factor) as an additional predictor. The increase in R and the R^2 show that adding the *g* factor improves the fit of the model. We also tested several curve-fit regression models but none offered a better fit than the linear model. These results show that the positive correlations between *g* and semen quality were not mediated by age or by three major health hazards: smoking cigarettes, alcohol and adverse BMI. Nor were they mediated by

Table 2
Correlations among *g*, semen measures and covariates (n=425)

	Intelligence	Sperm concentration (mil/ml)	Sperm count (mil/ejac)	Motility %	Abstinence	Alcohol	Smoking	Age	BMI
g factor	1.00								
Sperm conc. (mil/ml)+	0.15**	1.00							
Sperm count (mil/ejac)+	0.19**	0.82**	1.00						
Motility (%)	0.14**	0.63**	0.56**	1.00					
Abstinence (days)	0.01	0.16**	0.24**	0.08	1.00				
Alcohol (drinks/mo)	0.08	0.05	0.04	0.07	−0.01	1.00			
Smoking (cigs/day)	−0.09	−0.06	−0.08	−0.02	−0.01	0.11*	1.00		
Age	−0.03	0.09	0.06	0.01	0.00	−0.05	−0.13**	1.00	
Body mass index	−0.03	−0.02	−0.03	−0.05	−0.09	−0.03	−0.10*	0.07	1.00

*p<05 (2-tailed)
**p<.01 (2-tailed)
+indicates log base 10
Notes: Abstinence (days), Alcohol (current drinks per month), BMI (Body Mass Index) were $\log_{10}$ transformed. Smoking (current cigarettes per day), age at interview.

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Table 3
Multiple regressions of semen measures on covariates and g (n=425)

	Sperm conc. (mil/ml) (log_{10})				Sperm count (mil/ejac) (log_{10})				Motile sperm (%)			
	Model 1		Model 2		Model1		Model 2		Model 1		Model 2	
	ß	p	ß	p	ß	p	ß	p	ß	p	ß	p
Abstinence	0.16	0.00	0.16	0.00	0.24	0.00	0.24	0.00	0.07	0.13	0.07	0.13
Alcohol	0.07	0.17	0.05	0.27	0.05	0.30	0.03	0.48	0.08	0.12	0.07	0.18
Smoking	−0.05	0.27	−0.04	0.42	−0.08	0.10	0.06	0.19	−0.03	0.49	−0.02	0.67
Age	0.09	0.08	0.09	0.06	0.05	0.29	0.06	0.23	0.01	0.81	0.02	0.75
BMI	−0.01	0.78	−0.01	0.84	−0.02	0.76	−0.01	0.84	−0.04	0.39	−0.04	0.43
g factor			0.14	0.00			0.18	0.00			0.13	0.01
R	0.20		0.25		0.26		0.32		0.12		0.17	
R^2	0.04		0.06		0.07		0.10		0.01		0.03	
Adjusted R^2	0.03		0.05		0.06		0.09		0.00		0.02	

Notes: Abstinence (days), Alcohol (current drinks per month), BMI (Body Mass Index) were log_{10} transformed. Smoking (current cigarettes per day), age at interview.

abstinence, because abstinence and *g* were uncorrelated and therefore made independent contributions to variance in predicting semen quality.

The assumptions of the multiple regression demand that the errors, or residuals, are normally distributed (not that the predictors are normally distributed (Field, 2005 p.170). For each of the semen quality variables, we examined a scatterplot of the standardised predicted values with the standardised residuals to check for heteroscedasticity. We found, in each case, that the residuals were homoscedastic—having roughly equal variance at each level of the predictors.

We tested for influential cases that could bias the regression model by examining the range of Mahalanobis distances within the sample. Given our sample size and the number of predictors in our model, Mahalanobis values above 25 may indicate distortion; the largest value in our data was 16.57. A second measure of leverage, Cook's distance, was .18 at the maximum, where values over 1 indicate possible distortion. Together these analyses gave us confidence that the model does not suffer from serious biases of those kinds.

4. Discussion

The observed correlations between intelligence and semen quality may under-estimate the true correlations, given the limited reliability of single semen samples. We extracted a principal axis factor (unrotated) from the three semen measures to see whether this improved the reliability of the measures, but the correlation with *g* was very similar (r=.17). Semen quality varies across ejaculates not just according to days abstinence, but also by collection method (Gerris, 1999; Pellestor, Girardet, & Andreo, 1994), and psychological context (such as cues of partner infidelity (Baker & Bellis, 1989; Kilgallon & Simmons, 2005; Pound, Javed, Ruberto, Shaikh, & Del Valle, 2002). Thus, each man's single ejaculate as measured in this study is an imperfectly reliable indicator of his average semen quality across actual copulations. Finally, more functional aspects of semen quality can be assayed today (such as capacitation, acrosomal reactions and cervical mucus penetration (Aitken, 2006; Weber, Dohle, & Romijn, 2005); these might influence fitness more directly than do our measures.

The correlations between *g* and semen quality are small (r=.14 to.19). This is not evidence of their irrelevance; on the contrary the effect size is congruent with phenotypic correlations observed for other bodily correlates of intelligence such as height (r=.14, r=.15) (Silventoinen, Posthuma, van Beijsterveldt, Bartels, & Boomsma, 2006; Sundet, Tambs, Harris, Magnus, & Torjussen, 2005). Notably, these effect sizes fit with average effect sizes (r=.18–.19) found across all studies in evolution and ecology, as reported by a large survey of meta-analyses (Jennions & Moller, 2003). Very small correlations with fitness can, as Jennions and Moller put it, "turn a mouse into an elephant". This does not mean, however, that if intelligence or semen quality is positively correlated with fitness, high intelligence or semen quality would become fixed within each mating population. Although it used to be thought that any trait under selection would 'go to fixation', this has been falsified empirically: an extensive literature on the maintenance of additive genetic variation among fitness-related traits now exists, including for life-history traits (such as height, or time to first child) (Houle, 1992; Merila & Sheldon, 1999).

The results in this paper are consistent with the hypothesized general fitness factor (*f* factor) which, if confirmed, might help explain the many correlations between intelligence and physical health measures now being documented in cognitive epidemiology (Batty & Deary, 2004; Hart et al., 2005; Kuh, Richards, Hardy, Butterworth, & Wadsworth, 2004; Osler, 2003). If a fitness factor does exist, and if *g* is a component of a more general factor, we will want to know how this fitness factor arises.

One possibility is that an *f* factor emerges from individual differences in mutation load (Houle, 2000; Miller, 2000). While everyone carries many mildly harmful mutations (Nachman & Crowell, 2000), people differ in mutation load—the overall number of mutations that disrupt fitness-related traits. Assortative mating for overall genetic quality in socially monogamous species such as humans would amplify such variance in mutation load. If most genes have pleiotropic effects on several traits, then most mutations will harm several traits in parallel and create positive genetic correlations among traits, as manifest in an *f* factor. The new field of phenomics (Oti, Huynen, & Brunner, 2008) reveals correlations among complex human phenotypic traits, often hinting at underlying genetic correlations. Such correlations are also found throughout research on body symmetry (Furlow, Armijo-Prewitt, Gangestad, & Thornhill, 1997) and mate preferences (Thornhill &

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Gangestad, 1999). The correlations between intelligence and semen quality add to the plausibility of a phenotype-wide *f* factor precisely because there is no obvious morphological or functional relationship between the two traits.

Mutations acting on pleiotropic genes will result in correlations between the traits affected by those genes. Gene expression is more similar between brain and testes than between many other human tissues investigated (Guo, Huang, Studholme, Wu, & Zhao, 2005). Mutations in several genes on the X chromosome result in both mental retardation and gonadal abnormalities (Graves, 2006; Wilda et al., 2000). If a gene is very widely expressed and its products have a pervasively useful and important job to do, then massive pleiotropy should be detectable with the appropriate sample size. Some genes now on the human X chromosome were earlier on autosomes (Kohn, Kehrer-Sawatzki, Steinbach, Graves, & Hameister, 2007). Evidence concerning the recruitment of ancestrally old genes to new functions (including spermatogenesis and intelligence) will elucidate the connection between sperm quality and intelligence (Kohn et al., 2007).

A second possibility is that traits under positive selection may become linked—by assortative mating occurring over many generations—resulting in what is called gametic-phase disequilibrium. In a landmark study of people in 37 countries, intelligence was found to be valued highly by both men and women as a mate choice characteristic (Buss, 1989). If this preference has been stable for an evolutionarily-relevant period (see Hawks, Wang, Cochran, Harpending, & Moyzis, 2007 for a discussion of selection rates), then trans-generational, cross-trait assortative mating preferences may be another source of covariance between intelligence and sperm quality.

The notion of the *f* factor is under-explored empirically, yet it is theoretically important for understanding human genomics, phenomics, evolution, and intelligence itself. It is also practically important for interpreting any observed correlations between physical health, intelligence and socio-economic outcomes affected by intelligence such as education, occupation, and income. Research on a wider range of psychological and physical traits will be required to establish or refute the existence of a genuine *fitness* matrix in our species.

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