ORIGINAL RESEARCH PAPER

Arts

RELATIONSHIP OF VERBAL IQ WITH PERFORMANCE IQ AND FULL SCALE IQ ALONG WITH ANATOMICAL CHARACTERISTICS

KEY WORDS: Anatomical characters; Complete brain size; Intelligence quotient (IQ); full scale IQ (FSIQ); Joint generalized linear models (JGLMs); Verbal IQ (VIQ).

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ABSTRACT

The connection between the complete brain size and general mental ability (GMA) was acknowledged universally. Connection between the performance intelligence quotient (PIQ) score and anatomical characteristics such as complete brain size, height, gender and weight are also narrated in many research papers. Very little study has been compiled to derive the relationship of verbal IQ (VIQ) with PIQ, full scale IQ (FSIQ) and anatomical characteristics. The current research report aims to develop the relationship of VIQ with the above mentioned variables. It is identified herein that VIQ is unequal variance random variable, and its mean is positively connected with FSIQ ($P<0.0001$), PIQ ($P=0.1903$), height ($P= 0.0002$), brain size ($P=0.0181$) and gender ($P=0.0002$), while it is negatively interrelated with the joint interaction effects of PIQ and height (PIQ*Height) ($P<0.0001$) and FSIQ*Gender ($P<0.0001$). Variance of VIQ is negatively interrelated with gender ($P=0.0017$), brain size ($P=0.0040$), height ($P=0.0970$), FSIQ*Gender ($P=0.0032$), while it is positively interrelated with PIQ ($P=0.0321$), Gender* Height ($P=0.0322$) and Gender*Brain size ($P=0.0441$). It is concluded herein that VIQ is higher for females with higher FSIQ, PIQ, larger brain size, longer height, and lower interaction effects of FSIQ*Gender and PIQ*Height.

INTRODUCTION

In the nineteenth and beginning of twentieth centuries, the interrelation between the complete brain size and GMA was acknowledged universally (Morton, 1849; Broca, 1873; Topinard, 1878; Ankney, 1992). The interrelation between GMA and complete brain size has been broadly explored and illustrated in some review reports by Rushton and Ankney (1995, 1996, 2007, 2009). These above stated review articles have reported many interesting outcomes, which have been developed and narrated in many prior published papers. These prior published papers have exhibited that IQ is positively interrelated with the complete brain size. Besides, both GMA and complete brain size are interrelated with age, socioeconomic position, gender, and population group differences (Darwin, 1871; Rushton and Ankney, 2009).

A distinguished neurologist Dr. Paul Broca (1824–1880) critically investigated internal & external skull volumes and weighted wet brains at autopsy. The scientist found that adults averaged a bigger brain than either very elderly, or children, celebrated individuals averaged a greater brain than less celebrated, and expert employees averaged a greater brain than the non-expert (Broca, 1873). Broca's views were recorded in the book entitled- *The Descent of Man* written by Charles Darwin (1871). The distinguished scientist Galton (1888) first explained numerically the interrelation between the complete brain size and GMA on the surviving people, and reported that the male persons who received higher honors degrees had a greater brain size approximately more than 2% to 5% than the persons who did not.

The distinguished statistician Karl Pearson (1906) first investigated Galton's data applying the simple product moment correlation coefficient (r), and derived the value of r (=0.11) between GMA and complete brain size, which is insignificant statistically. So, Galton's investigation was partially supported by Karl Pearson's correlation measure. Spearman (1904, 1927) surveyed the different GMA items, and observed positive interrelation of each subset, and also located a general IQ factor. National Collaborative Perinatal Project (Broman et al., 1975, 1987) data were obtained separately by sex, and simple product moment correlation for body size was not considered. Rushton and Ankney (2009) narrated the results of 28 separate investigation studies that adopted brain computed tomography (CT) and imaging techniques such as magnetic resonance imaging (MRI) in a total of 1,389 normal persons, where the range of correlations between complete brain size and GMA was 0.04 to 0.69.

It is recognized for a bivariate data set that a simple product moment correlation coefficient does not reflect cause, while zero correlation reveals no confirmation for a relationship of cause and effect, but nonzero correlation does show confirmation. Many recent reports on IQ studies have been performed simply by percentage, simple correlation and multiple regression (Black et al. 2010; Mackintosh, 2011; Warsito et al. 2012). It is clear that any IQ data set is a multivariate form, where zero, or nonzero simple product moment correlation values do not reveal cause and effect, while partial non zero correlation values do provide support. Moreover, any IQ data set is always physiological, thus the variance of IQ may be heteroscedastic (Das and Ghosh, 2020). So, the ordinary multiple regression model may provide inappropriate results. Thus, most of the prior IQ analyses invite many suspicions and debates. Best of our knowledge, very few articles focus on the relationships of VIQ with anatomical characteristics, PIQ and FSIQ, based on advance and appropriate statistical analysis considering the heterogeneity of IQ data set. The current report is prepared as follows. The following section displays the materials & methods, and the subsequent sections gives results & discussion, and followed by conclusion.

MATERIALS & METHODS

An IQ data set of 40 college students was collected by Willerman et al. (1991). Data illustration and collection procedure is neatly reported by Willerman et al. (1991). This is also very shortly reproduced by Das and Ghosh (2020). It is not reproduced herein elaborately. The researchers used MRI to account the complete brain size of the investigated students, and also their body height & weight were considered. The investigation was done at a southwestern university on 40 randomly selected Anglo psychology college students whose Scholastic Aptitude Test Scores below 940, or above 1350. The selected subject received a course requirement by protecting the administration of four sub-examinations such as vocabulary, similarities, picture completion and block design of the Wechsler (1981) Adult Intelligence Scale-Revised. Following the University's research protocol prior approval, considered subjects MRI were necessary to take prorated full-scale IQs of above 130, or below 103. The considered subjects were equally classed by sex and IQ classification.

Willerman et al. (1991) narrated the IQ data set of the considered 40 random subjects on 07 interested characters such as VIQ, PIQ and FSIQ scores founded on the four Wechsler (1981) sub- examinations, sex (male=1, female=2), along with considered subject's height in inches, total pixel count from the 18 MRI (MRI count) scans, and body weight (Weight) in pounds. The data set contains two missing information for two subject, which are excluded in the current study. One new variable is defined based on the existing data set which is known as body mass index (BMI= Weight(kg) / Height(m^2) is considered in the current study. For examining the current reported results the considered data is displayed in Appendix. Recently, an article by Das and Ghosh (2020) has shown that the response PIQ is heteroscedastic and the earlier results such as correlations and regression analysis reported by Willerman et al. (1991) related to PIQ are incorrect. Similar studies as Willerman et al. (1991) have been reported by Gur et al. (1991), Gould(1996).

Statistical Methods

The current IQ data set is heteroscedastic (Das and Ghosh, 2020). The response VIQ is unequal variance, positive, continuous and non-normally distributed that can be modeled by adopting appropriate transformation, when the variance is stabilized using that transformation. In practice, the variance is unstable mostly under many transformations (Myers et al. 2002). It is known that a positive continuous random response with constant variance can be analyzed either by a lognormal, or gamma model (Firth, 1988). For a positive response variable with unequal variance, analysis can be done using JGLMs applying lognormal, or gamma models (Das and Lee 2009). JGLMs is broadly narrated in the book by Lee et al. (2017). As a ready reference, JGLMs for both the distributions are displayed very shortly herein.

JGL Lognormal Models:

Here **V**IQ $=y_i$ say, is the inquisitive continuous & positive random variable with unequal variance (σ_i^2), and mean μ_i = E(VIQ=y_i), satisfying Var(VIQ=y_i) = $\sigma_i^2\mu_i^2=\sigma_i^2\, V(\mu_i)$ say, where V(.) is recognized as variance function. Commonly, the log transformation z_i= log(VIQ=y_i) is taken to stabilize the variance that may not be stabilized always (Myers et al., 2002). For deriving an advanced model, JGLMs for the mean and dispersion are used frequently. Treating the dependent variable VIQ distribution as log normal, the JGLMs of the mean and dispersion model (dependent variable VIQ= y_i, with z_i = log(VIQ=y_i)) are displayed by

$$E(z_i)=\mu_{zi}=x_i^t\beta,\ Var(z_i)=\sigma_{zi}^2, \text{and } \log(\sigma_{zi}^2)=g_i^t\gamma,$$

where x_i^t and g_i^t are the vectors of explanatory variables connected to the regression coefficients β and γ, respectively.

JGL Gamma Models:

For the dependent study variable VIQ=y_i as stated above, whose variance has two elements such that σ_i^2 (free of mean changes) and $V(\mu_i)$ (depends on the mean changes), while V (.) is called as the variance function that characterizes the GLM family distribution. For instance, if $V(\mu)=\mu$, it is Poisson, and it is Normal, or gamma according as $V(\mu)$= 1, or $V(\mu)=\mu^2$, etc. Mean & dispersion JGLMs for VIQ under gamma distribution are given by

$$\eta_i = g(\mu_i)=x_i^t\beta \text{ and}, \varepsilon_i=h(\sigma_i^2)=w_i^t\gamma$$

where g(.) & h(.) are the link functions connected to the mean & dispersion predictors respectively, and x_i^t, w_i^t are the mean and dispersion parameters associated explanatory variable vectors, respectively. Maximum likelihood (ML) method is employed to derive mean parameters, but the restricted ML (REML) method is employed to compute dispersion parameters (Lee et al., 2017).

STATISTICAL & GRAPHICAL ANALYSIS

The inquisitive response variable VIQ is modeled on the rest explained variables using both gamma and lognormal JGLMs. Gender, height, FSIQ, weight, BMI, PIQ and brain size are taken as explained variables, while VIQ is taken as the dependent random variable that is with unequal variance. The best JGLM has been chosen based on the lowest Akaike information criterion (AIC) value that reduces both the predicted additive errors and squared error loss (Hastie et al. 2009, p. 203-204). The best VIQ log normal and gamma JGLMs analyses outcomes are shown in Table 1. Note that in the log normal dispersion model, one joint interaction effect namely Brain size*Gender is allied, so it is not included in the fitted dispersion log normal model in Table 1. AIC selects the VIQ gamma fitted model as the best, so its graphical analysis is examined in Figure 1.

Table 1: Final JGL Gamma & Log Normal Fitted Models Of VIQ On PIQ, FSIQ And Others

Model	Covarite	Gamma fit				Lognormal fit			
		estimate	s.e.	t(30)	P-value	estimate	s.e.	t(30)	P value
Mean	Constant	2.6622	0.26536	10.03	<0.0001	2.5288	0.24261	10.42	<0.0001
	FSIQ	0.0150	0.00017	89.64	<0.0001	0.0150	0.00016	92.14	<0.0001
	Gender	0.1653	0.03834	4.31	0.0002	0.1733	0.03615	4.79	<0.0001
	FSIQ*Gender	-0.0015	0.00029	-5.27	<0.0001	-0.0015	0.00028	-5.53	<0.0001
	PIQ	0.0029	0.00216	1.34	0.1903	0.0037	0.00206	1.81	0.0803
	Height	0.0154	0.00356	4.32	0.0002	0.0172	0.00319	5.37	<0.0001
	PIQ*Height	-0.0001	0.00003	-4.78	<0.0001	-0.0002	0.00003	-5.50	<0.0001
	Brain size	0.0001	0.00001	2.50	0.0181	0.0001	0.00001	2.33	0.0267
Disper-sion	Constant	51.76	12.564	4.120	0.0003	50.95	13.101	3.889	0.0005
	FSIQ	-0.03	0.038	-0.893	0.3790	-0.05	0.038	-1.418	0.1664
	Gender	-67.04	19.511	-3.436	0.0017	-69.78	19.071	-3.659	0.0010
	FSIQ*Gender	-0.10	0.031	-3.201	0.0032	-0.06	0.025	-2.531	0.0169
	PIQ	0.09	0.041	2.248	0.0321	0.08	0.042	1.904	0.0665
	Brain size	-0.01	0.001	-3.119	0.0040	- 0.01	0.001	-2.506	0.0179
	Height	-0.35	0.207	-1.713	0.0970	-0.64	0.185	-3.473	0.0016
	Height*Gender	0 .69	0.308	2.246	0.0322	1.09	0.259	4.201	0.0002
	Brain*Gender	0.01	0.001	2.102	0.0441	---	---	----	
AIC		**115.374**				**121.0**			

The derived VIQ gamma fitted JGL (Table 1) probabilistic model is a data developed model that is examined applying model diagnostic plots in Figure 1. Figure 1(a) expresses the VIQ gamma fitted absolute residuals plot against the VIQ fitted values that is nearly flat straight except the right tail, interpreting that variance is equal to the running means. Right tail of Figure 1(a) is little decreasing as three smaller absolute residuals are located at the right boundary. Figure 1(b) shows the VIQ mean gamma fitted normal probability plot (Table 1), which does not express any lack of fit. So, Figure 1 does not represent any lack of fit of the VIQ model (Table 1), and it proves that the gamma fitted VIQ model (Table 1) is nearly to its true model.

RESULTS & DISCUSSION

Table 1 reflects the summarized VIQ lognormal and gamma fitted outcomes, while gamma fitted VIQ model is the best model according to the AIC criterion. So, the VIQ gamma fitted results are reported herein. Table 1 shows that mean VIQ is positively connected with FSIQ (P<0.0001), PIQ (P=0.1903), height (P= 0.0002), brain size (P=0.0181) and gender (P=0.0002), while it is negatively interrelated with the joint interaction effects of PIQ and height (PIQ*Height) (P<0.0001) and FSIQ*Gender (P<0.0001). Variance of VIQ is negatively interrelated with gender (P=0.0017), brain size (P=0.0040), height (P=0.0970), FSIQ*Gender (P=0.0032), while it is positively interrelated with PIQ (P=0.0321), Gender*Height (P=0.0322) and Gender*Brain size (P=0.0441). Some partially significant, or insignificant effects such as PIQ (in the mean model), FSIQ, Height (in the variance model) are included in the model due to marginality rule given by Nelder (1994).

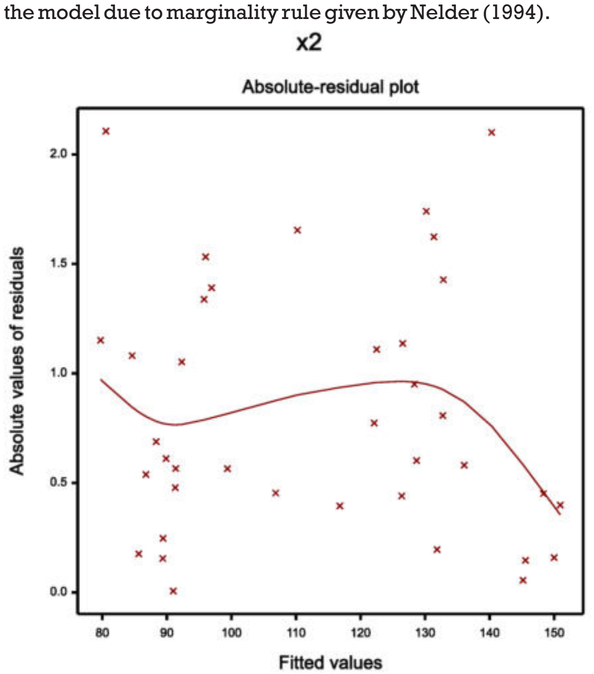

Figure 1(a)

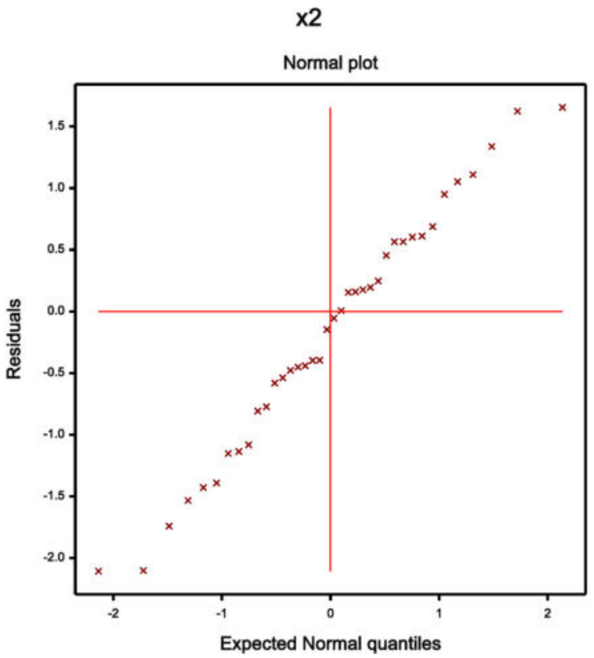

Figure 1(b)

Figure 1: For the JGL gamma fitted VIQ models (in Table 1), the (a) absolute residuals plot against the VIQ fitted values, and (b) the mean VIQ normal probability plot model.

Final gamma fitted VIQ mean (μ) model (Table 1) is

μ= exp.(2.6622 + 0.0150 FSIQ + 0.1653 Gender - 0.0015 FSIQ * Gender + 0.0029 PIQ + 0.0154 Height - 0.0001 PIQ * Height + 0.0001 Brain size),

and the final gamma fitted VIQ dispersion (σ^2) model is

σ^2= exp.(51.76 - 0.03 FSIQ - 67.04 Gender - 0.10 FSIQ*Gender + 0.09 PIQ - 0.01 Brain size - 0.35 Height + 0 .69 Height*Gender + 0.01 Brain size*Gender).

IQ data sets are multivariate in nature, and the interconnection between any two variables can be identified through appropriate modeling of the dependent variable on the rest independent variables. Moreover, IQ data sets are heteroscedastic as their source is physiological (Das and Ghosh, 2020). Therefore, by adopting only JGLMs of VIQ, exact associations of it with other explanatory variables can be obtained. Best of our knowledge, JGLMs of VIQ on FSIQ, PIQ and other anatomical characters are not examined in any prior reports. It is hoped that JGLMs of VIQ can produce all new findings in the IQ literature.

The computed regression coefficient estimates of VIQ for both fittings (in Table 1) have smaller standard error, implying that the derived estimates are stable in both the models. The best accepted mean and dispersion models of VIQ have been chosen based on graphical diagnosis, lowest AIC value and lower standard errors of the estimates. So, the developed mean and dispersion models of VIQ (in Table 1) are very close to their true models. Anyone can test these reported results (in Table 1) with the data in the Appendix.

Table 1 displays the summarized VIQ lognormal and gamma fitted JGLMs analyses results. It is identified herein that mean VIQ is positively connected with FSIQ (P<0.0001), and partially positively connected with PIQ (P=0.1903), concluding that VIQ is higher for the subjects with higher level of FSIQ and PIQ. Mean VIQ is positively connected with gender (Male= 1, Female= 2) (P=0.0002), implying that VIQ level is higher for females than men. Mean VIQ is positively connected with height (P= 0.0002), brain size (P=0.0181), interpreting that VIQ increases as the height or brain size increases. In addition, mean VIQ is negatively interrelated with the joint interaction effects PIQ*Height (P<0.0001) and FSIQ*Gender (P<0.0001), indicating that VIQ is higher as the joint effect PIQ * Height, or and FSIQ * Gender is lower. Note that FSIQ, PIQ, Height and Gender are positively associated with VIQ, but their joint interaction effects PIQ * Height and FSIQ * Gender are negatively associated with VIQ. Therefore, for a longer individual (even female) with high PIQ and FSIQ, VIQ may not be so high, as PIQ * Height, FSIQ * Gender are negatively associated with VIQ. This indicates that average VIQ represents a very complex relationship with the others.

Table 1 shows that variance of VIQ is negatively interrelated with gender (Male= 1, Female= 2) (P=0.0017), concluding that VIQ is less scattered for female students than male. VIQ variance is negatively interrelated with brain size (P=0.0040) and height (P=0.0970), interpreting that VIQ is less scattered for the longer students with bigger brain size than others. FSIQ is insignificant, and gender is negatively associated with VIQ, but FSIQ * Gender (P=0.0032) is also negatively associated with VIQ. It concludes that variance of VIQ increases as the joint effect FSIQ * Gender decreases. Again, VIQ variance is positively interrelated with PIQ (P= 0.0321), Gender* Height (P=0.0322) and Gender*Brain size (P=0.0441). These conclude that VIQ variance increases as the effect of PIQ, or Gender*Height, or Gender*Brain size increases. Note that gender, height and brain size are negatively associated with VIQ variance, while their joint interaction effects Gender*Height and Gender*Brain size are positively associated with it. This shows that VIQ variance presents a very complex relationship with the others.

Most of the IQ determinants are clearly illustrated in some review reports by Rushton and Ankney (1995, 1996, 2007, 2009). Prior reports are based on correlation, percentage, usual multiple regression analysis which are unable to identify the determinants of heteroscedastic IQ data. Moreover, these above procedures are unable to identify determinants of the mean and variance model of a IQ data set along with interaction effects. The determinants of VIQ in the current report are completely new in the IQ literature, therefore, these can not be compared to the prior studies, as VIQ has not been examined properly in any prior article. Table 1 represents the very complex relationship of VIQ with the rest of the variables. Mean and dispersion models of VIQ (Table 1) express non-linear complex relationships with the rest explanatory variables. Therefore, all the prior findings related to VIQ invite many disputes and doubts.

CONCLUSIONS

The current report has derived the non-linear mean and variance VIQ models which are little reported in the prior IQ articles. The reported VIQ model (in Table 1) has been adopted through different steps of judgements such as comparison of distributions, AIC criterion, model diagnostic checking and smaller standard error of the estimates. JGL gamma fitted VIQ model has been accepted as the best model. It is expected that any IQ data set with these eight variables must satisfy the same relationships as reported herein. This is not verified herein as the similar data sets are not available. Future IQ researchers may consider similar data sets to verify these reported results. This report may give the prediction idea of VIQ of an individual to the IQ experts. It is concluded herein that VIQ is higher for females with higher FSIQ, PIQ, larger brain size, longer height, and lower interaction effects of FSIQ*Gender and PIQ*Height.

Conflict Of Interest:

The authors confirm that this article content has no conflict of interest.

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APPENDIX

App 1: Intelligence data along with FSIQ, VIQ, PIQ, BMI, height & weight.

Gender	FSIQ	VIQ	PIQ	Weight	Height	MRI count	BMI
Female	133	132	124	118	64.5	816932	19.93967
Male	139	123	150	143	73.3	1038437	18.71041
Male	133	129	128	172	68.8	965353	25.54506
Female	137	132	134	147	65	951545	24.45941
Female	99	90	110	146	69	928799	21.55808
Female	138	136	131	138	64.5	991305	23.31927
Female	92	90	98	175	66	854258	28.24265
Male	89	93	84	134	66.3	904858	21.43054
Male	133	114	147	172	68.8	955466	25.54506
Female	132	129	124	118	64.5	833868	19.93967
Male	141	150	128	151	70	1079549	21.66388
Male	135	129	124	155	69	924059	22.887
Female	140	120	147	155	70.5	856472	21.92344
Female	96	100	90	146	66	878897	23.56244
Female	83	71	96	135	68	865363	20.52444
Female	132	132	120	127	68.5	852244	19.02733
Male	100	96	102	178	73.5	945088	23.16331
Female	101	112	84	136	66.3	808020	21.7504
Male	80	77	86	180	70	889083	25.82449
Male	97	107	84	186	76.5	905940	22.3432
Female	135	129	134	122	62	790619	22.31165
Male	139	145	128	132	68	955003	20.06834
Female	91	86	102	114	63	831772	20.19199
Male	141	145	131	171	72	935494	23.18924
Female	85	90	84	140	68	798612	21.2846
Male	103	96	110	187	77	1062462	22.17254
Female	77	83	72	106	63	793549	18.77501
Female	130	126	124	159	66.5	866662	25.27605
Female	133	126	132	127	62.5	857782	22.85594
Male	144	145	137	191	67	949589	29.91156
Male	103	96	110	192	75.5	997925	23.67896
Male	90	96	86	181	69	879987	26.72611
Female	83	90	81	143	66.5	834344	22.73255
Female	133	129	128	153	66.5	948066	24.32223
Male	140	150	124	144	70.5	949395	20.36759
Female	88	86	94	139	64.5	893983	23.48825
Male	81	90	74	148	74	930016	19
Male	89	91	89	179	75.5	935863	22.0757

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