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RELATIONSHIP OF FULL-SCALE INTELLIGENCE QUOTIENT (IQ) WITH VERBAL IQ, PERFORMANCE IQ & PHYSICAL CHARACTERISTICS

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Abstract:The correlation between the whole brain size and general mental ability (GMA) was adopted almost universally. Relationships between the performance intelligence quotient (PIQ) score and anatomical characteristics such as height, brain size, gender and weight are also illustrated in many research articles. A little study has been made to derive the relationship of full scale IQ (FSIQ) with physical characteristics, verbal IQ (VIQ) and performance (PIQ). The current paper aims to establish the relationship of FSIQ with the above components. It is developed herein that FSIQ is heteroscedastic random variable, and its mean is positively associated with VIQ ($P<0.0001$), PIQ ($P<0.0001$), and the joint interaction effect of VIQ and gender (VIQ*Gender) ($P<0.0001$), while it is negatively associated with brain size ($P=0.0003$), gender ($P<0.0001$) and the joint interaction effect VIQ*PIQ ($P<0.0001$). Variance of FSIQ is positively associated with gender ($P=0.0038$), PIQ ($P=0.0299$), while it is negatively associated with brain size ($P=0.0002$) and VIQ*Gender ($P=0.0002$). It is derived herein that FSIQ is higher for the male people having higher VIQ, PIQ, lower interaction effect of VIQ*PIQ, smaller brain size and higher interaction effect of VIQ with gender.

Keywords-Anatomicalfactors;Brain size; Intelligence quotient (IQ); Joint generalized linear models (JGLMs); Full scale IQ; Verbal IQ.

I. INTRODUCTION

During the whole nineteenth and early twentieth centuries, the relation between the general mental ability (GMA) and whole brain size was almost universally agreed (Morton, 1849; Darwin, 1871; Broca, 1873; Topinard, 1878). The relation between GMA and brain size has been extensively examined and described in many review papers by Rushton and Ankney (1995, 1996, 2007, 2009). The above review papers illustrated many important results that were derived and discussed in most of the previous published papers. Most of the papers have shown that IQ is directly correlated with brain size, and both GMA and brain size are correlated with socioeconomic position, gender, age, and population group differences (Rushton and Ankney, 2009).

The great neurologist Paul Broca (1824–1880) critically studied internal and external skull dimensions and surveyed wet brains at autopsy and observed that mature adults averaged a larger brain than either children, or very elderly, renowned persons averaged a larger brain than the less renowned, and skilled workers averaged a bigger brain than the unskilled (Broca, 1873). Broca's observations were noted in the book entitled- *The Descent of Man* written by Charles Darwin (1871). The renowned scientist Galton (1888) first described numerically the association between brain size and GMA in living people, and noted that men who obtained higher honors degrees had a brain size 2%–5% bigger than those who did not.

The statistician Karl Pearson (1906) first studied Galton's data using the simple bivariate correlation coefficient (r), and computed that the value of r between brain size and GMA is $r = 0.11$, that is statistically not significant. Therefore, Galton's study was little supported by Karl Pearson. Spearman (1904, 1927) examined the various GMA items, and noted positive correlation of each subset, and also identified a general factor of IQ. National Collaborative Perinatal Project (Broman *et al.* 1975, 1987) data were collected separately by sex, and correlation for body size was not considered. Rushton and Ankney (2009) described the findings of 28 separate studies that applied brain computed tomography (CT) and imaging techniques such as magnetic resonance imaging (MRI) in a total of 1,389 normal individuals, where the range of correlations between GMA and brain was 0.04 to 0.69.

Note that for a bivariate data set, simple correlation coefficient does not establish cause, but, just as zero correlation provides no support for a hypothesis of cause and effect, while nonzero correlation does provide support. Most of the above stated studies were prepared adopting simple correlation coefficient, or percentage difference, or simple and multiple regression analysis. Note that any IQ data set is always a multivariate form. Therefore, for a multivariate data set, zero and nonzero simple correlation coefficient values do not prove cause and effect, while multivariate partial nonzero correlations do provide support. In addition, any IQ data set is physiological, so the response variable IQ is always heteroscedastic (Das and Ghosh, 2020). Therefore, usual multiple regression analysis provides inappropriate outcomes. Thus, all the previous IQ studies invite many debates and doubts. Best of our knowledge, there are a few studies regarding the association of FSIQ with physical characteristics, VIQ and PIQ, based on appropriate statistical modeling considering the non-constant variance in the IQ data set. The present report is organized as follows. The following section presents the materials & methods, and the subsequent sections presents respectively results, discussion and conclusion.

II. MATERIALS & METHODS

Willerman *et al.* (1991) surveyed an IQ data set of 40 students. Data description and collection method is clearly presented by Willerman *et al.* (1991), which is not restated herein. These scientists adopted MRI to measure the brain size of the study students, and considered subject body height & weight also. The above study was conducted at a large southwestern university. A simple random sample of size 40 right-handed Anglo introductory psychology students were selected. It was maintained that the selected students had reported no history of brain damage, unconsciousness, alcoholism, heart disease, or epilepsy. The study units (students) were taken from a larger pool of introductory psychology students with total Scholastic Aptitude Test Scores greater than 1350, or lower than 940. The randomly selected study units had agreed to accept a course requirement by maintaining the administration of four sub-tests (Picture Completion, Similarities, Block Design, and Vocabulary) of the Wechsler (1981) Adult Intelligence Scale-Revised. Following the University's research review board prior approval, selected study units MRI were required to receive prorated full-scale IQs of less than 103, or greater than 130. The selected study units were equally divided by IQ classification and sex.

Willerman *et al.* (1991) illustrated the IQ data set from the accepted 40 random study students on seven study variables such as FSIQ, PIQ and VIQ scores based on the four Wechsler (1981) subtests, sex (male=1, female=2), along with selected subject's total pixel count from the 18 MRI (MRI Count) scans, height (Height) in inches, and body weight (Weight) in pounds. The data set is neatly described by Willerman *et al.* (1991), which contains missing records for two study units. Thus, the two incomplete subjects are excluded in the present study. From the given data, one more new variable termed as body mass index (BMI) that is defined as BMI= Weight(kg) / Height(m^2) is included in the current study. For ready reference, the data set is presented in Table 2

Willerman *et al.* (1991) studied the correlation of PIQ on only the physical characteristics such as sex, brain size, height and weight. These researchers have not included VIQ and FSIQ along with the physical characteristics in studying the relationships of PIQ. They obtained a simple bivariate correlation coefficient between PIQ and brain size before and after controlling body size, respectively as for women r = 0.33 and r = 0.35, for men$r$ = 0.51 and r = 0.65, and for both gender together r = 0.51. Moreover, these researchers obtained the relationship of PIQ on physical characteristics using the usual multiple regression line, and obtained the multiple correlation R^2 =0.2949 and adjusted R^2=0.2327 (Willerman *et al.* 1991). These derived outcomes are not satisfactory, as both the R^2 and adjusted R^2 values are very small, concluding that the fitted model is not appropriate (Das and Ghosh, 2020; Das, 2021). For ready reference, the estimated usual multiple regression line of PIQ by Willerman *et al.* (1991) is as follows.
Estimated PIQ = 111.35 + 2.06 Brain - 2.73 Height +0.001 Weight.

III. STATISTICAL METHODS

Intelligence data sets are physiological, so they must be heteroscedastic (Das and Ghosh, 2020; Das, 2021). Moreover, they are continuous, positive and non-normally distributed, which can be analyzed by applying appropriate transformation, if the variance is stabilized with that transformation. In practice, variance is not stabilized always under some suitable transformation (Myers *et al.* 2002). Generally, a positive homogeneous and continuous random response variable can be modeled either by a gamma, or lognormal model (Firth, 1988). But for a non-constant variance random response variable analysis, joint generalized linear models (JGLMs) under lognormal and gamma models can be applied (Das and Lee, 2009). JGLMs is cleanly illustrated in the book by Lee *et al.* (2017). For ready reference, JGLMs under gamma distribution are illustrated very shortly in this section. Note that the response FSIQ is not fitted suitably under a lognormal model, so it is not reproduced herein.

JGL Gamma Models: HereFSIQ $= y_i$ say, isthe study positive & continuous response random dependent variable with non-constant variance (σ_i^2), and mean $\mu_i = E(y_i)$, satisfying $Var(y_i) = \sigma_i^2 \mu_i^2 = \sigma_i^2 V(\mu_i)$ say, where $V(.)$ is known as variance function, which has two elements such that σ_i^2 (free of mean changes) and $V(\mu_i)$ (depends on the mean changes), while $V(\cdot)$ 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 FSIQ 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 $g(\cdot)$ & $h(\cdot)$ are the GLM link functions related with the mean & dispersion linear predictors respectively, and x_i^t, w_i^t are the vectors of independent variables, related with the mean and dispersion parameters respectively.Maximum likelihood (ML) method is used to estimate mean parameters, while the restricted ML (REML) method is used to estimate dispersion parameters (Lee *et al.* 2017).

STATISTICAL RESULTS & GRAPHICAL DIAGNOSIS

Statistical results

The dependent variable FSIQ is modeled on the rest independent variables using JGLMs under the gamma distribution. Weight, height, BMI, PIQ, sex, brain size, VIQ are treated as independent variables, while FSIQ is treated as the response random variable that is heteroscedastic. The final, or the best JGLM has been taken based on the lowest Akaike information criterion (AIC) value (within each class) that minimizes both the predicted additive errors and squared error loss (Hastie *et al.* 2009, p. 203-204). The final FSIQ gamma JGLMs analysis results are displayed in Table 1.

In Table 1, it is derived herein that FSIQ is heteroscedastic random variable, and its mean is positively associated with VIQ (P<0.0001), PIQ (P<0.0001), and the joint interaction effect of VIQ and gender (VIQ*gender) (P<0.0001), while it is negatively associated with brain size (P=0.0003), gender (P<0.0001) and the joint interaction effect VIQ*PIQ (P<0.0001). Variance of FSIQ is positively associated with gender (P=0.0038), PIQ (P=0.0299), while it is negatively associated with brain size (P=0.0002) and VIQ*Gender (P=0.0002).

Final gamma fitted FSIQ mean ($\hat{\mu}$) model (Table 2) is

$\hat{\mu}$ = exp.(2.8545 + 0.0127 VIQ + 0.0122 PIQ - 0.0001 PIQ*VIQ - 0.0001 Brain size -0.0664 Gender + 0.0006 VIQ*Gender),

and the final gamma fitted FSIQ dispersion ($\hat{\sigma}^2$) model is

$\hat{\sigma}^2$ = exp.(7.631 + 0.010 VIQ + 8.882 Gender - 0.106 VIQ*Gender + 0.050 PIQ - 0.001 Brain size).

Table 1: Final Joint gamma model fitting of FSQ on PIQ, VIQ and others

Model	Covariate	Estimate	Standard error	t-value	P-value
Mean	Constant	2.8545	0.052271	54.61	<0.0001
	Verbal IQ (VIQ) (x2)	0.0127	0.000486	26.23	<0.0001
	Performance IQ (PIQ) (x3)	0.0122	0.000410	29.70	<0.0001
	VIQ*PIQ (x2.x3)	-0.0001	0.000004	-17.36	<0.0001
	Brain size (x6)	-0.0001	0.000001	-4.06	0.0003
	Gender (Fx9 2)	-0.0664	0.012875	-5.16	<0.0001
	VIQ*Gender (x2.Fx9 2)	0.0006	0.000101	6.21	<0.0001
Dispersion	Constant	7.631	5.351	1.426	0.1639
	VIQ (x2)	0.010	0.026	0.406	0.6875
	Gender (Fx9 2)	8.882	2.843	3.124	0.0038
	VIQ*Gender (x2.Fx9 2)	-0.106	0.026	-4.156	0.0002
	PIQ (x3)	0.050	0.022	2.276	0.0299
	Brain size (x6)	0.001	0.001	-4.172	0.0002
AIC		**88.749**			

Graphical diagnosis

The obtained joint generalized linear gamma fitted FSIQ (Table 1) probabilistic model is a data derived model that is tested using model diagnostic plots in Figure 1. Figure 1(a) reveals the absolute residuals plot for the gamma fitted FSIQ against the fitted values that is almost flat straight line except the right tail, concluding that variance is constant with the running means. Right tail is little decreasing as a lower absolute residual is located at the right extreme boundary. Figure 1(b) presents the normal probability plot for the gamma fitted FSIQ mean model (Table 1) that does not reveal any lack of fit. Therefore, Figure 1 does not reveal any discrepancy in the final gamma fitted FSIQ model (Table 1), and it shows that the fitted FSIQ model (Table 1) is very close to its unknown true model.

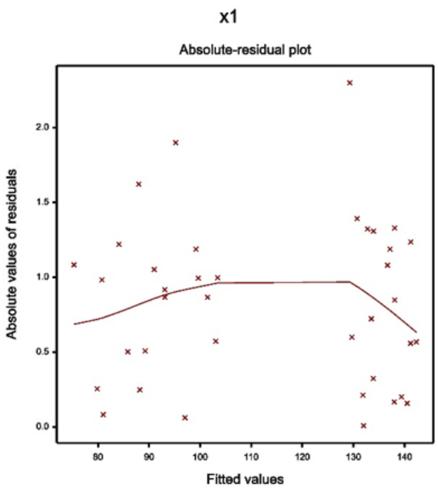

Figure 1(a)

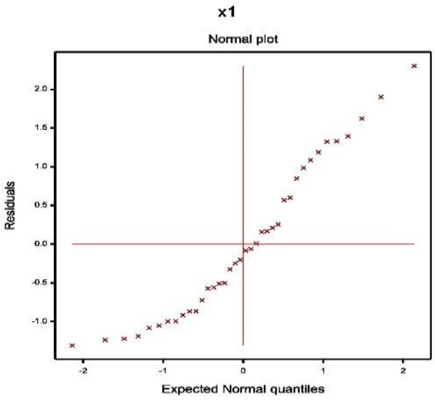

Figure 1(b)

Figure 1: For the joint gamma fitted models of FSIQ (Table 1), the (a) absolute residuals plot with respect to the fitted FSIQ values, and (b) the normal probability plot for the mean FSIQ model.

IV. DISCUSSION & CONCLUSIONS

Intelligence data sets are always a multivariate form, and the relationship between any two variables can be derived only by suitable modeling of the response (or dependent) variable on the independent variables. In addition, intelligence data sets are physiological data, so the response variance may be heteroscedastic always. Therefore, by applying only JGLMs of FSIQ, appropriate associations of it with other independent variables can be derived. Best of our knowledge, JGLMs of FSIQ on VIQ, PIQ and other physical characters are not studied in any earlier reports. It is expected that JGLMs of FSIQ can give all new outcomes in the IQ studies literature.

The obtained regression coefficient estimates of FSIQ fitting (in Table 1) have smaller standard error, indicating that estimates are stable. The final, or the best selected mean and dispersion models of FSIQ (in Table 1) have been accepted based on graphical diagnosis, smallest AIC value and smaller standard errors of the estimates. One can verify these results using the data set is given in Appendix. Best of our knowledge, the derived mean and dispersion models of FSIQ (in Table 1) are very close to its true models.

Table 1 gives the summarized FSIQ gamma fitted JGLMs analysis results. It is derived (in Table 1) that mean FSIQ is positively associated with PIQ ($P<0.0001$), or VIQ ($P<0.0001$), concluding that FSIQ increases as PIQ, or VIQ increases. Also, mean FSIQ is negatively associated with PIQ*VIQ ($P<0.0001$), implying that FSIQ increases as PIQ*VIQ decreases. These results indicate that even PIQ and VIQ are very high for an individual, but FSIQ is not so high, as their joint interaction effect is negatively associated. This helps psychologists to understand about the FSIQ of an individual based on PIQ and VIQ. Mean FSIQ is negatively associated with brain size ($P=0.0003$), concluding that FSIQ is higher for smaller brain size. It is completely a contradictory outcome related to PIQ (Rushton and Ankney, 2009; Das and Ghosh, 2020; Das and Chakratorty, 2021). Based on the present analysis, it can be concluded that FSIQ and brain size is negatively associated for every IQ data set. Mean FSIQ is negatively associated with gender (male=1, female =2) ($P<0.0001$), concluding that FSIQ is higher male than female. Also mean FSIQ is positively associated with VIQ*Gender ($P<0.0001$), concluding that FSIQ is greater for a female with higher VIQ than a man with higher VIQ.

Table2: 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

From Table 1, variance of FSIQ is positively associated with PIQ (P=0.0299), concluding that individuals with higher PIQ have highly scattered FSIQ. In other words, any individual with a higher PIQ may not have a higher FSIQ. Also variance of FSIQ is positively associated with gender (male=1, female=2) (P=0.0038), concluding that FSIQ is highly scattered in females than male. Variance of FSIQ is negatively associated with brain size (P=0.0002), concluding that individuals with smaller brain size have highly scattered FSIQ. In addition, variance of FSIQ is negatively associated with VIQ*Gender (P=0.0002), concluding that FSIQ is less scattered for females with higher VIQ than men with higher VIQ. Best of our knowledge, these outcomes are not reported in any previous article (Rushton and Ankney, 2009), they are completely new in the intelligence literature.

Intelligence literature and most of the recent findings on IQ studies can be obtained easily in the review articles by Rushton and Ankney (1995, 1996, 2007, 2009). Using percentage, simple bivariate correlation, partial correlation, and usual multiple regression analysis, it is not possible to derive the significant interaction effects that are associated with FSIQ. The present findings related to FSIQ can not be compared with any previous studies, as it has not been properly studied in any previous article. In Table 1, it is observed that the relationship of FSIQ is very complicated with the other explanatory factors. Mean and dispersion models of FSIQ (Table 1) show non-linear complicated relationships of it with the rest explanatory variables. Thus, all the earlier results related to FSIQ invite many debates and doubts.

From Table 1, it is concluded that FSIQ is independent of height, weight, BMI, but it depends on VIQ, PIQ, brain size and gender. It can be concluded that FSIQ is higher for the male people having higher VIQ, PIQ, lower interaction effect of VIQ*PIQ, smaller brain size and higher interaction effect of VIQ with gender.

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

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