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Construct Validity for the JobMatchLogic (JMLQ) Aptitude Performance Test

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Abstract

The present study, the purpose of which was to assess the levels of external and internal construct validity intrinsic to the new JMLQ recruitment instrument, involved three groups of participants: (I) that involving internal construct validity and consisting of 1025 individuals, of whom roughly 75 % were female and 25 % male, of a mean age of 44.7 years (II) that involving participants' educational level, consisting of 929 individuals, and (III) that consisting of participants' occupational level, consisting of 469 individuals. For this purpose, the status of 'Construct validity' issues of the JMLQ instrument was analyzed: (i) empirical analysis of the theoretical structure of the constructs, (ii) construct reliability, and (iii) associations between the constructs and the external objectives. It was observed that strong internal construct validity was assured by the high mean factor standardized loadings, measures of reliability, whereas the high external relationships between the JML factors and the 16pf dimensions and the invariant patterns of correlations between both the former and the latter all argue the case for strikingly high external construct validity. Furthermore, the results indicated that (a) low educational level (i. e. involving II), and (b) less specialized occupational level and prowess (i.e. involving III), had predicted successfully the lower accuracy and slower speed of performance, by "low-capacity" reasoners, in the JMLQ and 16pf tests of logical reasoning aptitude all of which may imply that "high-capacity" reasoners mobilize their 'deepest' or semantic levels of processing. Finally, Cronbach's alpha testing indicated satisfactory to good reliability values. These findings lend credence to the suitability of the JMLQ instrument for purposes of facilitating effective recruitment and imply central components relating to the highest levels of functional cognitive capacity.

Keywords: ***Cognition; JMLQ; 16pf dimensions; Construct validity; External; Internal; Higher-order factor model; Reliability; External relationships; Correlations; Educational level; Occupation; Logical reasoning; Levels of processing; Central components***

1. Introduction

'Rationality' and/or 'Logic aptitude' present notions, involving both intricacy and entanglement, that are traditionally associated with the realms of physical and social sciences, computing, chess, philosophy, and economy, as well as other scientific endeavors pertaining to the "intuitive rationalization for logical inferences" [1,2]. It was discussed previously [3], that the so-called 'intuitive' or 'Type I' processes, as opposed to so-called "deliberate" or "type II" engagement, may distinguish between "high-capacity" and "low-capacity" rationalizers, i.e., individuals, in estimating the cognitive performance difference phenomenon separating high-capacity from low-capacity individuals on reasoning/logic aptitude tasks [4,5]. In one logical reasoning study, it was observed that the high-capacity reasoners performed at higher levels for logic/statistics than they did for belief judgments when these two types of material were conflicted, whereas the opposite situation was observed for the low-capacity reasoners. It was shown recently that, in the case of the "high-capacity" reasoners, statistical information, i.e. that type oriented towards the collection, storage, transformation and distribution, obstructed the subjects' capacity to present 'belief-based' judgements implying that for these individuals the application of probabilities may have caused greater intuitiveness than that of stereotypic assumptions [6]; thus, the expanse of prevailing accuracy-capacity relationships that are 'part-and-parcel' of reasoning may be seen as the aftermath of these subjects' intrinsic "intuitive", or "Type I", processing predisposition.

Nevertheless, several lines of evidence indicate that those processes adapted to present 'probabilistic inferences' ought to be less subject to variation than those processes applied to make inferences concerning logical validity [7].

It seems to be case that the direct and indirect relationships between word problem solving, logical reasoning, inference making, and reading comprehension skills may contribute to the performance of logical aptitude testing. It was shown also that reading comprehension affects a partial mediating role in the relationship between logical reasoning and word problem-solving supported by positive correlations between word problem solving and logical reasoning skills presupposing that those activities intended to improve word problem-solving performance ought also to be supported by logical reasoning and inference making-related activities [8]. Aptitudes present components of a competence(s) to perform certain tasks at certain levels, whether physical or psychological, with outstanding aptitude considered a "talent", the inborn potential to perform these tasks whether developed or undeveloped.

Contrastingly, skills present acquired abilities that are developed through learning and diligence, i.e., the learned ability to perform actions with determined outcomes entailing good execution often within a specified amount of time, energy, or both. Skills can often be divided into "domain-general" and "domain-specific" skills; both aptitude and skill contribute to cognitive performance [9]. The notion of "levels of processing" in cognitive psychology [10] may offer a conceptual backdrop to individual performance in logical aptitude testing through reference to a series of processing hierarchies whereby the 'shallower', or perceptual, processing level renders perception to the physical and sensory characteristics of the stimulus material.

On another level, the 'deepest', or semantic, processing is associated with pattern recognition and meaning-extraction with the weight of emphasis upon semantic analysis rather than 'shallow' processing and therewith a deeper level of abstract thinking [11].

Other studies have converged upon understanding cognitive performance of logic mathematics amongst young college-attending Chinese students' performance on a test battery consisting of advanced mathematics and a battery of seventeen cognitively oriented tasks utilizing basic numerical processing, complex numerical processing, spatial abilities, language abilities, and general cognitive processing [12]. It was shown that their spatial abilities were significantly correlated with the subjects' performance in advanced mathematics, after controlling for other factors. In addition, certain language abilities, for instance the comprehension of words and sentences, rendered unique contributions to their findings too. Contrastingly, the levels of basic numerical processing and computation were not generally correlated with performance in advanced mathematics [13]. In this context, among a population of young adult medical students several characteristics of logic reasoning ability were presented, such as taking control of events, recognizing and responding to relevant information concerning issues, specifying signs and symptoms, asking specific questions that focused upon the pathophysiological thinking and etiology, placing each question in its logical order, checking for agreement with patients, as well as summarizing conclusions and body language [14]. They found that to the students the patients' acts and the course, the results and efficiency of the conversation were identified as indicators of clinical reasoning, whereas context, using self as a reference, and emotion/feelings were identified by the clinicians as variables in their assessment of clinical reasoning.

The JobMatchLogic Aptitude (JMLQ), a new test instrument introduced recently, presents a recruitment instrument designed to estimate potential cognitive performance within the scope of logic aptitude and intelligence estimations; thus, the JML test requires an analysis of construct validity. In a previous study [15], it was found that the correlations between "Correct answers" and "Time to answer" were, to the greater extent, both high and in the negative direction (-0.60 to -0.89), which implied that the "correct answers" related strongly with the shorter intervals within the "time to answer", thereby rendering the conclusion that high cognitive performance was associated with a higher rate of responding (i.e. quicker responses). Central to its endeavors, the processing of rational reasoning within cognitive tasks of complex demands is required. In this context, the responses of "high-capacity", as opposed to "low-capacity", reasoners, applying the accuracy-capacity relationship observed in reasoning occurring as a consequence of the "intuitive" or "Type I" processing propensity, is expected to produce both higher levels of accuracy combined with a greater rate-of-processing (more speed) in cognitive performances thereby presupposing the 'deepest' or semantic levels of information processing. Both construct and discrimination validity are necessary determinants of the eventual utility of instruments applied in psychometric research, particularly with regard to logic and reasoning ability [16].

Construct validity was analysed through the application of a "higher-order factor model" with a general factor; note that the General factor did not influence single items directly but rather that is occurred through lower-order factors (see text). External construct validity refers to the extent to which the outcome of a particular study may be expected to apply to other settings, i. e. the generalizability of the findings; in this context, ecological validity may construe a not negligible aspect of external construct validity. Internal Validity refers to those factors that are the reason for affecting the dependent variable and is assessed through estimation of loadings, normality of distribution, and sufficiency of the second-order factor.

In the present study, the presiding status of 'Construct validity' issues pertaining to the JMLQ instrument was analyzed through three approaches:

i. An empirical analysis of the theoretical structure of the presented constructs.

ii. the caliber of the presented construct reliability.
iii. the associations between the constructs and the external objectives.

The first two aspects of analysis may be labeled as 'internal' aspects of

'Construct validity', and the final one as 'external' aspects. Thus, one major aim of the present study was to assess the level of external construct validity intrinsic to the JMLQ recruitment instrument through methods including the analyses of ‘internal’ features, e. g. factor structure, as well as corresponding estimations of reliability. Additionally, the relationships between JML categories and ‘external’ issues were investigated also.

2. Method and Materials

2.1 Participants

Participants were recruited by use of two social networking services. Invitations were sent to specific groupings in LinkedIn and Facebook. In all, 1,025 participants were included in the study. Almost 75 % of these were female participants who took part in the study, and 25 % male participants. The mean age was 44.7 years (SD=12.6) with the female participants being somewhat older. In addition, most of the participants reported their educational level (N=926), and about half as many (N=469) stated their occupational orientation.

2.2 Instruments

The JMLQ instrument presents the five main categories:

I. Complex Cognition: The person’s ability to understand complex ideas and information.
II. Mathematical understanding: The person´s general understanding of mathematics principles.
III. Numeric understanding: The person´s general understanding of numbers based on basic arithmetic’s.
IV. Logical reasoning: The individual’s ability to make inference-based conclusions.
V. Va. Cognitive Processing Speed: The speed in which the person can understand and react to information. Vb. Cognitive Processing Speed2: This category differs from Speed by having a mix of Numerical and spatial items (whereas Speed only consists of spatial items).

The 16pf dimensions of inference ability (Logical, Verbal, Numerical) presents more illustrative features than verified psychometric factors. Nevertheless, for the purpose of the present study, these dimensions were deemed suitable for comparative purposes.

2.3 Design and statistical procedures

The 'internal' analyses were based on a second-order factor model, following a classical model of aptitude testing. The General factor influenced the observable items (in all, 77 items) by full mediation via the four lower-order factors, which between themselves were noncorrelated.

The items for each JMLQ factor were binary (true/false). For binary observed dependent variables, probit regression was used to estimate factor loadings. Probit regression, which is also referred to as the probit model, is applied to model dichotomous or binary outcome variables. In the probit model, the inverse standard normal distribution of the probability is modeled as a linear combination of the predictors. The latent factors were related to items by a probit link. A WLSMV estimator (weighted least square parameter estimates using mean- and variance- adjusted chi-square test statistic) was applied for estimation of the confirmatory factor analysis (CFA) model.

Estimations of the model were performed through regression coefficients. Model-fit is expressed in the table (TABLE 1). Model fit was controlled with the following measures. The Chi-square value was reported, as well as the 'normed' Chi-square value (divided by degrees of freedom). Furthermore, approximate fit indices were accounted for. These indices were CFI (comparative fit index), TLI (Tucker-Lewis index, an incremental fit index), RMSEA (root mean square error of approximation) and SRMR (standardized root mean square residual). Suggested cut-off values for CFI and TLI were close to .95, for RMSEA 0.05, and for SRMR 0.08 [17].

Furthermore, two measures of reliability were reported: AVE (Average Variance Extracted) and CR (Composite reliability, [17]). Also, Cronbach’s alpha was computed with use of observed items for each JML category.

INDIVIDUAL JMLQ-scores: for all the latent factors the individual (true) JML-scores were calculated. These z-values for General facto rare presented in the histogram (see FIG. 2).

RELIABILITY: the factor-model reliability was calculated through application of the factor-loadings (see TABLE 2). If the reliability is acceptable, then the factors are related to the external criteria. The ‘external' construct validity analyses were based upon correlations between the JMLQ and the 16pf dimensions (logical, verbal, numerical) that related to inference ability. Moreover, comparisons of 'extreme' groupings (low vs high expected performance on the JMLQ), associated with educational levels and with occupational orientation, were analyzed.

For education, a low level (upper secondary school) was compared to a high level (university, 5 years, or more). In a similar manner, a grouping with relatively low anticipated JML outcome (Care, Manual work, Service/support, Allround) was compared to another grouping of higher-level educational development (Specialist, IT/Technics) with anticipated scores.

EXTERNAL RELATIONS: the analysis of construct validity was performed through assessment of the relationship between the model’s factors and three types of external criteria (shown in FIG. 3, and TABLE 3 and 4).

The statistical analyses were performed with Mplus (version 8.5) and SPSS (version 26).

3. Results

The standardized factor loadings for the lower-order factor were relatively high, and as expected were even higher for the higher-order general factor. The means of factor loadings ranged between about 0.50 to 0.70. It should be noted that loadings for the Complex and Logical factors were lower compared to the Mathematical and Numerical values.

Thus, the items for Complex and Logical, were more difficult to predict, than were the others (see FIG. 1).

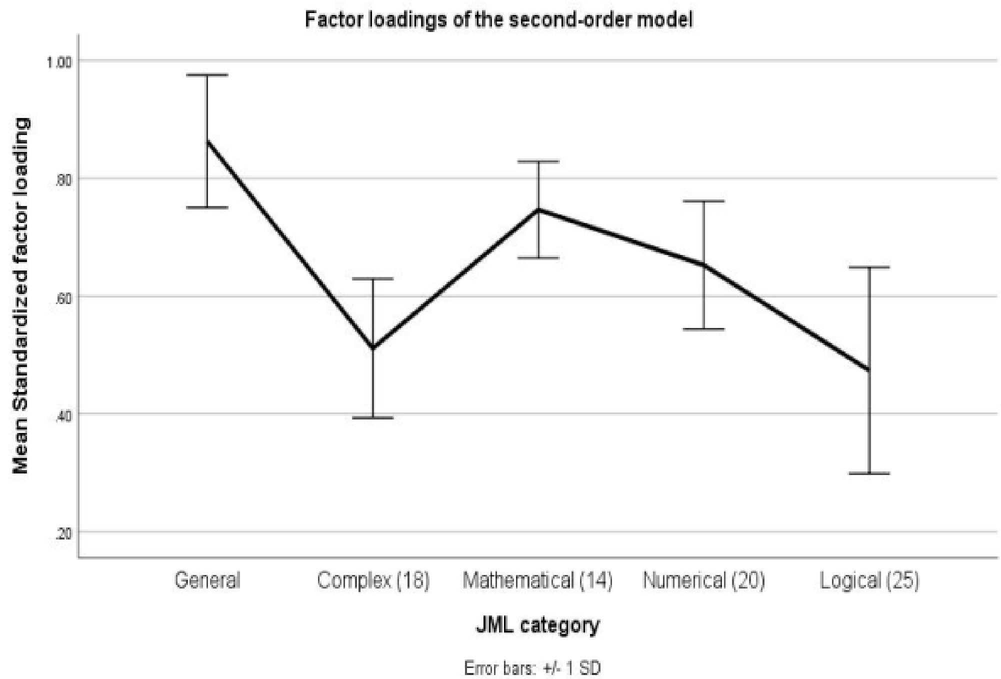

FIG. 1. **Mean size of standardized factor loadings for the second-order factor model of the JMLQ (N=957). Note that the numbers of observable items for each lower-order latent factor are reported. Moreover, error bars include about two thirds of the factor loadings.**

Model fit for second-order factor model was concluded to be sufficient-to-good. It should be emphasized that the normed Chi-square value was fairly close to 1. See TABLE 1, for a detailed overview.

TABLE 1. **Model fit for the second-order factor model of the JMLQ.**

Measure	Value
Chi-Square Test of Model Fit (df=2845)	3856.687
'Normed' Chi-Square Test/df	1.356
RMSEA	0.019
90% CI	0.018 - 0.021
Probability RMSEA <=.05	1.000
CFI	0.956
TLI	0.955
SRMR	0.075

RMSEA=Root Mean Square Error of Approximation;

CFI=Comparative Fit Index; **TLI**=Tucker-Lewis Index;

SRMR=Standardized Root Mean Square Residual. In addition, the distributions of all latent factors were strictly normal. See FIG. 2 with z-scores for the General ability.

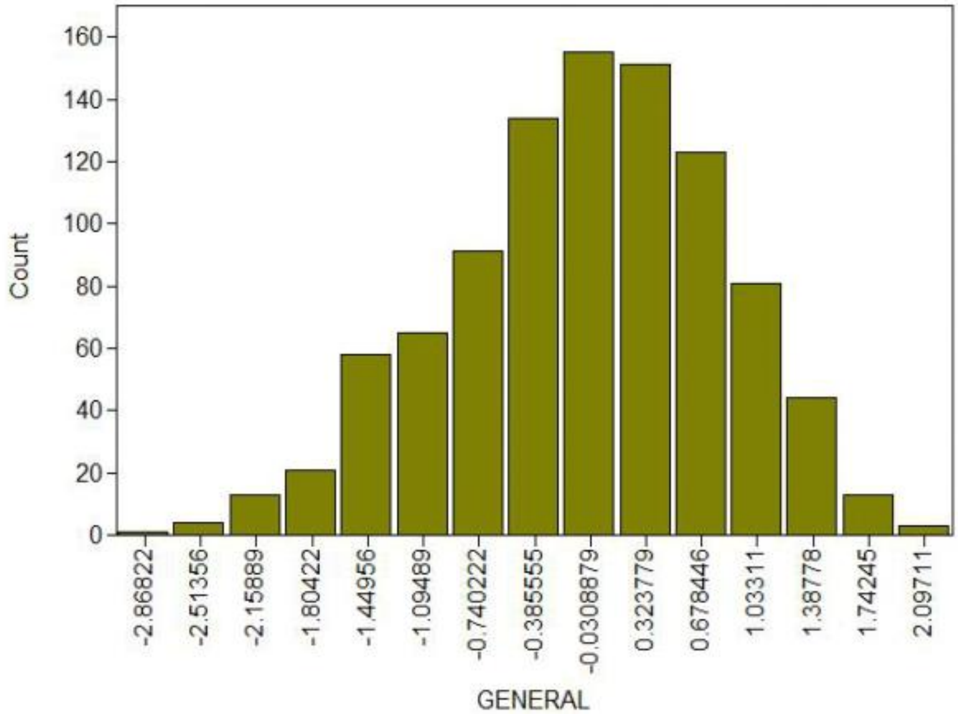

FIG. 2. **Histogram presenting the z-scores for the General JMLQ factor (N=957).**

The measures of reliability were high for the Average variance extracted (AVE) and the Composite reliability (CR). The Cronbach's alpha values ranged between 0.72 and 0.88 for the factors included in the CFA. Values were lower for the Speed factors. Nevertheless, it should be noted that the alpha value for Speed2 was close to 0.70. For further information, see further in TABLE 2.

TABLE 2. **Measures of reliability based on internal consistency, and on second-order model factor loadings (CFA) of the JMLQ (N=957- 60).**

Constructs	**n items**	**CA/CA-std**	**AVE**	**CR**
GENERAL	(4 LVs)	0.815/.843	0.863	0.962
Complex	18	0.752/.752	0.511	0.949
Mathematical	14	0.876/.878	0.747	0.976
Numerical	20	0.827/.832	0.653	0.974
Logical	25	0.717/.743	0.474	0.956
Speed	11	0.555/.581	-	-
Speed2	12	0.657*/.683**	-	-

JMLQ=JobMatchLogic; **CFA**=Confirmatory Factor Analysis;

LV=latent variable; **CA/CA-std**=Cronbach's alpha, and standardized alpha, respectively;

AVE=Average Variance Extracted; **CR**=Composite reliability.

*Note**. Observed alpha=0.657 (N=960; number of items=12) gives two-tailed p=0.006 against alternative alpha of 0.70 with a 95% confidence interval from 0.624 to 0.688.

*Note***. Observed alpha=0.683 (N=960; number of items =12) gives two-tailed p=0.257 against alternative alpha of 0.70 with a 95% confidence interval from 0.653 to 0.712.

The external relationships between the JMLQ factors and the 16pf dimension ranged between 0.30 to 0.60. It should be noted that both the four 'basic' and the three 'generated' JML factors were included in this correlational analysis. Moreover, the invariant pattern of correlations was striking. Differences in correlations for 16pf dimensions were fairly intact across the JMLQ categories. However, there was one minor exception. Speed2 increased unexpectedly for Logical (16pf). See FIG. 3, for an overview.

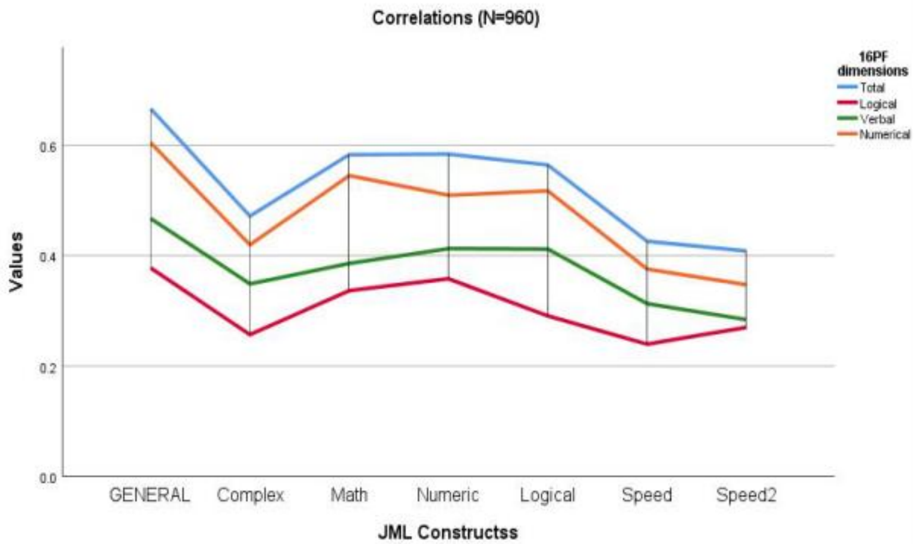

FIG. 3. **Correlations between the JMLQ constructs, and dimensions of inference ability for the 16PF (N=960).**

The assumptions about JMLQ outcome for low vs high educational level were all confirmed (p<0.05). See TABLE 3 (below), for a detailed overview.

TABLE 3. **t-test of differences between low vs high expected test scores related to education (N=436).**

						95% Cl of the Difference	
	Mean Difference	**Std. Error Difference**	**t**	**df**	**Sig. (2-tailed)**	**Lower**	**Upper**
GENERAL	-.09	.016	-5.61	339.829	.000	-.122	-.059
Complex	-.04	.02	-2.053	407.624	0.041	-.081	-.002
Math	-.17	.026	-6.655	332.201	.000	-.22	-.12
Numeric	-.10	.016	-6.122	319.037	.000	-.13	-.067
Logical	-.05	.014	-3.552	357.797	.000	-.079	-.023
Speed	-.05	.016	-2.993	368.802	.003	-.078	-.016
Speed2	-.04	.012	-3.563	272.193	.000	-.066	-.019

A similar result was found for low vs high expected JMLQ outcome for selected groupings of occupations. All differences were significant (p<0.05), but with one exception. For Speed, the difference was significant at p=0.081.

TABLE 4. **t-test of differences between low vs high expected test scores related to type of occupation (N=206).**

						95% Cl of the Difference	
	Mean Difference	Std. Error Difference	t	df	Sig. (2-tailed)	Lower	Upper
GENERAL	-.12	.021	-5.869	180.192	.000	-.164	-.082
Complex	-.12	.029	-3.994	129.013	.000	-.176	-.059
Math	-.20	.032	-6.288	199.765	.000	-.268	-.140
Numeric	-.12	.021	-5.875	198.457	.000	-.164	-.082
Logical	-.05	.019	-2.469	141.848	.015	-.085	-.009
Speed	-.04	.021	-1.755	139.439	.081	-.077	-.005
Speed2	-.05	.013	-4.003	206.939	.000	-.080	-.027

4. Discussion

The present findings concerning aspects of construct validity of the JMLQ instrument may be summarized as follows: (i) They support the conclusion of a strong internal construct validity, with high mean factor standardized loadings obtained for General, Mathematical and Numerical (>0.60), whereas that for Complex and Logical were somewhat lower (>0.40 but <0.60), implying that the latter constructs appear less facilitatory for prediction than the former. Yet, for the second-order factor the model was sufficient-to-good. Additionally, the distributions of all latent factors were strictly normal, all of which provided further support for internal construct validity. (ii) Further support for internal construct validity accrued from the measures of reliability which were high for the AVE and CR, with Cronbach's alpha values ranging between 0.72 and 0.88 for the factors included in the CFA. (iii) The external relationships between the JMLQ factors and the 16pf dimension ranged between 0.30 to 0.60, with Cronbach's alpha values ranging from between 0.72 and 0.88 for the factors included in the CFA, although the Speed factor vales were lower (ca. 0.70). (iv) The external relationships, subsuming the level of external construct validity, between the JMLQ factors and the 16pf dimension ranged between 0.30 to 0.60 wherein ought to be noted that both the four 'basic' and the three 'generated' JMLQ factors were included in this correlational analysis. Remarkably, there was a striking invariant pattern of correlations with fairly intact differences in the correlations for 16pf dimensions. Differences in correlations for 16pf dimensions were fairly intact across the JMLQ categories with the minor exception of Speed2 which increased unexpectedly for Logical (16pf). (v) The assumptions about JMLQ outcome for low vs high educational level, as well as for type of occupation (with the exception of Speed, only significant at the 0.081 level), were all confirmed. Thus, the expectation that lower levels of education and lower levels of educational specialization would be associated with lower logical reasoning aptitude received undeniable support.

One precept concerning the informational processing of rational and logical reasoning within cognitive tasks designed to assess performance pertained to the expectation that the responses of "high-capacity", as opposed to "low-capacity", reasoners, applying the accuracy-capacity relationship observed in reasoning that would be observed as a consequence of the "intuitive" or "Type I" processing propensity, and was expected to produce both higher levels of accuracy and higher levels of Speed than for the "low-capacity", i.e. "deliberate" or "type II" individuals. By this line of reasoning, the results ought to have indicated that (a) low educational level, and (b) less specialized occupational prowess, would predict lower accuracy and slower speed of performance in the JML and 16pf tests of logical reasoning aptitude. In this regard, using Inductive Reasoning Test for Children (IRTC), Muniz et al., [18] found, in addition to appropriate reliability by internal consistency, the sensitivity of IRTC in showing differences in the performance of students attending from the early to the late grade levels similar to the 'levels-of-education' result discussed above. Unsurprisingly, semantic processing yields higher levels of recall than orthographic and phonological processing congruent with a 'depth-of-processing' notion [19]. The present result, obtained unequivocally and indubitably, appear to render evidence of broader generalizability in the context of logical aptitude and its performance relationships to skills whereby higher levels of education (see TABLE 3) and greater specialization of occupations (see TABLE 4) demonstrated a decided reinforcement of aptitude with skills (see above). Thus, higher level of education, on the one hand, and occupational specialization, on the other hand, would appear to have enhanced the "intuitive" or "Type I" processing propensity. Furthermore, high mean factor standardized loadings, measures of reliability, the high external relationships between the JMLQ factors and the 16pf dimensions and the invariant patterns of correlations between both the former and the latter all argue the case for strikingly high internal and external, respectively, construct validity.

Relationships between the spatial, linguistic, and arithmetical capacities of individuals remain issues that challenge resolution [20]. In order to elucidate this conundrum, an empirical quest that implicated logic, language, and arithmetic components that consisted of three stages: (a) a functional step involving neurobehavioral and neuroimaging substrates that focused on the distinctiveness of linguistic, logical, and numerical functioning among a group of healthy subjects [21], (b) an anatomical step comprising the neuroanatomical properties of an implicated cortical area from a series of postmortem brains, microstructure-analysis, and the derivation of a three-dimensional, cytoarchitectonic map, and (c) the eventual integration of neuroimaging and microstructural evidence that showed high extents of overlap between the neuroanatomical and the functional components, implying a unit of functional brain anatomy [21]. Taken together, these studies [22] define the congruence between the histologically- and functionally defined brain regions over multiple measures through the positioning in the left anterior insula implying a mediatory role between language and reasoning areas.

In a meta-analysis study taking into account the findings of 32 neuroimaging experiments concerning logical reasoning, subdivided over structure, content, and requirements for world knowledge, the neurocognitive mechanisms involved in reasoning functions were resolved and there were shown conspicuous distinctions between the type of task and its content [23]. Finally, it has been observed that sensory regions of the brain that are activated during the primary perception assessment appear to be reactivated during subsequent retrieval with concurrent activation in the frontal and medial-temporal regions of the brain associated with the depth of information processing and achieved level of memory performance thereby offering evidence supporting the role of central brain components within the levels-of-processing framework [24].

5. Limitations

All observed variables were binary (true, false), while the generated latent variables were continuous. For such an analytical approach, the estimates are generated through application of Item Response Theory (IRT) which is appropriate to be reported. However, in this particular study this was not carried out. Diagrams such as ICC (item characteristic curves) and IIC (item information curves) will be reported in a coming study.

6. Conclusions

The higher levels of internal construct validity obtained for General, Mathematical and Numerical compared with Complex and Logical may relate to deeper, semantic, levels of processing, with the Speed factor presenting a somewhat 'shallower' level. Nevertheless, the higher Cronbach's alpha values of the former five factors imply satisfactory-good reliability, throughout.

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8. Contributors

All contributed equally to this manuscript and approved its final version of the manuscript

9. Conflict of Interest

The authors declare no conflict of interest.

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