Measuring Intelligence by Raven Standard Progressive Matrices Test: A PCA Approach

Dr. Shaista Ismat[1]
Dr. Junaid Saghir[2]

Abstract

There are many ways to measure the intelligence, especially when it comes to measuring through multidimensional scaling. This study examines the nonverbal abilities of the individuals using Raven Standard Progressive Matrices (RSPM) test. RSPM is a nonverbal culture fair test that identifies nonverbal reasoning abilities. It has 60 visually presented geometric-parallel-like problems based on five sets, having 12 items in each set. The tool was administered collectively (group-class) to a representative sample of 267 adolescents (both boys and girls) studying at higher education institutions in Pakistan. The sample was drawn from two public sector universities. The data was analyzed through descriptive statistics and principle component analysis (PCA) to extract nonverbal abilities. The results indicate that 25% participants have secured 60% or less tests scores, 50% participants have secured 73% or less tests scores, and 25% participants secured more than 81% tests scores. It is also found that participants have very sound intellectual capacity and nonverbal reasoning abilities which is generally identified as fluid intelligence and it is correlated with measures of abstract reasoning, puzzle solving, problem solving, learning and pattern recognition. Principle component analysis has revealed the grouping of the individuals and the common factor that affects the performance of the participants.

Keywords: Fluid intelligence, intelligence measure, RSPM

1. Introduction

Intelligence is an underlying concept and a latent variable, therefore, cannot be measured directly. However, literature suggests that it can be measured by a variety of tests available which are applied at different levels to capture the individual scores and are used as an indirect measure of intelligence. It is also evident that the assessment of intelligence requires good measurement instruments considering purpose, level of participants, IQ scores and maturity of respondents. Intelligence tests as described by Demirtasli (2002) are psychometric instruments, consisting of standardized questions and tools for assessing the potential of an individual in a given domain or for a particular ability. These are designed specially to measure complex mental abilities of young and adults; and the designing of these tools requires deeper understanding of metal capabilities of respondents based on age, educational background, language, and culture. A careful analysis is needed to extract the findings, controlling diverse threats to reliability, and ensuring internal and external validity of the tool. In practice, there are lots of suitable measurement instruments are available on the basis of verbal scales like: information, digit span, vocabulary, comprehension, similarities; and non verbal scales like: picture completion, picture arrangement, block design, object assembly, digit symbol etc. (Wechsler 1981).

In this study intelligence is measured on the basis of nonverbal scale developed by Raven's Standard Progressive Matrices (RSPM) test items by using statistical procedure principle component analysis. RSPM test is a nonverbal culture fair test that was developed by Raven

[1] Dr. Shaista Ismat is Professor at FUUAST, Karachi, ismat_shaista@yahoo.com
[2] Dr. Junaid Saghir Siddiqui is Professor at Karachi University, jssdr123@yahoo.com

in 1939. RSPM test measures the ability to extract and understand information from a complex situation (Raven, Raven, & Court 1998), and is widely used as a test of nonverbal reasoning ability. This ability is generally identified as fluid intelligence (e.g., Caroll 1993; Jensen 1998; McGrew & Flanagan 1998). Fluid intelligence exhibits the psychobiological capacity of the individual to acquire knowledge whereas reasoning processes are an important part of this ability. Fluid intelligence generally correlates with measures of abstract reasoning; puzzle solving, problem solving, learning and pattern recognition. This test is also used as a general intelligence test in the world (Demirtasli 2002). It is a standardized intelligence test that consists of visually presented parallel geometric problems in which both sections A and B contain 12 matrices with a dimension of 2x2, while the sections C, D, and E contain 12 matrices with a dimension of 3x3. Section A involves simply filling in the missing part of an image; later sections require more abstract reasoning. The correct missing entry must be selected from a set of six possible answers from the 2x2 matrices, or a set of eight possible answers in case of 3x3 matrices. Standard progressive matrix (SPM), therefore, assesses the ability to make new insights and information out of already perceived or existing knowledge, which is a necessary ability to extract meanings out of a state of confusion or during solving multifarious puzzles.

Principle component analysis (PCA) a statistical technique, developed by Pearson and Hotelling, is concerned with explaining the variance-covariance structure of a set of 'p' variables through a few 'k' linear combinations known as principle components of these variables. Its general objectives are data reduction and interpretations. There is almost as much information in the k principle components as there is in the original p variables. The k principle components can replace initial p variables and the original data set (Johnson & Wichern 2006).

2. Literature Review

Raven's progressive matrices were initially developed with an intention to capture genetics and environmental determinants related to measuring intelligence of a person (Raven 2000). The basic purpose of development of these matrices was to help in conducting and interpreting these tests among the participants of different ages and culture. Raven (2000) argued that there are two main components of general cognitive ability, known as 'g'; first is eductive ability which is directly related to the capability of drawing meanings from the confusion and handling complex schemas; while the second is reproductive ability which is concerned with absorption, recall and reproduction of general information. There are several versions of Raven tests available which are applied in myriad situations; and work is widely accepted by various researchers like Styles and Anbdrich (1997), Deary (1995) and Stough (1996). Various studies conducted by using Raven tests show that the tests are consistent over different cultures and ages; however, not consistent over time (Raven 2000).

Over last few decades, there has been a debate regarding the true measurement of SPM. The debate revolves around whether the SPM is a true measure of 'g' or it also measures some aspects of visualization or spatial ability. Jenson (1998, p. 541) argued that "total variance of Raven scores in fact comprises virtually nothing besides 'g' and random measurement error." It was further endorsed (Raven, Raven & Court 2000, p. 34) as "the progressive matrices have been described as one of the purest and best measure of g or general intellectual functioning." But it is not universally accepted that these tests are a pure measure and not accounting for spatial and other abilities related to visualization. Van der Ven and Ellis (2000) concluded this debate as "[the] SPM contains two significant factors which they identified as (1) Gestalt continuation present in early time for which the correct solution must be found according to some Gestalt continuation rule…, and (2) analogical reasoning, present in later items" (Lynn, Allik & Irwing 2004, p. 412).

Gabriel and Vernon have also contested that the SPM is largely a pure measure of general cognitive ability 'g' but also contains a small spatial ability factor (Demirtasli 2002). Gustaffson (1984, 1988) contended that the SPM has a reasoning factor and another factor that he labeled as cognition of figural relations. Van der Ven and Ellis (2000) concluded that the RSPM have Gestalt continuation. Gestalt continuation is a visual perception law that says human brain try to organize information and make meaningful order from what we see. Gestalt psychologists assume that brain does not prefer sudden changes in the movement of a line. In other words, the brain seeks a smooth continuation of a line as much as possible. Demirtasli (2002) was investigated the order of item's difficulty indexes of RSPM according to classic test theory and Rasch model; this study showed that difficulty estimation of RSPM's items were ranked from the easiest to the hardest. Lynn and Irwing (2004) completed a meta-analysis investigating sex differences on the progressive matrices. Lovett, Forbus and Usher (2010) introduced a structure-mapping model of RSPM as more advanced model, consisting of four most complex sections of the test. Earlier (Lovett, Forbus, & Usher 2007), described the same model by only using two sections of the SPM test.

Rushton, Skuy and Fridjhon (2002) have used RSPM to highlight Jensen Effects among engineering students in South Africa based on African, Indian and White races. Their claim was that a bimodal distribution exists in African population which in fact is not distinguishable in Whites. There was a significant difference in terms of g, general factor of intelligence among African, Indian and White students, although there was no difference among those students in terms of gender and races. Earlier studies (e.g. Jensen 1980; Osborne 1980 & Rushton 1998) also tested the Jensen Effect and proved that there is a difference among the races like black-white, in terms of general intelligence by using SPM.

There are many versions of SPM, like colored and advanced versions etc. Using a particular test to a certain type of participants is essentially required before validating the results obtained from these tests. Raven (2000) posited that "it is important to note that the SPM was, from the start, known to have both certain strengths and limitations. Its strengths were that it could be used with the respondents of all ages from early childhood to old age and was such a length that it could reasonably be administered in homes, schools, and workplaces (where time is necessarily limited) as well as in laboratories … it had limited discrimination at the upper and lower levels. This was overcome by developing Advanced Progressive Matrices (APM) and Coloured Progressive Matrices (CPM) tests for use among the more and less able, respectively" (p. 4).

3. Research Methodology

The SPM (1338) test was administered collectively (group-class) in Karachi to a representative sample of 268 adolescents, including boys and girls both through gallop survey. The ages of participants ranged from 17 to 25 years, belonging to graduate and postgraduate levels. The sample was drawn from two public sector universities in Karachi having multiple departments. Data was collected over a period of three months. The test was administered in different departments like: Statistics, Physics, Mathematics, Business Administration, Computer Science, Microbiology and Chemistry, without any time limitations so that this could allow the researchers to asses intellectual capacity without the interruption of speed in completing the task. The test scores of 60 items have been analyzed using the MINITAB for descriptive statistics and for principle component.

Table1: Descriptive Statistics for RSPM Test Scores

Test items	Mean	Median	Q1	Q3	Skewness	Kurtosis
A	10.97	12	11	12	-3.28112	14.30137
B	9.843	11	9	12	-1.58759	2.631928
C	8.172	9	7	10	-1.04384	1.036164
D	8.507	9	7	10	-1.19733	1.345288
E	4.679	5	2	7	0.34004	-0.71309
Total Score	41.877	44	36.25	49	-1.17649	1.68752

The above-mentioned table presents the descriptive analysis of all test sets (A to E) and total score, showing mean, median, upper and lower quartiles, skewness and dispersion.

Furthermore, analysis is conducted by using PCA to extract the factors from the data and it is found that there are five significant factors that are contributing towards the most of variance in the data. The Eigen values analysis of these components is given in the following table.

Table 2: Eigen Analysis of the Correlation Matrix for SPM Test Scores

Variable	PC1	PC2	PC3	PC4	PC5
A	0.379	0.787	0.412	-0.07	0.248
B	0.470	0.237	-0.437	0.334	-0.648
C	0.476	-0.235	-0.334	0.379	0.68
D	0.482	-0.202	-0.18	-0.833	-0.032
E	0.42	-0.478	0.703	0.215	-0.233
Variance	2.7873	0.7614	0.5885	0.436	0.4269
Proportion	0.557	0.152	0.118	0.087	0.085
% Of total	55.7	70.9	82.7	91.5	1

4. Discussion

Table 1 exhibits the information about the descriptive statistics, therefore, mean of the test scores is =10.97 and the standard deviation of the test score is s=1.76 in the 12 items of set A, since mean is very high, showing this task is very easy to respondent, but each progressively harder than the last, because the mean scores of the students in set E are showing very low. Demirtasli (1995), Lovett, Forbus, & Usher (2007) also investigated RSPM's items were ranked from the easiest to the hardest according to classic test theory and Rasch model. The entire RPM test which has 60 items, the median of total scores is 44 showing that 50% student secured less than 73% it seems that intellectual capacity is very sound, first quartile Q1 = 36.25 showing 25% student secured 60% tests scores, third quartile Q3= 49 showing 25% student secure more than 81% tests scores. Over all result shows 75% student of Karachi University as well as Federal Urdu University as having very sound intellectual capacity and nonverbal reasoning abilities, which generally identifies fluid intelligence and it correlates with measures of abstract reasoning, puzzle solving, problem solving, learning and pattern recognition, Cattell (1971). According to Gestalt continuation theory, students which have very strong visual perception their brain seeks as much as possible a smooth continuation of a line, indicating that these students are suitable for professions like interior designing, graphic designing and music. When graphic designers are laying out advertisements, posters, or even business cards, they lay out the information and graphics in such a way that readers follow the lines of the layout. When professional musicians

organize their musical expressions without breaking the rhythm, they too, conform to the law of continuation (Behrens 1984; Mullet & Sano 1995; Moore & Fitz 1993). It also exhibits that, items in section A have very large kurtosis >3, implicitly that the test results being highly concentrated around the mean, and the variations within the test results of 268 student are low, showing most of the student secure same test scores. The nonverbal abilities of the student for item A are strong. But items   B, C and D give kurtosis < 3, indicating that the distribution of scores have a large spread, that shows a platykurtic distribution. While a low kurtosis distribution has a more rounded peak and shorter thinner tails.

Table 2   Exhibits the first PC which is denoted by U1 where:

$$U1 = 0.379A + 0.470B + 0.476C + 0.482D + 0.420E$$

First PC may be interpreted as contribution of general intelligence on the score of the test RSPM. 55.7% marks are due to general intelligence. The ability to learn, understanding of complex instructions and success in problem solving i.e. "cognitive ability" as described by Eysenck (1982, p. 8) has 55.7% effect on the scores.

The second PC which is denoted by U2 that contributes 15.2%

$$U2 = 0.787A + 0.237B - 0.235 C - 0.202D - 0.478E$$

In U2 the signs of the coefficients for set A and set B are different from the set C, D and

E. This indicates the difference between easy sets (A, B) and relatively difficult sets (C, D, E).

The third PC which denote by U3:

$$U3 = 0.412A - 0.437B - .334C - .180D - 0.703E$$

U3 contributes 11.8%, which refers to a contrast between easy and difficult and medium type of sets, because the sign of coefficient correspond set A+ ve while the remaining have -ve sign.

5. Conclusion

The findings prove that above-mentioned results are in consonance with other studies conducted earlier in different cultures and among various races. This test is also applicable to the students at higher education level in Pakistan. However, these are required to be applied cautiously and must be checked though distribution analysis for representing the unimodal or bimodal distribution. Findings further reveal that two factors, general intelligent and students choice in selecting the particular matrices, may affect the studies and results. It is recommended further to use this test to check the results on the basis of gender and disciplines in which the students are enrolled. This test may also be used for employment after certain changes to test cognition of the employees and match with the existing ones, especially in creative departments or fields.

References

Behrens, R 1984, *Design in the Visual Arts,* Prentice-Hall, Inc, New Jersey.

Carroll, JB 1993, *Human Cognitive Abilities,* Cambridge University Press, Cambridge.

Cattell, RB 1971, *Abilities: Their Structure, Growth, and Action,* Houghton Mifflin, Boston.

Demirtasli, NJ 2002, "A study of Raven Standard Progressive Matrices test's items measures under classic and item response models: an empirical comparison", *Journal of Faculty of Educational Sciences,* vol. 3, issue 1-2.

Gabriel, KR 1954, "The simplex structure of the progressive matrices test", *British Journal of Statistical Psychology,* vol. 7, issue 1, pp. 9-14.

Gustaffson, J 1984, "A unifying factor model for the structure of intellectual abilities", *Intelligence,* vol. 8, issue 3, pp. 179-203.

Gustaffson, J 1988, "Hierarchical models of individual differences in cognitive abilities", in R J Sternberg (ed.), *Advances in the Psychology of Human Intelligence,* Laurence Erlbaum, New Jersey, pp. 35-72.

Hotelling, H 1933, "Analysis of a complex of statistical variables into principal components", *Journal of Educational Psychology,* vol. 24, no. 6, 417-441.

Johnson, AR & Wichern, WD 2006, *Applied Multivariate Statistical Analysis,* Prentice Hall, New Jersey.

Jollifee, I 1986, *Principle Component Analysis,* Springer, New York.

Lovett, A, Forbus, K, & Usher, J 2010, "A structure-mapping-model of Raven's Progressive matrices", Proceedings of CogSci-10.

Lynn, R, Allik, J & Irwing, P 2004, "Sex differences on three factors identified in Raven's Standard Progressive Matrices", *Intelligence,* vol. 32, pp. 411-424.

McGrew, KS, & Flanagan, D 1998, *The Intelligence Test Desk Reference,* Allyn and Bacon, Boston.

Moore, P & Fitz, C 1993, "Gestalt theory and instructional design", *Journal of Technical Writing and Communication,* vol. 23, no. 2, pp. 137-157.

Mullet, K & Sano, D 1995, *Designing Visual Interfaces: Communication- oriented Techniques*, Prentice Hall, New Jersey.

Raven, J 1939, *Progressive Matrices: A Perceptual Test of Intelligence*, HK Lewis, London.

Raven, J, Raven, JC, & Court, JH 2003, *Manual for Raven's Progressive Matrices and Vocabulary Scales,* Harcourt Assessment, San Antonio.

Spearman, C, & Wynn-Jones, L 1951, *Human Ability*, Macmillan, London.

Van der Ven, AHGS, & Ellis, JL 2000, "A Rasch analysis of Raven's standard progressive matrices", *Personality and Individual Differences,* vol. 29, issue 1, pp. 45-64.

Vernon, PE 1950, *The structure of Human Abilities*, John Wiley & Sons, Inc., New York.

Wechsler, D 1981, *WAIS-R manual* (Wechsler Adult Intelligence scale- revised) Tge Psychological Corporation.