INTERNATIONAL JOURNAL OF

LEARNING MANAGEMENT SYSTEMS

ISSN: 2785-9568 VOLUME 4, ISSUE 2, 2016, 1 – 8. www.egyptfuture.org/ojs/

A Comparison between the Psychometric Properties of Visuospatial and Verbal-Analytic Items in the Raven's Advanced Progressive Matrices

Ali Mohamed Ibrahim and Ali Mahdi Kazem*.

College of Education, Sultan Qaboos University, Oman.

Abstract: The current study investigated the psychometric properties of two subsets of the Raven's Advanced Progressive Matrices Test (APM) items, visuospatial (13 items) and verbal-analytic (12 items) as categorized by DeShon, Chan and Weissbein (1955). A model of 25 items was first subjected to confirmatory factor analysis which reduced these items to 15 which fitted the data adequately. Nine items were visuospatial and 6 were verbal-analytic. This finding lends support to the empirical literature which found some evidence of the still debatable issue concerning the multi-dimensionality of the APM. The two subsets were found to be comparable in many respects (item difficulties and discriminations, average performance of students in the two subsets, correlation with total APM score). No gender differences were found in both subsets. Moreover, while the visuospatial items were found to be more internally consistent than the verbal-analytic items, this was attributed to the smaller number of the latter subset of items in the model. The visuospatial subset had a small positive but significant correlation with GPA. Conversely, the verbal-analytic subset had a small positive insignificant correlation with GPA. No gender differences in both subsets were observed.

Keyword: psychometric properties, Visuospatial, Verbal- Analytic, Advanced Progressive Matrices, APM.

1 Introduction

The Raven's Advanced Progressive Matrices (APM) is a non-verbal intelligence test which was developed to assess individual differences in observation, clear thinking, and mental capacity (Raven, 1965). The APM consists of 36 items which represent visual analogy problems. Each item consists of a 3X3 matrix in which the bottom right entry is missing and has to be selected from among eight alternatives arranged below the matrix (Carpenter, Just & Shell, 1990). According to Abad, Colon, Rebollo & Escorial (2004) a lot of research has focused on the possible cognitive components or processes which account for performance on the APM. DeShon, Chan, & Weissbein (1995) said that many researchers consider the APM as a measure of general intelligence (g), others consider it as a measure of inductive ability, fluid ability, pattern perception, etc. Therefore, DeShon et al. (1995) suggest that it is important to understand the processing components which account for performance on the APM. Hence, a number of theoretical attempts were made tocategorize these cognitive processes (e.g. Hunt, 1974; Carpenter et al, 1990; DeShon, Chan, & Weissbein, 1995, DeShon et al., 1995). Nevertheless, DeShon et al. (1995) found "conflicting evidence for the dimensionality of performance on theAPM"(p. 136). While Dillon et al. (1981) argued that performance on the APM is accounted for by at least two factors which were referred to as "addition-subtraction" and "pattern progression", Arthur and Woehr (1993) found that a single- factor model is adequate for describing performance on the APM.

INTERNATIONAL JOURNAL OF

LEARNING MANAGEMENT SYSTEMS

ISSN: 2785-9568 VOLUME 4, ISSUE 2, 2016, 1 – 8. www.egyptfuture.org/ojs/

According to DeShon et al. (1995), the disagreement over the cognitive processes measured by the APM is largely centered around whether this test measures visuospatial ability or verbal-analytic ability. Embreson (1993) suggested that tasks which are presented in visual format can be processed by using visuospatial strategies, verbal-analytic strategies, ora combination of the two strategies.

In line with the above argument, DeShon et al. (1995) developed two sets of rules or strategies (visuospatial and verbal- analytic) that may be used to solve problems of the APM. The majority of these rules (as the authors admit) were adapted from Hunt (1974) and Carpenter et al. (1990). The visuospatial rules include: superimposition, superimposition with cancellation, object addition/subtraction, movement, rotation and mental transformation. On the other hand, the verbal- analytic rules include: constant in row, quantitative pairwise progression, and distribution of three values. Accordingly,13 items were categorized to be visuospatial which are: 3, 7, 9, 10, 11, 12, 16, 18, 22, 23, 24, 32, 33. On the other hand,

12 items were perceived to be verbal-analytic namely, 1, 4, 8, 13, 17, 21, 27, 28, 29, 30, 34, 36. This classification provided by DeShon et al. (1995) is a 2- factor hypothetical model based on theoretical analysis. Macintosh and Bennett (2005) found that men outperformed women on items that are believed to contain a spatial component. But they did not find gender differences in items involving analytic processes. The male advantage in spatial ability was frequently reported in the literature (Voyer, Voyer, & Bryden, 1995). Nevertheless, some studies did not find significant gender differences which could be attributed to item types (e.g. Colon & Abad, 2007; Chiesi, Ciancaleoni, Galli, Morsany & Primi, 20012).

The purposes of the current study were threefold. The first purpose was to ascertain this hypothetical 2-factor model using confirmatory factor analysis. The second purpose was to compare some psychometric properties and other descriptive characteristics of the items of these two subsets. The third purpose of the study was to investigate gender differences in the two subsets.

The following psychometric properties which will be investigated include:1- Internal consistency reliability as measured by Cronbach's alpha Item difficulties as measured by the percent correct.

Item discriminations as measured by corrected tem-total correlations

. 4- Correlation of each subset with GPA.

5- Correlations between each of the two subsets with the total APM scores. 6- Correlation between the scores of the two subsets.

7- Comparison between the average performance of students in each of the two subsets.

2 Method

2.1 Subjects

The sample of the study consisted of 433 undergraduate students from Sultan Qaboos University in the Sultanateof Oman. 152 (35.1%) were males, 281 (64.9%) were females. The mean age of the sample was 21.17 years, with standard deviation 1.45 and a range of 18-29 years. The mean GPA was 2.78 with standard deviation 0.49 and range 0.11
– 3.90.

INTERNATIONAL JOURNAL OF
LEARNING MANAGEMENT SYSTEMS
ISSN: 2785-9568 VOLUME 4, ISSUE 2, 2016, 1 – 8. www.egyptfuture.org/ojs/

2.2 Procedure

During regular classes, members of the sample were administered the APM Set II (36 items) as a preliminary standardization of the test among university students of in the Sultanate of Oman. The time limit was 40 minutes. All items were scored 0, 1. The Statistical Package for Social Sciences (SPSS) was used to analyze the data.

3 Results

3.1 Confirmatory Factor Analysis (CFA)

CFA was used to test a hypothesized correlated two-factor model that assume the two factors Visuospatial and Verbal-analytic (suggested by DeShon et al. (1995), are correlated. The Visuospatial factor consisted of 13 items, while the Verbal-analytic consisted of 12 items of the APM. Figure 1 shows the hypothesized CFA model.

The full information maximum likelihood estimation was used to analyze the variance covariance matrices and estimate model parameters and obtain fit indices (Byrne, 2010). The AMOS 22.0 program (Arbuckle, 2015) was used to run all analyses. Several absolute and relative goodness-of-fit indexes were used to evaluate each model's goodness-of-fit to the data. Absolute fit indices included Chi-square (χ^2), Standardized Root Mean-Square Residual (SRMR), and Root-Mean- Square Error of Approximation (RMSEA). Relative fit indices included Comparative Fit Index (CFI) and Non-normed Fit Index (NNFI). When modeling normally distributed data (which is assumed in the present dataset given 433 cases), SRMR values of approximately .08 or below, RMSEA values of approximately .06 or below, CFI values of approximately .95 or above, and NNFI of approximately .90 or higher suggest adequate model-data fit (Hu & Bentler, 1998; Vandenberg & Lance 2000). Because the χ^2 is sensitive to sample size, Hoelter (1983) recommended reporting the χ^2/df ratio and suggested that ratios below 2.0 indicate a reasonable fit.

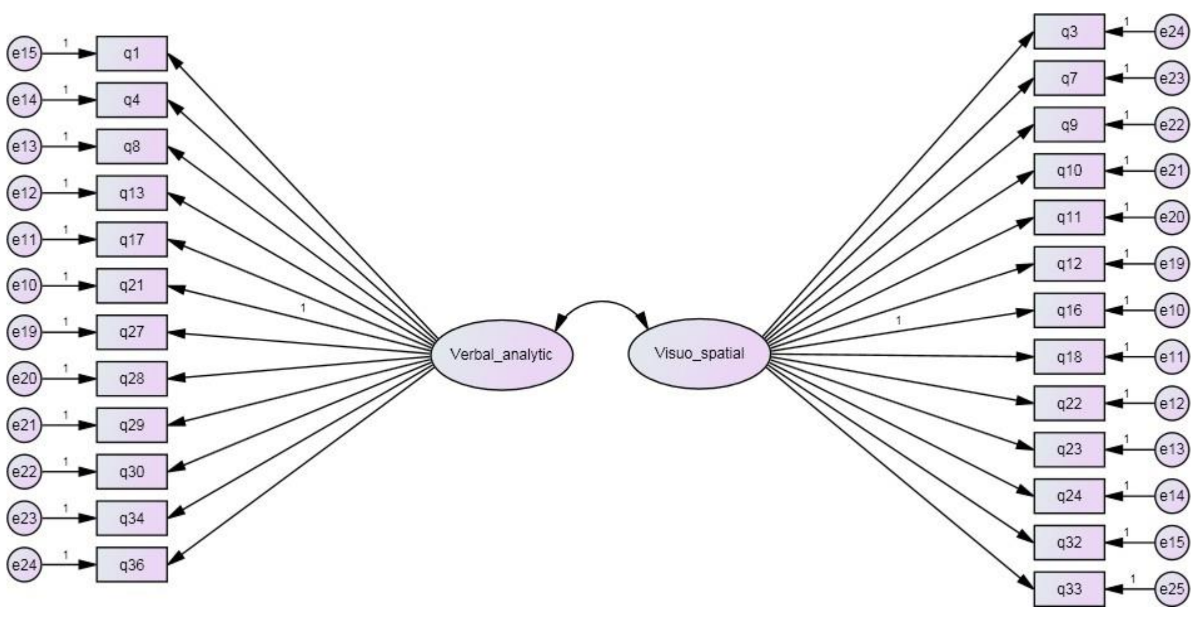

Figure 1: A hypothesized CFA model of the Visuospatial and the Verbal-analytic factors

The analysis showed that the correlated two-factor model fit the data adequately but after trimming 10 items fromboth factors (χ^2 = 182.359, df = 83, *p* = .16, χ^2/df =2.19, RMSEA = .049; CFI = .938; SRMR = .0423,

INTERNATIONAL JOURNAL OF

LEARNING MANAGEMENT SYSTEMS

ISSN: 2785-9568 VOLUME 4, ISSUE 2, 2016, 1 – 8. www.egyptfuture.org/ojs/

NNFI = .927). The two factors correlated at .97 (p < .001). The final model is displayed in Figure 2.

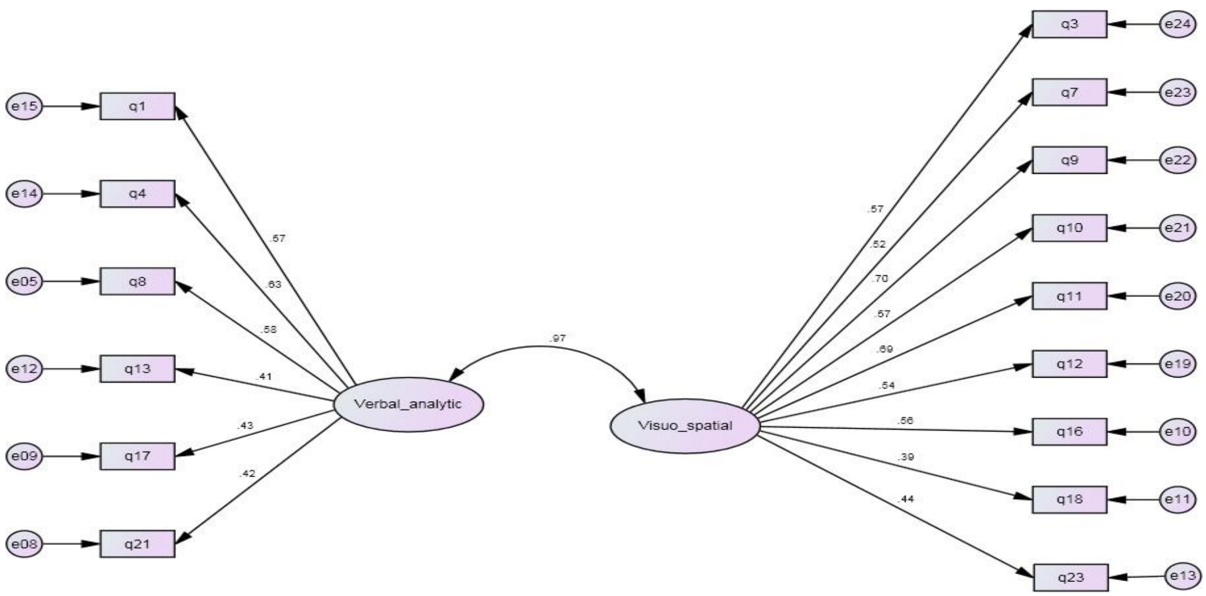

Figure 2: The final CFA model of the Visuospatial and the Verbal-analytic factors.

Table 1 shows item loadings, standard errors, and critical ratios for the items of each factor. The item loadings ranged from .41 to .63 for the verbal-analytic factor and from .39 to .70 for the visuospatial factor. The critical ratio values indicated that all items loadings were statistically significant. The critical ratio (CR) is the test statistic which represents the parameter estimate (i.e., item loading) divided by its standard error. As such, it operates as a z-statistic in testingwhether the estimate is statistically different from zero. Based on a significance level of 0.05, the test statistic needs to be
> ±1.96 before the hypothesis that the estimate equals 0.0 can be rejected (Byrne, 2010).

Table 1: Standardized path coefficients, standard errors, and the critical ratios of the verbal-analytical and visuospatialfactors

Paths	Unstandardized path coefficient	Standard error	Critical ratio (1)
Verbal-analytic			
q21	.422	-	-
q17	.433	.157	6.371
q13	.414	.158	6.208
q8	.577	.162	7.392
q4	.631	.175	7.677
q1	.570	.135	7.352
Visuospatial			
q16	.556	-	-
q18	.393	.112	6.914
q23	.438	.116	7.559
q12	.537	.106	8.821
q11	.687	.115	10.386
q10	.575	.115	9.258
q9	.703	.114	10.529

ISSN: 2785-9568 VOLUME 4, ISSUE 2, 2016, 1 – 8. www.egyptfuture.org/ojs/

q7	.520	.110	8.615
q3	.568	.112	6.914

Note. $N = 433$ (1) $p < .01$ for all critical ratio values

2.1 Descriptive Statistics

Descriptive statistics for both subsets are shown in table 2. It is interesting to note that both subsets have similar means. This indicates that the two subsets are of equal difficulty. Similarly, the subsets have equal standard deviations. Hence, it can be concluded that the two types of items differentiate similarly between students. Nevertheless, the standard deviations are much larger than expected. This could be attributed to the fact that a number of students responded carelessly as indicated by the 0 scores in both subsets. This resulted in the observed negative skewness in both distributions.

Table 2: Descriptive statistics for the two factors

Statistics	Factors	
	Visuospatial	Verbal-analytic
Mean*	68.18	68.86
Median*	77.78	66.69
Mode*	88.89	83.33
Std. Deviation	27.64	27.56
Skewness	-.86	-.88
Kurtosis	-.13	-.01
Minimum	0	0
Maximum	100	100

* Out of 100

2.1 Internal consistency

Cronbach's alpha for the two subsets were 0.79, for the visuospatial items and 0.66 for the verbal-analytic items. This indicates that visuospatial items are more internally-consistent than verbal-analytic items which can be attributed to the difference in the number of items.

Table 3: Cronbach's alpha for the two factors

Factor	**N of Items**	**Alpha**
Visuospatial	9	.79
Verbal-analytic	6	.66

2.1 Item difficulties and item discriminations

Tables 4 and 5, present item difficulties and discriminations for the visuospatial and the verbal-analytic items. These indices were calculated from the total items of the test. It is evident from these two tables that the visuospatial subset is quite comparable to the verbal–analytic subset in both difficulty and discrimination levels. The average difficultylevel of the visuospatial subset is 0.68 (with a range from 0.43 to 0.84), and that for the verbal –analytic subset is also 0.68(with a range from .58 to 0.85). The average discrimination levels for the two subsets are quite similar (.51 and .46). The discrimination levels for the visuospatial subset range from .40 to .64, and those of the verbal-analytic range from .41 to.54.

ISSN: 2785-9568 VOLUME 4, ISSUE 2, 2016, 1 – 8. www.egyptfuture.org/ojs/

Table 4: Item difficulties and discriminations of the visuospatial subset

Item	Visuospatial subset (9 items)	
	Difficulty	Discrimination*
3	0.84	0.53
7	0.70	0.46
9	0.76	0.64
10	0.69	0.49
11	0.75	0.61
12	0.75	0.52
16	0.72	0.51
18	0.43	0.40
23	0.51	0.45
Mean	0.68	0.51

*As measured by corrected item-total correlation

Table 5: Item difficulties and discriminations of the verbal-analytic subset

Item	Verbal-analytic subset (6 items)	
	Difficulty	Discrimination*
1	0.85	0.50
4	0.73	0.54
8	0.75	0.52
13	0.85	0.37
17	0.63	0.43
21	0.58	0.41
Mean	0.73	0.46

*As measured by corrected item-total correlation

3.2 Correlation of each subset with GPA

Pearson's correlation coefficient was obtained for each of the two subsets with GPA. Visuospatial subset has a small positive but significant correlation coefficient with GPA (0.13, *p*=.014). On the other hand, the verbal-analytic subset correlation with GPA is likewise small positive but insignificant (0.099, *p*=.070). Nevertheless, the difference between these two coefficients is not meaningful.

Table 6: Correlation of each subset with GPA (N= 336)

factor	**Correlation with GPA**	***p***
Visuospatial	.13	.014
Verbal-analytic	.099	.070

3.3 Correlation between the scores of the two subsets

As expected, the raw scores of the two subsets correlated significantly with each other (0.73, *p<0.001*). This means that 48% of the variance is shared between the two subsets.

ISSN: 2785-9568 VOLUME 4, ISSUE 2, 2016, 1 – 8. www.egyptfuture.org/ojs/

3.4 Comparison between the average performance of students in each of the two subsets

The mean percent scores for the students in the two subsets were equivalent (68.18 and 68.86). This indicates thatthe two subsets were of equal difficulty.

3.5 Investigation of gender differences in the two subsets

The mean performance of males and females was comparable in the two subsets. In the visuospatial subset the means of males females were 5.99 and 6.2, respectively, and in the verbal analytic subset, their means were 4.01 and 4.21,respectively. Hence, no significant differences were detected between the performance of males and females in the two subsets.

4 Discussion

The purposes of the current study were threefold. The first purpose was to test, using confirmatory factor analysis, a two-factor hypothetical model suggested by DeShon et al. (1995). The second purpose was to compare some psychometric properties and other descriptive characteristics of the items of these two subsets. The third purpose was to investigate gender differences in the two subsets. Regarding the first purpose, the results of confirmatory factor analysis data fit the two-factor model but after trimming 10 items from both subsets. This finding lends support to other findings inthe literature which advocated multi-dimensionality of APM (e.g. Dillon et al., 1981).

As regards performance in the two subsets, the mean percentage scores for the students in the visuospatial subset was 68.18 and in the verbal-analytic was 68.86. Thus, it is clear that performance of the students was equivalent in the twosubsets. This indicates that the two subsets were of equal difficulty. Likewise, average of discrimination indices (0.51 and 0.46) showed that the two subsets on the whole were equally discriminating.

The internal consistency of the nine visuospatial items was adequate (0.79), and for the 6 verbal-analytic items was less adequate (0.66) due the smaller number of items.

Both subsets had similar low correlations with GPA. But, the visuospatial items correlated significantly with GPA while the correlation of the verbal-analytic items with GPA was not significant.

No significant gender differences were found in both subsets of items. As regards the verbal-analytic subset, this finding is in conformity with the literature. On the other hand, although the insignificant difference between males and females in the visuospatial items contradicts with many findings, a number of researchers reported similar result (e.g. Colon & Abad, 2007; Chiesi, Ciancaleoni, Galli, Morsany & Primi, 20012).

References

1- Abad, F. J., Colom, R., Rebollo, I., & Escorial, S. (2004). Sex differential item functioning in the Raven's AdvancedProgressive Matrices: Evidence for bias. *Personality and Individual Differences*, 36, 1459-1470.

2- Arbuckle, J. L. (2015). *AMOS: Version 22.0* [Computer Program]. Chicago: SPSS.

3- Arthur, W., & Woehr, D. (1993). A confirmatory factor analytic study examining the dimensionality of the Raven's Advanced Progressive Matrices. *Educational and Psychological Measurement*, *53*(2), 471-478.

ISSN: 2785-9568 VOLUME 4, ISSUE 2, 2016, 1 – 8. www.egyptfuture.org/ojs/

4- Byrne, B. M. (2010). *Structural equation modeling with AMOS: Basic concepts, applications, and programming* (2 ed.). New York: Routledge.

5- Carpenter, P.A., Just, M.A., & Shell, P. (1990). What one intelligence test measures: A theoretical account of the processing in the Raven's Progressive Matrices Test. *Psychological Review, 97*, 404-431.

6- Chiesi, F., Ciancaleoni, M., Galli, S., Morsanyl, K. & Primi, C. (2012). Item rrsponse theory analysis and differentialitem functioning across age, gender, and country of a short form of the Advanced Progressive Matrices. *Learning and Individual Differences*, *22*, 390-396.

7- Colon, R. & Abad, F. J. (2007). Advanced Progressive Matrices and sex differences: Comment to Mackintosh and Bennett (2005). *Intelligence*, *35*, 183-185.

8- DeShon, R. P., Chan, D., & Weissbein, D. A. (1995). Verbal overshadowing effects on Ravens Advanced Progressive Matrices: Evidence from multidimensional performance determinants. *Intelligence*, 21, 135-155.

9- Dillon, R. F., Pohlmann, J. T., & Lohman, D. F. (1981). A factor analysis of Raven's Advanced Progressive Matrices freed of difficulty factors. *Educational and Psychological Measurement*, 41, 1295-1302.

10- Embretson, S. E. (1993). Learning and cognitive processes. In N. Frederiksen, R. J. Mislevy, & I. I. Bejar (Eds.), *Test theory for a new generation of tests* (pp. 125-150). Hillsdale, NJ: Erlbaum.

11- Hoelter, J. W. (1983). The analysis of covariance structures: Goodness-of-fit indices. *Sociological Methods and Research, 11*, 325-344.

12- Hu, L. T., & Bentler, P. M. (1998). Fit indices in covariance structure modeling: Sensitivity to underparameterized model misspecification. *Psychological Methods*, *3*, 424-453.

13- Hunt, E. B. (1974). Quote the Raven? Nevermore! In L. W. Gregg (Ed.), *Knowledge and cognition*. Hillsdale, NJ: Erlbaum

14- Mackintosh, N. J., & Bennett, E. S. (2005). What do Raven’s Matrices measure? An Analysis in terms of sex differences. *Intelligence*, *33*, 663-674.

15- Raven, J. C. (1965). *Advanced Progressive Matrices, Sets I and II*. London: H. K. Lewis.

16- Vandenberg, R. J., & Lance, C. E. (2000). A review and synthesis of the measurements invariance literature: Suggestions, practices, and recommendations for organizational research. *Organizational Research Methods, 3*, 4- 69.

17- Voyer, D., Voyer, S. D., & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin, 117*, 250-270.