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Sex differences on *g*, reasoning and visualisation tested by the progressive matrices among 7–10 year olds: some normative data for Mexico

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Abstract

Normative data for sex differences on the Standard Progressive Matrices are presented for a sample of nine-hundred and twenty 7–10 year olds in Mexico. Factor analysis of the test showed the presence of factors identifiable as *g*, reasoning ability and visualisation. There was no statistically significant difference between boys and girls on the test, on *g*, or on reasoning. There was, however, a significant advantage for boys on the visualisation factor. There was also a non-significant trend for the boys' advantage on the test to decline over the 4 years and to turn into an advantage for girls at age 10. This is consistent with the faster maturation of girls from the age of about 10 through 15 years.

Keywords: Sex differences; Intelligence; *g*; Progressive Matrices

1. Introduction

Raven's Progressive Matrices is widely regarded as one of the best tests of non-verbal or abstract reasoning ability. For instance, Mackintosh (1996, p. 564) writes that the Progressive Matrices is "the paradigm test of non-verbal, abstract reasoning ability". The Progressive Matrices is also widely regarded as an excellent test of Spearman's *g*, the general ability that is present to varying degrees in all cognitive tests. Thus, Jensen (1998, p.541) writes that "the Raven tests, when compared with many others, have the highest *g* loading" and are therefore the best

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tests for the measurement of *g*. It has been asserted that the Progressive Matrices is a pure test of *g*. For instance, "The total variance of Raven scores in fact comprises virtually nothing besides *g* and random measurement error" (Jensen, 1998, p. 541) and "The Progressive Matrices has been described as one of the purest and best measures of *g* or general intellectual functioning" (Raven, 2000, p.34).

It has also been widely asserted that there is no sex difference on the Progressive Matrices. Shortly after the test was published it was stated by Raven (1939, p. 30) that in the standardisation data "there was no sex difference, either in the mean scores or the variance of scores, between boys and girls up to the age of 14 years. There were insufficient data to investigate sex differences in ability above the age of 14″. This conclusion was reached by Court (1983) in a review of 118 studies on sex differences on the Progressive Matrices in which he reported that some studies found higher mean scores by males, others found higher mean scores by females, and yet others showed no difference in mean scores. From these inconsistent results he concluded that "the accumulated evidence at all ability levels indicates that a biological sex difference cannot be demonstrated for performance on the Raven's Progressive Matrices" (p. 68). Court's conclusion has been accepted by Mackintosh (1996) who writes that "large scale studies of Raven's tests have yielded all possible outcomes, male superiority, female superiority and no difference" (p. 564). Jensen also relies on Court's review for his conclusion that there is no sex difference on the Progressive Matrices and that this confirms his conclusion that there is no sex difference in *g*: "consistent with this finding of a near-zero sex difference in *g* is the fact that there is no consistent sex difference on Raven's Standard Progressive Matrices (for adults) or on the Coloured Progressive Matrices (for children)" (Jensen, 1998, p. 541).

The position that there is no sex difference on *g* or general intelligence has been adopted by many other authorities. This conclusion was reached in the first decade of the twentieth century by Terman (1916, pp. 69–70) on the basis of his American standardisation sample of the Stanford-Binet test on approximately one thousand 4–16 year olds. In this sample girls obtained a slightly higher average IQ than boys but "the superiority of girls over boys is so slight ... that for practical purposes it would seem negligible". A few years later Spearman (1923) asserted that there is no sex difference in *g*. Cattell (1971, p. 131) concluded that "it is now demonstrated by countless and large samples that on the two main general cognitive abilities—fluid and crystallized intelligence—men and women, boys and girls, show no significant differences". Brody (1992, p. 323) concluded that "gender differences in general intelligence are small and virtually nonexistent"; Jensen (1998, p.531) that "no evidence was found for sex differences in the mean level of *g*"); Mackintosh (1996, p. 567) that "there is no sex difference in general intelligence worth speaking of"; Lubinski (2000, p. 416) that "most investigators concur on the conclusion that the sexes manifest comparable means on general intelligence"; and Halpern (2000, p. 218) that "sex differences have not been found in general intelligence".

This view has been challenged by Lynn (1994, 1999) who has proposed a developmental theory of sex differences in intelligence. This states that boys and girls mature physically and mentally at different rates such that the growth of girls accelerates at the age of about 9 years and remains advanced until 14–15 years. At 15–16 years the physical growth and the intelligence of girls decelerates relative to boys. These sex differences are well established for physical growth and brain size (Eveleth & Tanner, 1990; Roche & Malina, 1983). The developmental theory of sex differences in intelligence proposes that the same differences are present for intelligence.

The developmental theory of sex differences in intelligence has been applied to the Progressive Matrices for adults and adolescents. With regard to adults, there are only three studies reporting sex differences for representative and reasonably large samples, all of which have found that men obtain higher mean scores than females. These are the Hawaii study of 2353 adults on which men had an advantage of approximately 3.8 IQ points (Wilson, De Fries, Mc Clearn, Vandenberg, Johnson, & Rashad, 1975); the Heron and Chown (1967) study of 600 adults in Britain in which men had an advantage of approximately 5.6 IQ points; and the Deltour (1993) study of 2104 adults in Belgium in which men had an advantage of approximately 6.4 IQ points. The evidence on adolescents from a standardization of the Progressive Matrices on a sample of 2689 in Estonia shows that females obtain higher means than males at the ages of 12 through 15, while males obtain higher means than females at the ages of 16 through 18 (Lynn, Allik, Pullmann, & Laidra, 2003). A study of 3979 15–16 year olds in South Africa found that among 15-year-old males had an advantage of 2.3 IQ points and among 16-year-old males had an advantage of 4.6 IQ points (Lynn, 2002). A study of six-hundred and four 18 year olds in Spain found that males had an advantage of 4.2 IQ points (Colom & Garcia-Lopez, 2002). The existing evidence therefore indicates females obtain higher means than males at the ages of 12 through 15 and that males have an advantage from the age of 15/16 onwards.

Hitherto the developmental theory of sex differences on the Progressive Matrices has not been applied to children of primary school age. An analysis of this question is the objective of the present paper. Sex differences on the 1979 British standardisation sample of the Progressive Matrices are presented in graph form by Raven (1981). These show that boys obtain slightly higher means than girls at the ages of 6, 7 and 8. From the ages of 9 through 12 girls obtain slightly higher means than boys. The difference is greatest among 11 year olds when the advantage of girls is approximately 2.7 IQ points and is statistically significant. From the ages of 13 through 15 boys obtain slightly higher mean scores than girls. The trend of the differences is consistent with the developmental theory in that the intelligence of girls accelerates relative to that of boys from the ages of 9 through 12, and then decelerates from the age of 13 onwards. However, there is an inconsistency between these results and the Estonian data for 13–15 year olds in so far as in the British data boys obtained slightly but not significantly higher means than girls while in the Estonian data girls obtained slightly higher means than boys. It should be noted that the size of the British standardisation sample was 3250 and was therefore only 325 for each of 10 age groups and is likely to contain sampling errors.

Our hypotheses with regard to children of primary school age are derived from the sex differences in the British standardisation sample. First, we predict that the sex difference will be very small. Second, we predict that there may be a slight advantage for boys at the ages of 6 through 8, and a slight advantage for girls at the ages of 9 and 10 as found in the British standardisation sample. Third, an examination of the items in the Progressive Matrices suggests to us that the test is not a pure measure of reasoning ability, as is frequently assumed, but that a number of the initial items are measures of visualisation ability for which the correct answer is obtained by examination of the pattern and visualising what is required to fill the missing space. This ability is one of eight second order factors in Carroll's taxonomy (1993, p. 624), in which it is designated *Broad Visual Perception* and defined as "involved in any task or performance that requires the perception of visual forms as such". Flanagan and McGrew (1998) designate it *Visual Processing* in their 10 second order factor taxonomy. We use the single word *Visualisation* for this ability.

The later items in the Progressive Matrices cannot be solved by visualisation but require reasoning ability to work out the principle of the arithmetical and geometrical progressions and project them to find the solution. We predict that the Progressive Matrices measures both these abilities. Fourth, we predict that if this is the case, and if boys have a slight advantage over girls among young children, this advantage will lie in the visualisation items and not in the reasoning items. Such a result would be consistent with other studies showing that boys of primary school age have a slight advantage over girls in visualisation abilities (Linn & Peterson, 1985).

2. Method

During October and November of 2000 the Standard Progressive Matrices was administered to a sample of nine-nundred and twenty 7–10 year old children from five socially representative primary schools in Mexico in the town of Ensenada, Baja California. Although in Mexico, with the exception of Indians, practically all children (white or dark) are mestizos, for the purpose of our research, three ethnic groups were considered: White, Mestizo and Native Mexican Indian. Boys and girls attended the same schools, so they came from families of the same socio-economic status. The test was administered without time limits, but in practice all children completed the test within 40 min.

3. Results

The numbers, mean scores and standard deviations of boys and girls on the Progressive Matrices are shown in Table 1 for each age group from 7 through 10. The right hand column shows these data for the total sample. The third row shows the raw scores differences between boys and girls (positive signs indicate higher means obtained by boys and minus signs indicate higher means obtained by girls). The fourth row gives the t values for the sex differences. None of the t values is statistically significant. Analysis of variance with Progressive Matrices scores shows a significant age effect ($F = 47.718$, $P < 0.001$). The sex effect is not statistically significant ($F = 0.380$, $P = 0.3800$) and the sex by age interaction effect is not statistically significant

Table 1
Means and standard deviations data for the Standard Progressive Matrices in Mexico

	7 years old			8 years old			9 years old			10 years old			Total/mean		
	N	Mean	S.D.	*N*	Mean	S.D.	*N*	Mean	S.D.	*N*	Mean	S.D.	*N*	Mean	S.D.
Male	105	22.47	10.04	129	26.76	11.01	130	31.49	10.37	108	31.86	10.79	472	28.27	11.18
Female	128	20.95	9.39	101	25.69	11.03	109	31.25	11.07	110	32.22	11.04	448	27.29	11.55
Difference		1.52			1.07			0.24			−0.36			0.98	
T value		1.194			0.733			0.169			0.247			1.131	
d		0.16			0.09			0.02			−0.03			0.09	
IQ		2.3			1.4			0.30			−0.40			1.3	

($F = 0.783$). Row 5 gives the sex differences expressed as *ds* (the difference between the means of boys and girls divided by the average of the two standard deviations). Row 6 gives the sex differences expressed as conventional IQs.

We now examine the hypotheses that the Progressive Matrices measures reasoning and visualisation abilities and that, if this is so, boys may have an advantage on visualisation ability. First, we factor analysed the data by principal components for the total sample and boys and girls separately. The results are shown in Table 2. Shown first are the eigenvalues and second the percentages of variance explained by the factors. It will be seen that the factors are closely similar for the total sample and for boys and girls analysed separately and show the presence of a strong first factor or component, a weaker second factor and still weaker third and fourth factors. Examination of the loadings of the items on the first two factors suggests that the first factor is reasoning and the second factor is visualisation ability. We have ignored factors 3 and 4 because they account for little of the variance and have no clear interpretation.

Second, the first two factors in the principal components analysis were rotated by varimax. The results of the loadings of the items on the first principal component and on the two varimax factors are shown in Table 3. Our interpretation of the factors is that the first principal component is *g* on which all items have positive loadings. The first varimax factor is reasoning ability and the second varimax factor is visualisation ability. Examination of the items suggests that those with higher loadings on varimax factor 1 require reasoning ability, namely A11, A12, B5 through 7 and 9 through 12, C 3 through 12, D 2 through 12, and E1 through 12. Items with higher loadings on factor 2 require visualisation ability, namely A1 through 10, B1 through 4, C1 and 2, and D1. The following are anomalous loadings. A1 has a very low loading because this was explained as a practise item and virtually everyone got the right answer. B8 with a higher loading on the visualisation factor looks anomalous. D11, D12 and E7 through 12 have low loadings on all the factors because these items are too difficult for nearly all children in this age group. The answers are largely random guesses and this is the reason for their low loadings on all the factors. Thus we believe that the higher loading of B8 on the visualisation than on the reasoning factor is the only truly anomalous result.

We consider now the sex differences on the three factors. To calculate these we have used only items with loadings of 0.30 and above on the factors. We have adopted two methods for calculating factor scores. The first is to multiply each correct answer by the factor loading of the item (designated weighted method) and the second is to score each correct item 1 (designated unweighted method). The results are shown in Table 4. It will be seen that both methods yield consistent results: boys have a non-statistically significant advantage over girls on *g* (the first

Table 2
Principal components analysis of total sample, boys and girls

Component	Total sample		Boys		Girls	
	Eigen.	% Var	Eigen	% Var	Eigen	% of Var
1	13.91	23.18	13.54	22.56	14.42	24.03
2	3.13	5.21	3.89	5.65	3.03	5.05
3	1.73	2.88	1.89	3.15	1.71	2.86
4	1.60	2.68	1.72	2.87	1.66	2.76

Table 3
Raven items loadings on the first principal component and the first two varimax factors unrotated and rotated components

Items	Unrotated factor	Rotated factors	
	First	First	Second
A_1	0.054	−0.009	0.131
A_2	0.209	0.026	0.394
A_3	0.323	0.015	0.657
A_4	0.276	−0.021	0.625
A_5	0.321	0.019	0.645
A_6	0.306	0.032	0.589
A_7	0.568	0.424	0.412
A_8	0.284	0.172	0.281
A_9	0.497	0.312	0.471
A_10	0.520	0.373	0.406
A_11	0.369	0.338	0.151
A_12	0.424	0.377	0.194
B_1	0.246	−0.011	0.541
B_2	0.397	0.150	0.562
B_3	0.581	0.376	0.528
B_4	0.485	0.353	0.369
B_5	0.589	0.473	0.364
B_6	0.556	0.490	0.263
B_7	0.519	0.462	0.238
B_8	0.524	0.343	0.469
B_9	0.585	0.610	0.099
B_10	0.666	0.678	0.144
B_11	0.642	0.664	0.119
B_12	0.485	0.519	0.059
C_1	0.537	0.354	0.478
C_2	0.410	0.288	0.332
C_3	0.617	0.564	0.253
C_4	0.620	0.579	0.231
C_5	0.733	0.673	0.297
C_6	0.599	0.578	0.190
C_7	0.686	0.656	0.226
C_8	0.536	0.540	0.127
C_9	0.657	0.592	0.286
C_10	0.406	0.418	0.079
C_11	0.257	0.322	−0.057
C_12	−0.119	−0.068	−0.125
D_1	0.511	0.353	0.422
D_2	0.695	0.682	0.198
D_3	0.614	0.585	0.208
D_4	0.747	0.681	0.310
D_5	0.786	0.673	0.410
D_6	0.701	0.691	0.193

(*continued on next page*)

Table 3 (*continued*)

Items	Unrotated factor	Rotated factors	
	First	First	Second
D_7	0.643	0.623	0.198
D_8	0.633	0.654	0.119
D_9	0.601	0.639	0.080
D_10	0.597	0.614	0.118
D_11	0.192	0.245	−0.051
D_12	0.051	0.127	−0.130
E_1	0.582	0.579	0.151
E_2	0.359	0.388	0.035
E_3	0.373	0.416	0.013
E_4	0.262	0.356	−0.110
E_5	0.302	0.394	−0.095
E_6	0.305	0.382	−0.069
E_7	0.091	0.127	−0.045
E_8	0.010	0.054	−0.080
E_9	0.143	0.182	−0.036
E_10	0.074	0.159	−0.140
E_11	−0.017	0.044	−0.119
E_12	−0.132	−0.085	−0.121

Table 4
Factor scores of boys and girls on *g*, reasoning and gestalt visualisation

Factor	Method	Gender	Mean	S.D.	F	Sig	d	IQ
9	Weighted	Boys	12.22	6.12	1.306	0.253	0.07	1.0
		Girls	11.75	6.42				
	Unweighted	Boys	22.92	10.59	1.667	0.197	0.08	1.2
		Girls	22.00	11.01				
Reasoning	Weighted	Boys	9.40	5.54	0.931	0.335	0.06	0.9
		Girls	9.04	5.81				
	Unweighted	Boys	18.76	10.25	1.589	0.208	0.08	1.2
		Girls	17.90	10.68				
Gestalt visualisation	Weighted	Boys	7.38	1.81	3.988	0.046	0.13	1.9
		Girls	7.14	1.84				
	Unweighted	Boys	15.23	4.03	5.013	0.025	0.15	2.2
		Girls	14.63	4.12				

principal component) and on reasoning ability (the first varimax factor) and a statistically significant advantage over girls on visualisation ability (the second varimax factor). The two columns at the right of the table give the sex differences expressed as *ds* (the difference between the means of boys and girls divided by the average of the two standard deviations) and the conventional IQs.

4. Discussion

We consider the results in relation to the four hypotheses set out in the introduction. First, it was hypothesised that the sex difference on the Progressive Matrices in children of primary school age would be very small. We see in Table 1 that this is confirmed in so far as for the total sample they amount to an advantage for boys of 1.3 IQ points. Second, it was hypothesised that the sex differences would show an increasing advantage for girls relative to boys as girls enter the growth spurt at an earlier age. This was confirmed in so far as the results show a trend for the advantage of boys to decline progressively from 2.3 IQ points at age 7 to 1.4 IQ points at age 8, to 0.3 IQ points at age 9, and then turn into an advantage of 0.4 IQ points for girls at age 10. This sex by age interaction is not statistically significant but it is similar to that in the British standardisation sample in which boys had an advantage in raw scores of 1.5 at age 6, 1.2 at age 7, 0.5 at age 8, and girls had an advantage of 0.6 at age 9, and 1.3 at age 10 (these figures are read off the graph in Raven, 1981). This trend is predictable from the developmental theory of sex differences in intelligence, although the changes in sex differences with age are so small over this age range that very large samples would be required to establish their statistical significance.

Third, it was hypothesised that the Progressive Matrices measures both reasoning and visualisation abilities. This was confirmed and the factor analysis shown in Tables 3 and 4 shows that the test can be analysed to provide measures of *g,* reasoning ability and visualisation. This result is contrary to the view that the Progressive Matrices measures nothing except *g*. It should however be noted that the visualisation factor identified in our data among primary school children may well not be present among adolescents and adults because the items measuring visualisation are so easy for adolescents and adults that they will mostly get them all correct and the factor will have virtually no variance. Fourth, the results confirm our hypothesis that an advantage for boys among primary school children is likely to lie largely in the visualisation factor. The results shown in Table 4 show that in the total sample boys have a statistically significant advantage on this factor of 1.9 (weighted) and 2.2 (unweighted) IQ points.

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