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Developmental gender differences on the Naglieri Nonverbal Ability Test in a nationally normed sample of 5–17 year olds

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Abstract

Lynn [Lynn, R. (2002). Sex differences on the progressive matrices among 15–16 year olds: some data from South Africa. *Personality and Individual Differences 33*, 669–673.] proposed that biologically based developmental sex differences produce different IQ trajectories across childhood and adolescence. To test this theory we analyzed the Naglieri Nonverbal Ability Test (NNA; [Naglieri, J. A. (1997). *Naglieri Nonverbal Ability Test-Multilevel Form*. San Antonio: Harcourt Assessment Company.]) standardization sample of 79,780 children and adolescents in grades K-12, which was representative of the US census on several critical demographic variables. NNAT data were consistent with Lynn's developmental theory of gender differences insofar as (a) there were no gender differences between 6 and 9 years; (b) females scored slightly higher between 10 and 13 years; and (c) males were ahead of females between the ages of 15 and 16. However, the discrepancies between the genders were smaller than predicted by Lynn. In fact they were so small that they have little or no practical importance. In other words, the NNAT did not reveal meaningful gender differences at any stage between the ages of 6 and 17 years.

Gender differences in cognitive ability as well as academic achievement has been a topic of considerable interest for some time, resulting in a substantial body of literature on the topic (e.g., Deaux, 1984; Fennema & Sherman, 1977; Geary, 1989, 1994, 1996; Halpern, 1986, 1989, 1997; Linn & Peterson, 1985; Lynn & Irwing, 2004; Maccoby & Jacklin, 1974; Voyer, Voyer, & Bryden, 1995). Hyde and Linn (1988) conducted a meta-analysis of 165 studies of gender differences and found a small mean effect size (favoring females) of .11 in verbal skills for studies of students aged 5 through 18 years. The differences between genders, however, were not uniform across tasks. For instance, the effect size for vocabulary was minimal ($d=.02$) but more substantial for speech production ($d=.33$). Geary (1996) found gender differences in quantitative skills. He reported that "the male advantage in certain areas of mathematics (e.g., problem solving) is related to a male advantage in spatial abilities" (p. 236). Females, on the other hand, have been found to have an advantage over males on basic arithmetic tests, at least through junior high school (Hyde, Fennema, & Lamon, 1990). Halpern (1997) summarized the research and concluded that females outperform males on tests of verbal fluency, foreign language, fine motor skills, speech articulation, reading and writing, and math calculation. In contrast, males do better on tasks that involve mental rotation, mechanical reasoning, math and science knowledge, and verbal analogies.

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Table 1
Demographic information by NNAT level groups

	NNAT levels															
	A				B				C				D			
	Male		Female		Male		Female		Male		Female		Male		Female	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Ethnic																
White	2027	69.6	2060	73.5	2342	68.6	2385	70.5	2595	64.2	2565	63.1	5198	64.8	5281	66.1
African-American	328	11.3	230	8.2	408	12.0	366	10.8	704	17.4	711	17.5	984	12.3	922	11.5
Hispanic	322	11.1	326	11.6	355	10.4	319	9.4	461	11.4	452	11.1	895	11.2	852	10.7
Asian	83	2.9	46	1.6	73	2.1	109	3.2	128	3.2	160	3.9	200	2.5	193	2.4
Native American	19	0.7	26	0.9	55	1.6	47	1.4	45	1.1	54	1.3	79	1.0	79	1.0
Other	30	1.0	28	1.0	57	1.7	39	1.2	35	0.9	41	1.0	104	1.3	89	1.1
Special schooling																
Special Ed	38	1.3	11	0.4	104	3.0	22	0.7	234	5.8	145	3.6	433	5.4	195	2.4
GT	9	0.3	12	0.4	61	1.8	101	3.0	232	5.7	144	3.5	555	6.9	580	7.3
Region																
Northeast	511	17.5	413	14.7	779	22.8	702	20.7	679	16.8	686	16.9	1729	21.6	1729	21.7
Midwest	818	28.1	790	28.2	896	26.3	902	26.7	875	21.6	828	20.4	1805	22.5	1710	21.4
Southeast	774	26.6	700	25.0	878	25.7	805	23.8	880	21.8	835	20.5	1573	19.6	1600	20.0
West	809	27.8	900	32.1	859	25.2	975	28.8	1610	39.8	1719	42.3	2909	36.3	2945	36.9
Urbanicity																
Urban	349	12.0	365	13.0	413	12.1	457	13.5	1055	26.1	1123	27.6	1891	23.6	1887	23.6
Suburban	1218	41.8	1259	44.9	1588	46.5	1566	46.3	1714	42.4	1640	40.3	3464	43.2	3499	43.8
Rural	1026	35.2	929	33.1	1026	30.1	1023	30.2	882	21.8	885	21.8	1768	22.1	1721	21.6
Non-public	319	11.0	250	8.9	385	11.3	338	10.0	393	9.7	420	10.3	893	11.1	877	11.0
SES																
1	534	18.3	479	17.1	522	15.3	551	16.3	746	18.4	738	18.1	1356	16.9	1302	16.3
2	489	16.8	557	19.9	411	12.0	455	13.4	963	23.8	1108	27.2	1460	18.2	1559	19.5
3	562	19.3	585	20.9	758	22.2	782	23.1	761	18.8	676	16.6	1415	17.7	1465	18.3
4	499	17.1	447	15.9	701	20.5	587	17.3	606	15.0	528	13.0	1285	16.0	1220	15.3
5	509	17.5	485	17.3	635	18.6	671	19.8	575	14.2	598	14.7	1607	20.0	1561	19.6

	NNAT levels											
	E				F				G			
	Male		Female		Male		Female		Male		Female	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Ethnic												
White	4343	56.3	4180	55.3	4935	55.6	5104	55.0	2474	53.1	2397	47.3
African-American	930	12.1	1007	13.3	904	10.2	1121	12.1	501	10.8	566	11.2
Hispanic	983	12.7	960	12.7	1061	12.0	1039	11.2	248	5.3	320	6.3
Asian	251	3.3	238	3.1	250	2.8	169	1.8	70	1.5	107	2.1
Native American	85	1.1	63	0.8	85	1.0	56	0.6	63	1.4	37	0.7
Other	95	1.2	82	1.1	95	1.1	102	1.1	53	1.1	76	1.5
Special schooling												
Special Ed	548	7.1	297	3.9	631	7.1	252	2.7	250	5.4	127	2.5
GT	499	6.5	609	8.1	438	4.9	669	7.2	159	3.4	319	6.3
Region												
Northeast	1462	18.9	1406	18.6	1928	21.7	2120	22.8	725	15.6	807	15.9
Midwest	1851	24.0	1781	23.6	2422	27.3	2450	26.4	1575	33.8	1385	27.3
Southeast	1458	18.9	1319	17.5	2130	24.0	2251	24.2	1225	26.3	1327	26.2
West	2945	38.2	3050	40.4	2398	27.0	2465	26.5	1131	24.3	1546	30.5
Urbanicity												
Urban	1560	20.2	1645	21.8	1356	15.3	1373	14.8	232	5.0	534	10.5
Suburban	3365	43.6	3272	43.3	3974	44.8	4038	43.5	2006	43.1	2167	42.8
Rural	2106	27.3	1903	25.2	2540	28.6	2817	30.3	1865	40.1	1843	36.4
Non-public	685	8.9	736	9.7	1008	11.4	1058	11.4	553	11.9	521	10.3

Table 1 (*continued*)

	NNAT levels											
	E				F				G			
	Male		Female		Male		Female		Male		Female	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
SES												
1	1310	17.0	1423	18.8	1457	16.4	1428	15.4	634	13.6	995	19.6
2	1494	19.4	1377	18.2	1615	18.2	1740	18.7	925	19.9	924	18.2
3	1493	19.3	1569	20.8	1521	17.1	1566	16.9	870	18.7	918	18.1
4	1246	16.1	1159	15.3	1588	17.9	1698	18.3	736	15.8	737	14.6
5	1488	19.3	1292	17.1	1689	19.0	1796	19.3	938	20.1	970	19.2

Some researchers have argued that gender differences cannot be adequately understood unless males and females are compared according to a theoretical model of cognitive functioning (e.g., McHough, Koeske, & Frieze, 1986; Naglieri & Rojahn, 2001). Geary (1989) further emphasized that conceptual models of cognitive differences between the genders should provide an integration of the neurological and socio-cultural components that influence the development of cognitive processes. More recently, Lynn (2002) and Lynn and Irwing (2004) argued that sex differences must be viewed developmentally and with consideration of the role played by biology.

Based upon his research using Raven's Progressive Matrices, Lynn (2002) argued that one would expect that (a) no sex differences exist between the genders during the ages of six to nine; (b) females move one IQ point ahead of males between the ages of 10 and 13; (c) after age 13 females' growth begins to decelerate relative to males and they begin to lose their advantage; and (d) from 15 to 16 onward males catch up and overtake females ending up with an advantage that reaches 2.4 IQ points among adults. Lynn's (2002) study was based on samples of 15 to 16 year old adolescents from South Africa using the Raven's Progressive Matrices. Although his sample was large ($N = 3979$), it did not provide a range of ages that could adequately test his expectations. Our goal was to do just that using a sample of children from the United States who ranged in age from 5 to 17 years.

1. Method

1.1. Participants

The subjects of this study were 79,780 children and adolescents from kindergarten to grade 12 who participated in the *Naglieri Nonverbal Ability Test* (NNAT; Naglieri, 1997) standardization during the 1995–1996 school years. Of these, approximately 67,000 were tested in spring 1996 and the remaining was tested in fall of 1995. The methods used to collect the sample which was representative of the U.S. population in terms of geographic region, socioeconomic status, urbanicity, ethnicity, and school setting (public or private) and the procedures used to create the NNAT norms are fully described by (Naglieri, 1997). The groups of children and adolescents used in this study are further

Table 2
Chronological ages and NAI scores for males and females by NNAT levels

Levels	Males					Females					*d*-ratio	NAI diff	*t*
	Age		NAI		*n*	Age		NAI		*n*			
	M	S.D.	*M*	S.D.		*M*	S.D.	*M*	S.D.				
A	6.1	0.4	100.0	15.5	2912	6.0	0.4	98.9	16.1	2803	0.07	1.1	2.5*
B	7.1	0.5	99.6	16.0	3412	7.0	0.5	100.9	15.8	3384	−0.08	−1.3	−3.3**
C	8.1	0.5	98.9	15.4	4044	8.0	0.5	98.6	15.5	4068	0.02	0.3	1.0
D	9.6	0.8	100.8	16.7	8016	9.5	0.7	100.5	15.5	7984	0.02	0.3	1.2
E	11.8	0.8	99.0	16.5	7716	11.7	0.7	99.9	15.4	7556	−0.06	−0.9	−3.5***
F	14.2	1.0	99.6	17.1	8878	14.0	1.0	100.3	15.9	9286	−0.04	−0.7	−2.1*
G	17.1	1.0	100.3	17.0	4656	16.9	0.9	99.6	14.7	5065	0.04	0.7	2.1*

*=$p<.05$; **=$p<.01$; ***=$p<.001$.
NAI diff=gender differences in NNAT NAI scores.

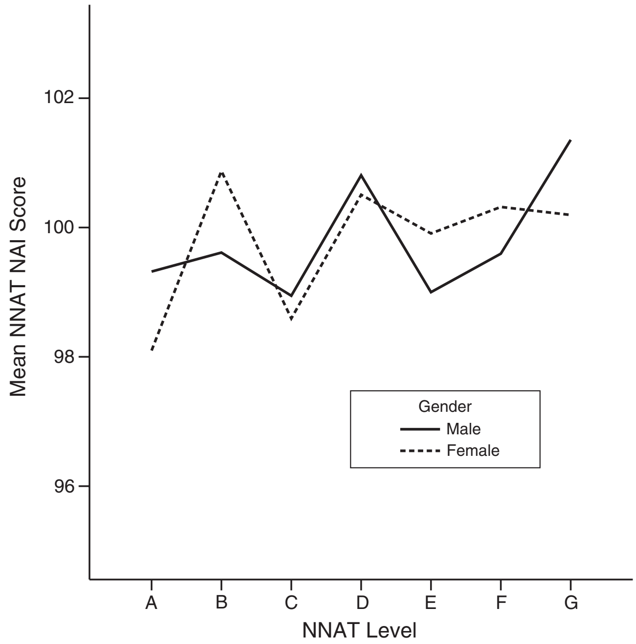

Fig. 1. Mean NNAT NAI scores across NNAT levels (6 to 17 year olds).

described in Table 1 which shows demographic characteristics for males and females by NNAT level and Table 2 which provides the means and standard deviation of the ages of participants who were administered the different NNAT levels.

1.2. Instrument

The NNAT (Naglieri, 1997) was designed to measure general ability of children and adolescents using a series of progressive matrix items that involve shapes

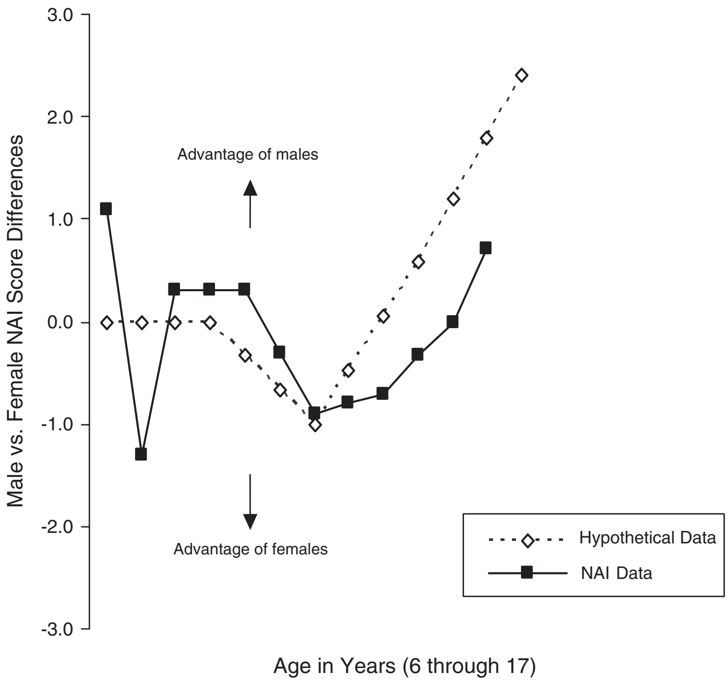

Fig. 2. Mean gender differences in IQ scores as predicted by Lynn (2002) and generated by the empirical NNAT NAI scores.

Table 3
NNAT NAI scores for males and females by Lynne's age groups

Lynn's age groups	Male			Female			NAI diff	*d*-ratio	*t*
	Mean	S.D.	*N*	Mean	S.D.	*N*			
6–9	100.2	16	14,468	100.2	15.6	14,668	0.05	0.000	0.3
10–13	100.0	16.5	14,273	100.2	15.6	14,443	−0.25	−0.012	−1.3
15–17	99.1	17	5681	99.1	15.4	5940	−0.03	0.000	−0.9

*= $p<.05$; **= $p<.01$; ***= $p<.001$.
NAI diff = gender differences in NNAT NAI scores.

and geometric designs interrelated through spatial or logical organization. Each item within the NNAT is similar in that the child must realize the relationship between the parts of the matrix to successfully solve the problem. The NNAT was designed so that it does not require the child to read, write, or speak and that the directions require minimal verbal comprehension. The test is organized into 38 dichotomously scored items in each of seven levels. Each level of NNAT includes items selected to be appropriate for children of different grades and ages to maximize the range of ability that could be assessed and to achieve good reliability. The KR-20 internal reliability coefficients for the NNAT by grade found in Naglieri (1997) range from .83 to .93 (median internal reliability across all levels is .87).The seven levels, or forms of the NNAT, and corresponding grades for which they are intended are as follows: Level A, kindergarten; Level B, Grade 1; Level C, Grade 2; Level D, Grades 3–4; Level E, Grades 5–6; Level F, Grades 7–9; Level G, Grades 10–12. Each level contains eight items common from both the adjacent higher and lower levels as well as unique items. The shared items were used to develop a continuous scaled score across the entire standardization sample.

A Nonverbal Ability Index (NAI) standard score (mean of 100 and S.D. of 15) is converted from the child's NNAT raw score through an intermediate Rasch value called a Scaled Score. The Scaled Scores for all ages are centered on Level D (Grades 3–4). The appropriate equating constant was then added to the spring standardization Rasch item difficulties of each level to produce a continuous Rasch ability scale across all levels of the test. Thus, each child's raw score is converted to a Scaled Score (Rasch value) based on the NNAT level administered and converted to a standard score with a mean of 100 (S.D. = 15) based on the age of the child. The two scores provide different perspectives from which to understand children's performance

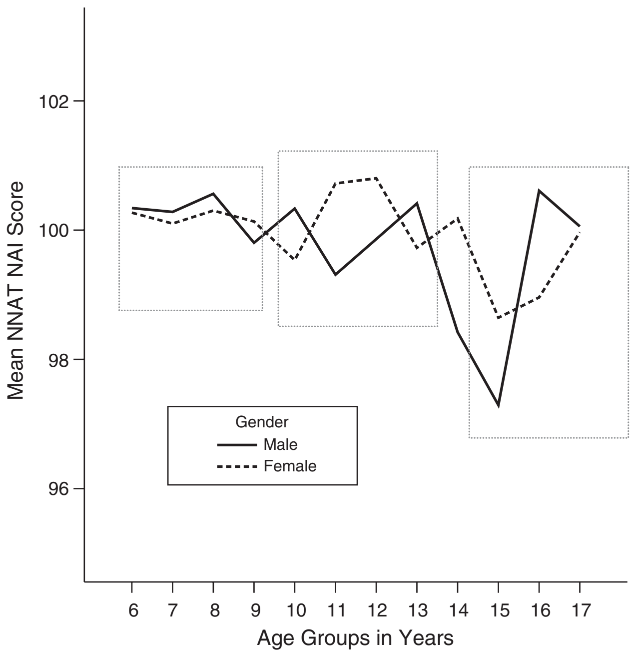

Fig. 3. Mean NNAT NAI scores across age groups (6 to 17 year olds) (the boxes identify the critical time periods according to Lynn's predictions).

Table 4
NNAT scaled scores for males and females by NNAT levels

NNAT level	Males			Females			*d*-ratio	SS diff	*t*
	Mean	S.D.	*N*	Mean	S.D.	*N*			
A	541.7	38.5	2912	537.7	40.3	2803	0.0014	4.0	3.9***
B	568.5	37.9	3412	570.4	37.4	3384	−0.0006	−1.9	−2.1*
C	585.7	34.2	4044	583.0	35.6	4068	0.0007	2.7	3.5***
D	617.3	40.3	8016	614.8	37.3	7984	0.0003	2.4	4.0***
E	630.7	39.4	7716	632.2	37.2	7556	−0.0002	−1.5	−2.4*
F	648.3	41.0	8878	648.7	38.4	9286	−0.0001	−0.5	−0.8
G	661.4	44.0	4656	658.7	38.0	5065	0.0006	2.7	3.3**

*=$p<.05$; **=$p<.01$; ***=$p<.001$.
SS diff=gender differences in NNAT scaled scores.

on the NNAT. The Scaled Score is useful for examining developmental changes across time (average scores are lower for younger children and higher for older children) while the NAI score is useful for comparing children based on their score relative to a specific age cohort (the mean score is 100 and S.D. 15 for all age groups). For more information, see Naglieri (l997).

2. Results

Examination of the differences between genders was conducted using two methods, factorial univariate analyses of variance (ANOVA) and *d*-ratios (Cohen, 1988). Dependent variables were either the NAI scores or the NNAT scaled scores. The *d*-ratio is an expression of the difference between the means in S.D. units based on the average standard deviations. Effect sizes were evaluated according to Cohen's criteria (1988) for small, medium, and large effects (d=.20, .50, and .80), respectively.

Two factorial ANOVAs were computed for the NAI scores. The first one examined the *NAI scores* as a function of gender and NNAT levels. Table 2 contains the means and standard deviations of the ages and the NAI scores for males and females across the NNAT levels. Fig. 1 illustrates the means across NNAT levels. A significant interaction effect was found (F [6, 79,766]=7.0, $p<.001$), which can be attributed to the alternating differences in the NAI scores between males and females across NNAT levels. The NAI score gender differences ranged from a 1.1 point advantage for males at NNAT level A (mean age=6.1, S.D.=0.4) to a 1.3 point advantage for females at NNAT level B (mean

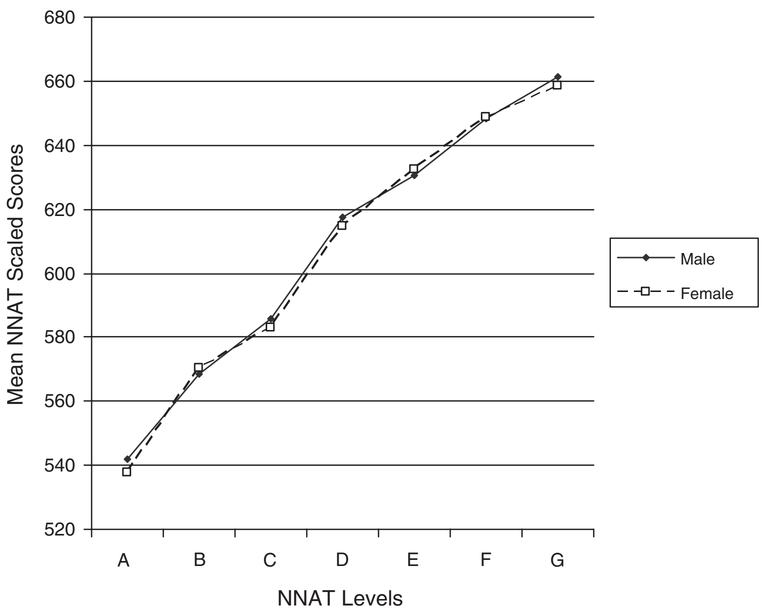

Fig. 4. Mean NNAT scaled scores across NNAT levels.

age = 7.1, S.D. = 0.5). No significant NAI differences were found for NNAT levels C (mean age = 8.0, S.D. = 0.5) and D (mean age = 9.6, S.D. = 0.8). Despite the statistical significance of these differences the results of the *d*-ratios indicated that there were *very* small discrepancies between the mean NAI scores earned by males and females. The largest *d*-ratio was .08, considerably smaller than the .2 needed for designation as small by Cohen (1988). Fig. 2 suggests that at the youngest ages (6 and 7 years) NNAT data were not consistent with Lynn's predictions; at the middle and upper ages there were similarities between Lynn's predicted and empirically established differences in trend, however not in effect size or in magnitude of differences.

The second factorial ANOVA compared *NAI scores* as a function of gender and age groups as defined by Lynn (2002). Table 3 shows NAI means and standard deviations for males and females by the 6–9, 10–13, and 15–17 year age groups described by Lynn (2002). Only the main effect for age groups was found to be statistically significant (F [2, 69,467] = 33.4, $p < .05$). Fig. 3 depicts the mean NAI scores across age groups (including the 14 year olds, which were not explicitly included in Lynn's, 2002 model). No significant differences between the genders were found.

The final factorial ANOVA examined the *NNAT scaled scores* as a function of the factors gender and NNAT levels. Table 4 shows the means and standard deviations for males and females by NNAT levels. A significant interaction effect (F [6, 79,766] = 9.1, $p < .001$) and a main effect for NNAT levels was found (F [6, 79,766] = 1182.1, $p < .001$) for the NNAT scaled scores, but no significant effect for gender. NNAT scaled score means and S.D.s were remarkably similar across the seven levels as shown in Fig. 4 indicating very similar rates of growth across the ages.

3. Discussion

The overall aim of this study was to test Lynn's (2002) developmental theory of gender differences on progressive matrices using a large representative sample of children in the US. In general, we found mixed support for Lynn's developmental theory. The first of Lynn's predictions was that there would be no sex differences between the ages of 6 and 9. When the analysis was conducted for all children ages 6 to 9 combined we found support for Lynn's hypothesis. However, when the analysis was conducted according to NNTA levels within the 6 to 9 year olds our findings were inconsistent with this expectation. We found very small but statistically significant differences between the genders for NNAT levels A (advantage of males, corresponding to the age of 6) and B (advantage of females, corresponding to the age of 7). Despite the statistical significance, the NAI differences were about one point and the *d*-ratios were quite small (<.09). We concluded that Lynn's prediction of no differences at the 6 to 9 age span was supported.

The second hypothesis that females should be one IQ point ahead of males between the ages of 10 and 13 was also somewhat consistent with our findings. Although the differences between the genders at Level D were not significant, Levels E and F showed differences in favor of females that were about 3/4 of a point. But again, despite the statistical significance of these findings, the *d*-ratios were very small (<.07). We concluded that Lynn's prediction was supported but the size of the differences was minor and the effect size tiny.

The third hypothesis that males should be 2.4 points ahead of females between the ages of 15 and 16 was, again, somewhat consistent with our findings. Although the differences between the genders at Level G were significant, the difference was about 3/4 of a point and the *d*-ratio was minuscule ($d = .04$). We concluded that Lynn's prediction of a difference was supported but at much less than 2.4 IQ points.

Finally, we examined the change in scores across the age groups using the NNAT scaled scores. Lynn's prediction that mental growth decelerates for females relative to males was not supported by the trajectory of the data. Additionally, whereas Lynn predicted that females lose their advantage from 15–16 onward and males begin to catch up and overtake females was not confirmed (Fig. 4).

In summary, although the NNAT data were partially consistent with Lynn's developmental theory of gender differences, the discrepancies between the genders were so small as to render them inconsequential. Statistical differences were found due to the large sample size and consequent statistical power. Importantly, the *d*-ratios indicated that those statistical differences that were found were minute and may have little or no practical importance. The data provided in this study suggest that when using the NNAT (Naglieri, 1997) meaningful differences were not found. The differences that were detected were small and vacillated between the genders and, as suggested by Mackintosh (1998), Lynn's (2002) suggestion of a "male advantage of 5.5 points seems a serious over-estimate" (p. 538). We conclude as Mackintosh (1998) did that Lynn's (2002) assertion of sex differences in general intelligence as measured by progressive matrices was not supported.

This study like most has limitations that should be considered. First, Lynn's (2002) study involved Raven's Progressive matrices which are similar to but not identical to those developed by Naglieri (1997). Raven's and Naglieri's progressive matrices are different in appearance, reliability, and standardization sample characteristics (Bracken & Naglieri, 2003) but have been shown to yield results that are highly correlated (see Naglieri, 1985, 2003). It is possible that differences between the research utilized by Lynn (2002) and ours resulted from the use of different tests but this seems unlikely. Another limitation is that, as Mackintosh (1998) noted, if the definition of intelligence changes different results may be found. Researchers have found sex differences when different methods of measuring ability were employed (e.g., Halpern, 1997) and when different ways of defining intelligence were used.

Naglieri and Rojahn (2001) studied sex differences in a large sample of children in the US aged 5–17 years and found some important differences when using the PASS theory to define intelligence as operationalized by the Cognitive Assessment System (CAS; Naglieri & Das, 1997). Girls outperformed boys between the ages of 5 and 17 years on measures of cognitive processing included in the Planning Scale. The difference of about 5 points (a .33 d-ratio) was consistent with previous research (Bardos, Naglieri, & Prewett, 1992; Warrick & Naglieri, 1993). Additionally, girls were better than boys on measures of Attention included in the CAS by about the same amount (d-ratio = .35). In contrast boys and girls differed minimally on measures of Simultaneous (d-ratio = .01) (which includes a measure of progressive matrices) and Successive (d-ratio = .08) cognitive processing. Like McHough et al. (1986) and Geary (1989) we further suggest that greater insights into sex differences could be obtained using a theory that is based on cognitive and neuropsychological theories like PASS rather than those based on the familiar verbal, quantitative, nonverbal content based conceptualization. We therefore encourage researchers to examine sex differences using methods that extend beyond the general intelligence approach.

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