

# Sex differences in mental arithmetic, digit span, and $g$ defined as working memory capacity

Richard Lynn<sup>a,\*</sup>, Paul Irwing<sup>b</sup>

<sup>a</sup> *University of Ulster, Coleraine, Northern Ireland*

<sup>b</sup> *University of Manchester, Manchester, M60 1QD, UK*

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## Abstract

Meta-analyses are presented of sex differences in (1) the (mental) arithmetic subtest of the Wechsler intelligence tests for children and adolescents (the WISC and WPPSI tests), showing that boys obtained a mean advantage of  $.11d$ ; (2) the (mental) arithmetic subtest of the Wechsler intelligence tests for adults (the WAIS tests) showing a mean male advantage of  $.47d$ ; (3) the digit span subtest of the Wechsler intelligence tests for children and adolescents (the WISC and WPPSI tests), showing that girls obtained a mean advantage of  $.134d$ ; (4) the digit span subtest of the Wechsler intelligence tests for adults (the WAIS tests) showing a male advantage of  $.116d$  among adults. These results show that the sex differences on mental arithmetic are not consistent with the sex differences on digit span. It is proposed that the reason for this is that mental arithmetic is a measure of working memory capacity while digit span is a measure of immediate memory capacity. If this is accepted, the results indicate that there is virtually no sex difference in immediate memory capacity (measured by digit span) but a small male advantage among children and a substantial male advantage among adults in working memory capacity (measured by mental arithmetic). The results are further interpreted in terms of Kyllonen's theory that working memory capacity is  $g$ . If this is accepted, it follows that males have an advantage in  $g$  and that the higher average means obtained by men in IQ tests like the WAIS and the Progressive Matrices is attributable to their advantage in  $g$ .

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## 1. Introduction

We have been struck by an apparent anomaly in the literature on sex differences in arithmetical computation and in mental arithmetic. This is that females tend to have an advantage in arithmetical computation among children and there is no sex difference among older adolescents and adults, while males tend to have an

advantage in mental arithmetic as children, adolescents and adults. The sex differences in arithmetical computation are quite well established from the meta-analysis of sex differences in mathematical abilities carried out by Hyde, Fennema and Lamon (1990), who calculated that girls have an advantage in arithmetical computation of  $.20d$  at ages 5–10 and of  $.22d$  at ages 11–14, and that there was no sex difference at ages 15–18. They do not give data for adults, but studies showing no sex difference in arithmetical computation among adults have been published by Schaie, Maitland, Willis and Intrieri (1998) and by (Schaie, 2005).

\* Corresponding author. Tel.: +353 01 275 392 092.

E-mail address: [lynnr540@aol.com](mailto:lynnr540@aol.com) (R. Lynn).

In contrast to the female advantage in mental computation among children and the absence of a sex difference among adolescents and adults, we have observed in several studies that males have an advantage in the Wechsler mental arithmetic subtest among children in Scotland and the United States (Lynn & Mulhern, 1991), and in the Netherlands (Born & Lynn, 1994), and among adults in Scotland (Lynn, 1998) and in Japan (Lynn & Hattori, 1997).

We have three objectives in this paper: (1) to present a meta-analysis of sex differences among children and adults in the Wechsler mental arithmetic subtest; we believe this has not previously been done and that this analysis would establish whether there is a male advantage in this; (2) to present a meta-analysis of sex differences among children and adults in the Wechsler digit span subtest; we believe that this also has not previously been done and that this analysis would establish whether there is a sex difference in digit span and whether this is consistent with the sex difference in mental arithmetic (it might be supposed that this would be the case, since both tests require holding material in immediate memory); (3) to consider what theories could be advanced to explain the results of the meta-analyses of sex differences in the Wechsler mental arithmetic and digit span subtests.

## 2. Sex differences in mental arithmetic

In this section we present meta-analyses of sex differences among children and adults in the Wechsler mental arithmetic subtest. We confine our analyses to normative standardization samples because these are considered to have the advantages of sample representativeness and minimization of publication or experimenter bias (Burnett, 1986; Hedges, & Nowell, 1995). In order to identify all possible studies meeting our inclusion criteria we conducted computerized database searches of PsychInfo, Medline, and Web of Science. In addition we relied on previous knowledge accumulated through comprehensive searches of Current Contents. We believe that this was sufficient to locate all standardization samples of the WAIS, WPPSI and WISC for which sex differences have been reported. We are aware that there are other standardization samples, such as the French and Canadian WAIS-III, which we have not used because we could not find publications giving sex differences for these. We introduce a further refinement by combining samples. Cohen's  $d$  (the difference between the male and female means divided by the within group standard deviation) was adopted as the measure of effect size, and the mean  $d$  was calculated using the inverse

variance method. Heterogeneity of effects sizes was tested using the  $Q$  statistic (Borenstein & Rothstein, 1999), and all statistics were calculated using a random effects model (Hunter & Schmidt, 2004).

The first analysis was of sex differences in 15 studies of the arithmetic subtest of the Wechsler intelligence tests for children and adolescents up to the age of 16 years (i.e. in the WPPSI and WISC tests). The results are shown in Table 1. The Forrest plot indicates a predominant but small male advantage, such that in 12 of the studies boys obtained higher average scores than girls. The weighted mean of the studies shows an advantage in favour of boys at .11*d*. However, the  $Q$  statistic clearly indicated heterogeneity in the sample ( $Q=57.15$ ,  $df=14$ ,  $p<.000$ ). Both age ( $Q=42.98$ ,  $df=6$ ,  $p<.000$ ) and test ( $Q=16.24$ ,  $df=3$ ,  $p<.001$ ) were identified as moderators, with the strongest effect due to age. The data show a fairly consistent trend whereby in the youngest age groups girls have an advantage, which is transformed into a male advantage with increasing age.

Our second meta-analysis applied the same techniques and logic to examine sex differences in 13 studies of the arithmetic subtest of the Wechsler intelligence tests for adults, i.e. in the WAIS tests (these data include a small number of adolescents above the age of 16 years). Cohen's  $d$ s and their weighted means, with 95% confidence intervals are shown in Table 2. Inspection of the Forrest plot shows that in all of the studies men obtained higher average scores than women, and in all cases the lower bound of the 95% confidence interval was greater than zero. The overall weighted mean of the studies is a male advantage of .467*d*. However, again the test of heterogeneity indicated the presence of moderator variables ( $Q=83.39$ ,  $df=12$ ,  $p<.000$ ). We found a major effect due to ethnicity ( $Q=48.51$ ,  $df=2$ ,  $p<.000$ ) and a somewhat smaller effect of type of test ( $Q=13.32$ ,  $df=3$ ,  $p=.004$ ). With regard to ethnicity, whereas the mean  $d$  for European and American samples is .47, that for East Asians is lower at .28 and that for South Asians is higher at .73.

## 3. Sex differences in digit span

In this section we present meta-analyses of sex differences among children and adults in the Wechsler digit span subtest. We have used the same techniques and logic as for the examination of sex differences in the studies of the arithmetic subtest. Sex differences in digit span in children and adolescents in the WPPSI and WISC tests are shown in Table 3. The overall Cohen's  $d$  shows a female advantage in digit span of .134 for children and adolescents, which contrasts with the small

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