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Sex differences in reasoning abilities: Surprising evidence that male–female ratios in the tails of the quantitative reasoning distribution have increased☆

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ABSTRACT

Sex differences in cognitive abilities, particularly at the extremes of ability distributions, have important implications for the participation of men and women in highly valued and technical career fields. Although negligible mean differences have been found in many domains, differences in variability and high ratios of males to females in the tails of the ability distribution have been found in a number of studies and across domains. A few studies have also observed trends over time, with some noting the decreasing ratios of boys to girls in the highest levels of mathematics test performance. In this study, sex differences in means, variances, and ratios were evaluated in four cohorts (1984, 1992, 2000, and 2011) in verbal, quantitative, and nonverbal/figural reasoning domains as measured by the Cognitive Abilities Test. Samples included US students in grades 3–11. Overall, the results were consistent with previous research, showing small mean differences in the three domains, but considerably greater variability for males. The most surprising finding was that, contrary to related research, the ratio of males to females in the upper tail of the quantitative reasoning distribution seemed to increase over time. Explanations for this finding are explored.

1. Introduction

Sex differences in cognitive abilities have long been a source of intense debate and concern among researchers. This is partly because of the implications of those differences for maintaining a strong workforce, particularly in mathematics-intensive fields (Ceci & Williams, 2006; Park, Lubinski, & Benbow, 2007; Wai, Lubinski, & Benbow, 2005), and partly because of the topic's inherently personal relevance and incendiary implications (Chipman, 1988; Eagly, 1995). Although research has established some areas of significant differences between men and women (e.g., mental rotation, mechanical reasoning, verbal memory, and spelling; Feingold, 1988; Kimura, 2004), research indicates that men and women have equal or nearly equal mean ability in general intelligence and many broad cognitive abilities (Ceci, Williams, & Barnett, 2009; Hyde & Linn, 2006). Despite this, many researchers have observed that men are disproportionately represented in both the top and bottom extremes of the ability distribution (Ceci et al., 2009; Feingold, 1992), giving rise to the variability hypothesis. The variability hypothesis proposes that men are more variable in their abilities than women in many domains and that a wider distribution, rather than mean differences accounts for the greater numbers of men at both the upper and lower extremes of the distribution of abilities (both general and broad; Feingold, 1992, 1994).[1] This hypothesis was proposed in early

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[1] Some researchers have augmented the variability hypothesis to claim that cognitive ability distributions are non-normal, with a discernible subpopulation of individuals (disproportionately male) with birth defects causing low cognitive ability (e.g., Johnson et al., 2008). This theory predicts greater numbers of males at the lower tail than the upper tail, but does not substantially affect the overall observation that men are overrepresented at the two tails of the distribution or change the impact that overrepresentation at the high end of ability has on the workforce in science and engineering fields.

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psychological research (see Feingold, 1992, and Johnson, Carothers, & Deary, 2008, for reviews) and has recently received more attention to explain male overrepresentation among elite math and science fields (Ceci et al., 2009).

In this study, I reviewed and extended a previous analysis (Lohman & Lakin, 2009) of male–female variability based on data from the Cognitive Abilities Test (CogAT; Lohman, 2011; Lohman & Hagen, 2001; Thorndike & Hagen, 1984, 1992) which measures verbal, quantitative, and nonverbal reasoning abilities for students in grades K–12 in the United States. The normative samples for each edition of the test were large and nationally representative, making the data appropriate for investigations of both means and variances. Lohman and Lakin (2009) examined male–female variance ratios and mean differences across grades 3–11 and three forms of the test administered in 1984, 1992, and 2000. However, they did not focus on changes in the distributions over time due to the limitations in identifying trends from only three data points. In this study, an additional cohort was added from the newest form of the CogAT that was administered to a nationally representative sample of US school children in 2011. This study focused primarily on changes in the ability distributions over time both in the overall sample and in the proportions of males and females in the highest and lowest levels of ability.

1.1. Previous research on secular trends in the variability of men and women

Researchers have accumulated evidence of secular trends in sex differences at the means of distributions of various abilities, with considerable evidence pointing to decreasing mean differences between men and women in many domains through the 1970s and 1980s (Feingold, 1988; Friedman, 1989; Hyde, Fennema, & Lamon, 1990). One notable exception (at least in the late 1980s) was a consistent male advantage at higher levels of mathematical achievement (Feingold, 1988). Despite this, the majority of domains studied were in decline, leading to a general belief that overrepresentation of men at the extremes of the ability distribution should also be diminishing. Group mean differences clearly influence overrepresentation at the extremes of the distribution, but must be understood independently of variability differences to account for overrepresentation at the extremes.

In a study focused on domains comparable to those of CogAT, Hedges and Nowell (1995) analyzed five large, nationally representative datasets that were collected from the 1960s to the early 1990s as well as the NAEP longitudinal trend data from 1971 to 1992 (1978–1992 for mathematics data). Most of the samples were gathered from high school aged students. In the large scale datasets, they found mean effect sizes of $d = -0.18$ to 0.0 (favoring girls) for reading comprehension, 0.03–0.26 (favoring boys) for quantitative measures, and -0.22 and 0.04 differences for nonverbal reasoning measures. These differences were consistent with later research, but showed no trends over time across testing programs. Likewise, the variance ratios[2] for the testing programs (besides NAEP) were consistent over time and with other research. Specifically, males were found to be more variable in almost all domains, with slightly greater differences in variability in quantitative domains (5 to 25% more variable) than reading (3 to 16%) and nonverbal reasoning (4 to 15%). In contrast, the NAEP testing program did show small trends in variance ratios over time. In their analyses of NAEP long-term trend data, Hedges and Nowell found that mean differences were consistent over time (approx. $d = 0.15$ from 1978 to 1992) and that variance ratios showed a slight, but consistent, increasing trend.[3]

Although studies of large, representative samples are critical to studying sex differences in the distribution of ability, complementary studies focused on the extremes of the distribution are also needed to understand the full distribution of the ability (Feingold, 1992) as well as to illuminate the male–female differences that exist among those competing in elite academic and professional fields (e.g., Benbow, Lubinski, Shea, & Eftekhari-Sanjani, 2000; Halpern, Benbow, Geary, Gur, Hyde, & Gernsbacher, 2007). Research has shown that increasingly elite levels of quantitative and spatial reasoning are associated with greater likelihood of engaging in STEM careers and creative occupational outcomes such as patents (Park et al., 2007; Wai et al., 2005). Thus, study of sex differences at high performance levels may illuminate sex differences in engagement with elite STEM fields.

In one of the few studies focused on longitudinal trends only on the right tail of ability, Wai, Cacchio, Putallaz, and Makel (2010) found that the differences in male–female ratios in the right tail have substantially decreased in mathematical ability between the early 1980s and early 1990s. Wai et al. (2010) analyzed an impressive dataset based on high-performing young students: the Duke University Talent Identification Program 7th grade talent search (Duke TIP; Putallaz, Baldwin & Selph, 2005). The Duke talent search recruits students who score in the top 5% on various school-administered standardized tests, which were administered as part of their school's regular assessment programs, to take the SAT or ACT in grade 7 in order to compete for a place in an enrichment program. Only students who responded to the opportunity to compete (and therefore completed the SAT/ACT) were included. Both the ACT and SAT were designed for use in college admissions among high school juniors and seniors and thus were expected to differentiate well among younger students with significant academic talents in one or more domains.

Wai et al. (2010) found a sharp decline in the ratio of males to females at the highest levels of mathematical ability (as measured by the SAT) among seventh grade students. In the early 1980s, the male–female ratio among the top 1 in 10,000 performers (0.01%) was an astounding 13.5:1 (13.5 boys for every 1 girl in the top 0.01%), but declined rapidly through the decade to remain stable at about 4:1 during the 1990s and 2000s. Wai et al. found that the ratio rapidly declined with less stringent cutoffs as well: In the top 1%, the ratio started at 1.4 in the early 1980s and declined to only 1.1 in the most recent cohort (2006–2010). For Wai et al.'s measures

[2] A variance ratio (calculated as the ratio of male variance to female variance) greater than 1.0 indicates that males were more variable than females. Feingold (1992) suggested that a variance ratio of 1.10 or greater would be of practical importance on these types of tests.

[3] Using the NAEP Data Explorer (National Center for Educational Statistics, no date), the trend can currently be extended up to 2008. The results indicate that mean differences continue on a similar trajectory and variance ratios continue to be somewhat elevated compared to the early 1980s.