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Sex differences in ability tilt in the right tail of cognitive abilities: A 35-year examination

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ABSTRACT

Sex differences in cognitive ability level and cognitive ability pattern or tilt (e.g., math > verbal) have been linked to educational and occupational outcomes in STEM and other fields. The present study examines cognitive ability tilt across the last 35 years in 2,053,265 academically talented students in the U.S. (SAT, ACT, EXPLORE) and 7119 students in India (ASSET) who were in the top 5% of cognitive ability, populations that largely feed high level STEM and other occupations. Across all measures and samples, sex differences in ability tilt were uncovered, favoring males for math > verbal and favoring females for verbal > math. As ability tilt increased, sex differences in ability tilt appeared to increase. Additionally, sex differences in tilt increased as ability selectivity increased. Broadly, sex differences in ability tilt remained fairly stable over time, were consistent across most measures, and replicated across the U.S. and India. Such trends should be carefully monitored given their potential to impact future workforce trends.

1. Introduction

The underrepresentation of women in high level science, technology, engineering, and mathematics (STEM) careers is widely researched and discussed. Given the importance of ensuring the full development of female talent for STEM fields (National Academy of Sciences, 2010), understanding the origins of and solutions to such underrepresentation remains an important area of inquiry. Although recent research suggests that female representation has been improving on many indicators (e.g., Ceci, Ginther, Kahn, & Williams, 2014; Miller & Wai, 2015), women still hold only about 7–16% of tenured faculty positions and < 30% of doctorates and bachelor's degrees in math-intensive fields (Ceci et al., 2014). Many interlocking factors have been proposed to explain this differential, including interests, encouragement, and bias (Ceci & Williams, 2010; Halpern et al., 2007; Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012).

1.1. *Ability differences in the extreme right tail of the distribution*

Another factor that has received substantial attention that may contribute to explaining female underrepresentation in STEM fields are differences in representation in the extreme right tail or top 5% to 0.01% of the distribution of math ability (Benbow & Stanley, 1980, 1983; Wai, Cacchio, Putallaz, & Makel, 2010), which may be linked to greater male variability in various aspects, such as personality (Borkenau, McCrae, & Terracciano, 2013), brain structure (Ritchie et al., 2017), and physical parameters (Lehre, Lehre, Laake, & Danbolt, 2008). Representation differences at these select ability levels may matter because even within the top 1% of math ability, higher scores at age 13 are related to significantly higher STEM educational and occupational outcomes decades later, including earning a STEM PhD, STEM publication, STEM patent, STEM university tenure, and having a job in a STEM field (e.g., Park, Lubinski, & Benbow, 2007; Wai, Lubinski, & Benbow, 2005). Although studies suggest that at least on some math measures females have improved their representation among top scorers in recent years (Makel, Wai, Peairs, & Putallaz, 2016), males continue to have higher representation in the right tail of math measures broadly and such a difference has been apparent for at least the last 35 years.

1.2. *Ability pattern or "tilt" differences in the extreme right tail of the distribution*

However, math abilities in isolation, especially relative to factors such as interests (e.g., Su, Rounds, & Armstrong, 2009), are likely a lesser factor explaining female STEM underrepresentation (e.g., Ceci et al., 2014; Miller & Wai, 2015). In addition to ability level, another factor that remains understudied is ability pattern or "tilt" in the

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extreme right tail of cognitive abilities. Ability tilt can refer broadly to the pattern and structure of multiple abilities within an individual or group. For the purposes of this study, we examine two abilities, math and verbal (e.g., math > verbal, or verbal > math). Ability tilt on the SAT and ACT college entrance exams predict college majors and jobs in STEM and other fields (Coyle, Purcell, Snyder, & Richmond, 2014; Coyle, Snyder, & Richmond, 2015) among general population samples. These findings have been proposed to support investment theories, the idea that investment in one area such as math relates positively to complimentary math and STEM outcomes, but negatively to non-complimentary verbal or humanities outcomes (Coyle, 2018).

1.3. Ability tilt predicts real world outcomes decades later

Additionally, because intra-individual discrepancies in ability scores appear larger for gifted students in the right tail of cognitive abilities in comparison to general population counterparts (e.g., Lohman, Gambrell, & Lakin, 2008), male-female tilt differences could have more salience for the academic, occupational, and creative pursuits for high ability populations. For students within the top 1% of ability, students who scored higher on math relative to verbal ability at age 13 (on the SAT) tended toward STEM occupations decades later, whereas students who scored higher on verbal relative to math ability at age 13 tended toward humanities occupations (Lubinski, Webb, Morelock, & Benbow, 2001; Park et al., 2007). Such trends have also been found in even more select samples of the top 0.01% (1 in 10,000 for their age group), where the pattern of ability, not just the magnitude of ability is associated with subsequent educational, occupational, and creative accomplishments (Kell, Lubinski, & Benbow, 2013; Makel, Kell, Lubinski, Putallaz, & Benbow, 2016). Moreover, individuals who score well in both math and verbal domains have been found to be less likely to pursue careers in STEM fields than individuals who only score well in math (Wang, Eccles, & Kenny, 2013). This same research showed that females are more likely than males to score well in both math and verbal domains, thus giving females “more options” than males in terms of what fields they may choose to pursue. These links between early scores in ability tilt and subsequent pursuits suggest that in addition to ability level, ability tilt should be considered when investigating female STEM underrepresentation.

1.4. Ability differences across time and across cultural contexts

Examining whether ability tilt differences between males and females have remained stable or changed over time and whether ability tilt is similar in different cultural contexts is important to assess given the link between tilt and long-term STEM outcomes. One cultural context in which females may particularly face biases and barriers is in India. Males outnumber females beginning at birth (Sen, 1992, 2003) and literacy rates favor males (UNESCO, 2014). Indian female representation in STEM careers remains low (Leggon, McNeely, & Yoon, 2015), and females tend to have low representation among the prestigious Institutes of Technology (Rao, 2015), though some have argued that highly educated females may be doing well in terms of high level STEM and business careers (Hewlett & Rashid, 2011). Makel, Wai, et al. (2016) showed that patterns across male-female math ability differences in the extreme right tail replicate across the U.S. and India, however, it has not yet been established whether male-female ability tilt (math vs. verbal) differences in the extreme right tail replicate across cultural contexts.

2. Present study

The current study examined math-verbal ability tilt in the extreme right tail at different ability levels, whether tilt changed over time across the last 35 years, and whether the pattern of math-verbal ability tilt is similar or different in the U.S. and India. Our basic research questions (RQs) are as follows:

- RQ1 : Are there sex differences in ability tilt in the right tail of cognitive abilities?
- RQ2 : Do sex differences increase as ability tilt increases (distance between math and verbal scores increases)?
- RQ3 : Do sex differences in ability tilt increase as ability selectivity increases (top 5%, top 1%, top 0.01% of academic ability)?
- RQ4 : Have sex differences in ability tilt changed over time?
- RQ5 : Do sex differences in ability tilt vary as a function of measure and cultural context?

3. Method

3.1. Participants

Data from the U.S. and India came from the Duke University Talent Identification Program (Duke TIP). To qualify for participation in the Duke TIP talent search, students must score in the top 5% on a within grade standardized test either on a composite score or relevant subtest. Students then take an above-level test. In the U.S., the above-level test is either the SAT or ACT; for the younger elementary aged students, the above-level test is the ACT EXPLORE test (hereafter referred to as EXPLORE). The full samples were as follows: SAT, 1981–2015, N = 1,343,890 (female = 673,756, male = 670,134), ACT, 1990–2015, N = 589,453 (female = 286,523, male = 302,930), and EXPLORE, 1996–2015, N = 119,922 (female = 57,002, male = 62,920).

For the Duke TIP India talent search, the above-level test is the ASSET test by Educational Initiatives. It is not a college entrance exam, but like in the U.S., 7th standard (7th grade) Indian students qualify for talent search participation by scoring at or above the 95th percentile on their regular grade-level tests. Then, in India, students took the version of the ASSET test designed and normed for typical Indian students in the 9th or 10th grade. Thus, the ASSET serves as an above level test with sufficient headroom capacity to capture the full spectrum right-tail of test scores in comparison to grade-level tests. Males outnumbered females in India roughly 1.74 to 1 in Indian talent search participation. From 2011 to 2015, there were N = 7119 Duke TIP Indian talent search participants who took the ASSET (female = 2595, male = 4523; and one student whose data were not included whose sex was not reported).

3.2. Data analysis approach

In this paper, we examined math-verbal ability tilt across multiple measures in the U.S. (SAT, ACT, EXPLORE) and India (ASSET), across multiple ability levels (full sample, top 1%, top 0.01%), and across time (SAT: 1981 to 2015; ACT: 1990 to 2015; EXPLORE: 1996 to 2015; ASSET: one time point grouping, 2011 to 2015). Given that the purpose of the analysis was to determine the relationship between *math/verbal ability tilt* and two independent variables (*sex* and *year*), a regression model was used (Faraway, 2014).

3.2.1. Dependent variable

This study modeled a dependent variable: *tilt*. *Tilt* was calculated by subtracting a student's verbal score from their math score (*tilt* = math − verbal). For the SAT this was simply SAT-Mathematics minus SAT-Verbal. For the ACT and EXPLORE tests, verbal composites were computed as an average of the Reading and English subtests (hereafter referred to as ACT-Verbal and EXPLORE-Verbal). For the ASSET test, tilt was determined by taking the difference between the ASSET-Math and ASSET-English (hereafter referred to as ASSET-Verbal).

3.2.2. Independent variables

Two independent variables were assessed in the model: *sex* and *year*.