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Breadth-Based Models of Women's Underrepresentation in STEM Fields: An Integrative Commentary on Schmidt (2011) and Nye et al. (2012)

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Abstract

Relative strength of math and verbal abilities and interests drive science, technology, engineering, and math (STEM) career choices more than absolute math ability alone. Having one dominant aptitude (e.g., for mathematics) increases the likelihood of a strong self-concept in that domain and decreases the likelihood of equivocation about career choices in comparison with individuals with equivalent mathematical aptitude who have comparable strength in non-math areas. Males are more likely than females to have an asymmetrical cognitive profile of higher aptitude in math relative to verbal domains. Together, these two points suggest that the academic and career pursuits of high math ability males may be attributable to their narrower options among STEM fields, whereas females' more symmetrical cognitive profile means their math and verbal interests compete in the formation of their ability self-concept and, hence, in their broader career choices. Such equivocation about STEM careers is in fact already evident in girls with high math aptitude as early as junior high school. Thus, we argue that asymmetry in interests and aptitudes is an underappreciated factor in sex differences in career choice. To the extent this is true, focusing on strengthening young women's STEM-related abilities and ability self-concepts to increase female STEM representation may be an unproductive approach; to increase representation, it may be more effective to focus on harvesting the potential of those girls and women whose breadth of interest and high ability spans social/verbal and spatial/numerical domains. The use of interventions that play to this greater breadth by socially contextualizing STEM is one potential solution.

Keywords

cognitive sex differences; STEM underrepresentation

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An issue as complex as women's underrepresentation in science, technology, engineering and math (STEM) is typically approached with level-based distinctions between factors (i.e., bottom-up biological effects to top-down sociocultural influences). But as developmentalists, we try to see all factors on the same plane within a common developmental trajectory in which interests, abilities, culture, stereotypes, role models, hormones, and choices dynamically interact and biological predeterminism gets lost on the way from bottom-up to top-down. Schmidt (2011) and Nye, Su, Rounds, and Drasgow (2012), the *Perspectives* articles we chose to focus on, could have been integrated in a number of ways in a more traditional, self-contained commentary. But within the bigger developmental picture of cognitive sex differences, STEM career development, and the alternative model of women's STEM underrepresentation elaborated below, these studies represent crucial links in a model that carries exciting implications for intervention. As such, we hope readers will excuse our less traditional approach to commentary.

The broader goal of this commentary is to bring attention to an alternative perspective on the nature of cognitive sex differences—that the "nature" of cognitive sex differences lies not in absolute ability, but in breadth of intrinsic interests—and its downstream developmental effects on interests, abilities, and career choices. A nascent but growing body of work is converging on this idea, and the findings of Schmidt (2011) and Nye et al. (2012) help fill inferential gaps in the new model.

These studies and the gaps they fill are described in detail below, but in brief the importance of Schmidt's study is that it disentangles interest from ability developmentally and supports the premise that interests precede ability. The importance of Nye et al. is that it shows that the topical nature of occupations and the context in which those topical skills are used in that occupation are actually two different factors, and important career decisions depend more on the combination of the two than on either individually. As we will see, this difference between topic and context—between skills and how those skills are used in a given occupation—is a subtle but significant distinction that may open new avenues for intervention. In the short term, though, we hope this commentary is a small first step toward broader consideration and synthesis of breadth-based models of STEM underrepresentation.

Ability Asymmetry: The "Real" Cognitive Sex Difference?

Wang, Eccles, and Kenny (2013) demonstrated that the decision to pursue a STEM career hinges on two things: (a) a high math ability (in their analysis of over 1,500 Project Talent 12th graders, only a tiny percentage of those lacking high SAT-M math scores went on to enter a STEM profession) accompanied by (b) relatively lower verbal ability (for similar demonstrations, see Wai, Lubinski, & Benbow, 2005; Wang & Degol, in press). Debates over causes of women's underrepresentation in STEM typically focus on the first factor. For instance, research has linked women's underrepresentation in STEM fields to their lower likelihood of scoring at the extreme right tail of the math and science distribution (e.g., with a handful of exceptions, males outnumber females among the top 1% of the math distribution by a 2:1 ratio, prompting some to opine that this is a reason they are underrepresented among mathematics PhDs—see Ceci & Williams, 2009; Ceci, Ginther, Kahn, & Williams, in press) and to their lower mean STEM-related ability self-concepts (e.g., Eccles, 2004). As a result of this emphasis on absolute math ability and the attendant math self-concept, intervention efforts have focused on strengthening young women's STEM-related abilities and associated ability self-concepts.

Wang et al. (2013), however, provided evidence that the second factor—math/verbal ability symmetry—may exert a greater influence on women's STEM entry than absolute math ability. As noted, among women with the high quantitative skills needed to pursue a STEM career, more of them (compared with men) possess equally strong verbal ability. Taken together, these two points imply that an important cognitive sex difference underlying female STEM underrepresentation may be breadth of ability across math and verbal domains. The sex difference in ability self-concept cited by Eccles, then, might be explained by the fact that any asymmetry between math and verbal ability coincides with stronger ability self-concept rather than a symmetrical ability pattern. The ability self-concept of high math ability men is bolstered by their asymmetry because they have a clear forte in math domains and, thus, no conflict in how they choose to devote their time and energy. In contrast, women with equally high math and verbal ability have no clear forte and thus an ambiguous ability self-concept. Concretely, it is as if a man reasons "I'm strong at math and plan to pursue a career that allows me to use this strength," whereas a woman who has both high math and verbal skills may not foreclose careers in law, psychology, veterinary medicine, or the humanities as her self-concept is broader.

This evidence supports a breadth-based model of female STEM underrepresentation that is gaining traction in the literature (e.g., Ceci & Williams, 2010). Valla et al. (2010) argued similarly, based on evidence that sex-dependent symmetry extends beyond math and verbal skills, including intrinsic interests in physical and social phenomena and facial emotion recognition and configural processing. As these sex-dependent symmetries predicted likelihood of being in a STEM major, the male flipside of the breadth-based model is suggested: that math talent narrows men's career options to STEM. Women's greater array of choices and men's narrow options together may play a larger role in women's STEM underrepresentation than do differences in math ability.

The implications of a breadth-based model of women's STEM underrepresentation cannot be overstated. If symmetry drives STEM career choices more than absolute ability in spatial/numerical domains, it would mean a misdirection of efforts focusing on strengthening young women's STEM-related abilities and ability self-concepts, as it means that many women who opt out of STEM majors and careers already have the ability and self-concept to succeed in STEM careers (as Lubinski and Benbow found, 1992, 2006); STEM fields are losing out to fields tapping the equally high social/verbal interests and abilities of these women.

The Nature of Asymmetry: Interests, Not Ability

Before a shift in intervention strategy can be justified, breadth-based models must show that abilities and interests can be developmentally disentangled. Sex-dependent ability symmetries may start with asymmetries in interests (Ceci, Williams, & Barnett, 2009; Valla et al., 2010), a causal pathway that Schmidt (2011) traced from interests to experience to knowledge to sex differences in technical aptitude. In a previous *Perspectives* article (Valla & Ceci, 2011), we hypothesized biological roots of the initial interests that start this developmental "snowball"—that brain organization effects of prenatal androgens, typically tied to later sex differences in ability, actually influence early, basic predilections—and suggested sex-dependent developmental trajectories of these effects as one way of reconciling conflicting evidence in the literature. Our review, however, focused on studies using an indirect, anatomical proxy measure of prenatal testosterone exposure: the 2nd-to-4th finger length ratio.

Evidence from the Cambridge Child Development Project has since found more direct support for these hypotheses using amniocentesis assays of prenatal hormones and longitudinal follow-ups. Auyeung, Lombardo, and Baron-Cohen (2013) found evidence indicating that prenatal hormonal influences sex-dependent social and physical predilections in infancy and childhood, including eye contact at 12 months, vocabulary size at 2 years, mental and affective language at 4 years, and gender typical play and theory of mind at 6 to 9 years.

More importantly for the present discussion, Auyeung et al. (2013) found that prenatal hormone exposure predicts early interest symmetries, with concomitant sex differences in social relationships and narrowness of interests, at 4 years and social and physical interests (*empathizing* and *systemizing*) at 6 to 9 years. They also review the growing body of evidence that prenatal hormone exposure predicts related sex-dependent neural organization, such as right-leaning hemispheric symmetry in males versus females and sex differences in grey matter volume in the temporo-parietal junction (a theory of mind-related region), and activation-related differences in sensitivity to facial emotions. The latter relationship between fetal testosterone and valance sensitivity also mediates behavioral approach tendencies—tendencies that, with time, become interests.

The Nurture of Asymmetry: Interests to Abilities to Careers

Schmidt (2011) argued that women's potential technical aptitude and job performance in technical fields is underestimated if one mistakes the long-term influence of technical interests for technical ability potential. When the gender gap in technical experience is closed, Schmidt argued, the gap in aptitude should follow suit. If such is the case, this justifies the distinction between interests and ability in breadth-based models and suggests that experience-based interventions can reduce aptitude gaps from the bottom-up by increasing underlying interest.

Yet increased interest and aptitude in specific skills is not enough to affect field choices. Nye et al. (2012) showed that the best predictor of occupational performance and persistence is not topical interest alone, but topical interest in combination with congruence between the individual and the occupation based on how these topical interests are utilized in said occupation. Two individuals may have equal interest and ability in spatial/numerical domains, but if one prefers application, their congruence with fields like civil engineering will be higher. These findings suggest, alternatively, that women choose social and biological sciences (where they comprise the majority of baccalaureates and PhDs—see

Ceci et al., in press) over more math-intensive STEM disciplines not because they are less interested in STEM, but because their preferences are more congruent with social and biological sciences—fields allowing women with equally high spatial/numerical and social interests to apply their skills in more socially influential ways than does, say, theoretical physics. This may help explain why the representation of women in fields like biological sciences and medicine is so much greater than in math-intensive STEM fields (National Science Foundation, Division of Science Resources Statistics, 2009). Perhaps the female STEM talent on our campuses would rather apply their spatial rotation skills to architecture and medicine than to engineering and computer science.

School-age girls' attitudes support this idea. By 14 years, girls report being less certain than boys that science has a positive societal influence, less certain that science can help solve environmental and social problems, more likely to think scientists are "uncaring," and more unsure of their interest in STEM careers (Bennett & Hogarth, 2009). The same study also found significantly greater interest in biology among girls and greater interest in chemistry and physics among boys. Supporting the congruence argument, girls' reduced interest in chemistry and physics was attributed to the fact that they "did not see the point" of these subjects in comparison with life sciences. By adolescence, social relevance may already be important to girls' STEM congruence.

Nye et al.'s (2012) congruence factor suggests interesting intervention possibilities, such as teaching STEM subjects using societal contexts (e.g., describing engineering low-energy water treatment devices for rural villages in Africa). Evidence supporting this approach already exists; gender gaps in attitudes towards chemistry and physics are reducible with the use of science-and-technology-studies-based (STS-based) teaching approaches, teaching standard topics within contexts of societal importance (Bennett, Lubben, & Hogarth, 2007). In comparison with standard chemistry curricula, STS-based curricula using contexts like essential elements of life and how medicines work produce greater reductions in attitude gaps between males and females. By conveying the social utility of fields in which the societal relevance is not as readily apparent as in life sciences (e.g., studying biology or medicine to treat AIDS is obvious to high schoolers), STS-based curricula play to girls' breadth. Even if increasing aptitude via experience-based interventions (as Schmidt's study suggests) does not affect technical interests per se, providing experiences using social contexts could foster technical interests indirectly.

Shortchanging the Role of Preference and Choice

The utility of a breadth-based model of women's STEM underrepresentation highlights a larger issue in the current debate: that personal interests and proactive choices deserve more consideration in research on STEM under-representation. Children have more say in the interests they are drawn to than we give them credit for, just as adults' career decisions are not all reactions to external influences.

Indeed, this issue of underestimating intrinsic agency goes beyond research on abilities and interests. For example, some have proffered a position that ignores women's interests and life choices and, as a consequence, misestimates the actual number of women who apply for tenure-eligible positions at Research I institutions, leaving the gap between the number of women who received PhDs and those who are hired to suggest, on the one hand, the need for gender sensitivity training of search committees (e.g., Handelsman et al., 2005), or, on the other hand, that women's representation reflects their presence in the hiring pool.

Neither suggestion is warranted, however, as both are based on the false assumption that the numbers of men and women in the PhD pipeline are the correct denominator for comparisons of sex differences in tenure-track hiring. Illustrative of this erroneous reasoning, some have framed the gap between the proportion of women in the PhD pipeline and the assistant professor and/or tenure-eligible pipeline in terms of so-called "utilizations" of female PhDs. Said reasoning is reflected in their use of the PhD pool and applicant pool interchangeably even though they are often not interchangeable. There are documented sex differences in the likelihood that PhDs will apply for assistant professor posts, particularly at research-intensive institutions (Ceci et al., in press; Williams & Ceci, 2012). If fewer female PhDs apply for research-intensive careers, it is not evidence of bypassing the female talent pool because the portion of that pool that desires academic jobs is smaller than their fraction of the total (male and female combined) PhD pool—sometimes much smaller. Although female PhDs are less likely to apply for tenure-eligible posts than their male PhD counterparts, when females do apply, they are more likely to be interviewed and hired.

The role of children in women's decisions to stay in a research-professor career track or opt out has been amply documented by Mason, Goulden, and Frasch (2009). They showed that once children—or even merely plans to have children—exist, women become more likely to opt out of the research professor pipeline. Women with no plans for children show opt-out rates comparable to men. This sex difference in opting out is very large in magnitude, often resulting in twice as many women dropping out of the fast-track academic market than their male counterparts. Basing arguments on utilization measures obscures this sex difference, leading to unwarranted conclusions about biased search committees. Support for this view comes from a number of sources, including studies of hiring and persistence in STEM fields by Kaminski and Geisler (2012) and the 2009 National Research Council (NRC) report, which demonstrates that if women apply for tenure track posts they are somewhat more likely to be invited to interview and to be offered the position; once hired they get tenure and persist as well as men in 8 out of the 9 fields examined by Kaminski and Geisler (2012). By attributing underrepresentation to biased hiring practices, utilization models diminish the importance of self-determination in women's career outcomes—in this case relegating a difficult, deliberate choice between family and career to passive victimhood.

Reasoning based on utilization of PhDs also ignores field-specific practices such as those in psychology, where women comprise over 70% of recent doctorates in clinical and counseling programs and men comprise the majority of doctorates in experimental and neuroscience programs. Clinically trained doctorates are far more likely to aspire to careers outside of academia, and as a group they have a lower rate of applying for tenure-eligible positions, thus resulting in search committees' seeming failure to utilize the female PhD pool. Consider a recent commentary in this journal:

> There are large disparities between women's shares of recent Ph.D.s versus assistant professors in some disciplines. The most notable is chemistry (32.4% recent Ph.D. recipients versus 21.2% assistant professors, giving 65% utilization), psychology (67.8% versus 48.5%, giving 72% utilization), and biological sciences (46.3% versus 35.0%, giving 76% utilization). In all other disciplines studied, the representation of women among assistant professors is over 88% of women among Ph.D. recipients (1996–2005). Although chemistry, psychology, and biological sciences have quite large representations of women in their hiring pools (32.4%, 67.8%, and 46.3% respectively), the underutilization is not merely a consequence of a large hiring pool. Other disciplines with high representations of women in their hiring pools have high utilizations, such as sociology (where women are 60.8% of recent Ph.D. recipients versus 56.1% of assistant professors, giving 92% utilization), political science (38.9% versus 37.0%, giving 95% utilization), and earth sciences (31.8% versus 28.2%, giving 88.7%). (Nelson & Brammer, 2010, p. 15)

Readers in psychology will immediately see the flawed reasoning here; psychology and sociology differ in their extra-academic employment prospects, with many more psychology PhDs never intending to train for academic careers than sociology PhDs and opting instead for clinical/counseling areas of psychology in which women dominate (area mental health centers, private practice, hospitals, schools). In terms of the breadth-based interest model, women's exodus from academic psychology may reflect the fact that clinical practice allows high math ability women to apply their empirical talents in a more directly socially influential way (interpersonally) than may be possible in academic psychology. Equating the number of PhDs awarded to women in a discipline with the number of women who actually choose to apply for academic positions in that discipline misses the fact that women who apply are often hired at rates above their fraction of the applicant pool.

Conclusion

Women's choices (e.g., to have children) and interests (equal parts social and mathematical) are part of the underrepresentation explanation and will help reveal the non-STEM contexts in which scientifically talented women may prefer to apply their talents. Schmidt makes a persuasive case that the male advantage in technical aptitude results from their greater interest in technical areas, which leads to their greater acquisition of technical knowledge and, in turn, leads to their greater technical aptitude in STEM areas. Interests rather than self-concepts are the primary driver; this is why Lubinski and Benbow (1992, 2006) found that fewer math-talented females choose STEM majors despite having very high math achievement and self-concepts. Recognizing the role of interests suggests interesting, novel and potentially fruitful interventions that can move us forward.

Efforts aimed at strengthening young women's STEM-related abilities and ability self-concepts are not likely to increase the numbers of women in STEM fields because this is not the cause of contemporary women's decision to opt out of the academy. Instead, the focus ought to be on harvesting the potential of girls and women who are equally skilled in both

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math and verbal domains, as they are the ones who have what it takes to succeed in STEM careers, but they are also the ones most likely shift away from STEM fields.

Although strengthening girls' math ability and confidence at earlier ages is a worthwhile endeavor, it is important to tap into the already existing potential of females who are both mathematically and verbally skilled. One way might include increasing these intellectually capable women's interest in math and science and ensuring they are well informed of the diverse options available in various STEM careers. Continual depictions of math and science careers having a beneficial impact on society and involving work with people may allow math-competent females to better equate the utility of these careers with their personal goals and values. Exposing math- and verbal-capable females to STEM role models during secondary school may also increase female interest in pursuing STEM fields.

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