

# Comment

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## Cognitive Sex Differences and Mathematics and Science Achievement

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Spelke (December 2005, p. 950) considered “three claims that cognitive sex differences account for the differential representation of men and women in high-level careers in mathematics and science.” The focus of this comment is on the claim regarding gender differences in mean levels of cognitive abilities. Spelke claimed (p. 954) that “most investigators of sex differences have concluded that males and females have equal cognitive ability, with somewhat different profiles.” There are two major components to this comment. The first is mainly theoretical, and the second is both theoretical and empirical.

The first component has to do with the basis for asserting that males and females have “equal cognitive ability.” The problem with this assertion is that since the early 1900s, modern intelligence researchers and theorists have documented extensively mean sex differences on many, if not most, cognitive ability measures. For some abilities, the differences between the sex groups is small (e.g., as in the case of abstract reasoning—see Lynn & Irwing, 2005), but for other abilities the differences are quite large (e.g., mechanical reasoning; see Halpern, 2000). As a result, whether males or females have higher mean general intelligence depends on the operationalization of the content of the tests selected to assess cognitive ability. Early test develop-

ers realized this problem but dealt with it in two strikingly different fashions. Yerkes, Bridges, and Hardwick (1915) concluded that these differences required separate norms for males and females:

We are fully convinced, however, that the accurate determination of norms for the sexes is eminently desirable, and we suspect that at certain ages serious injustice will be done to individuals by evaluating their scores in light of norms which do not take account of sex differences. (p. 73)

In contrast, Terman noted similar sex differences on the various subscales of his Stanford-Binet Intelligence Scale, but he decided that the differences in overall score were small enough to be ignored. Later refinements to the Stanford-Binet ensured equal mean IQ levels for boys and girls by eliminating individual scales in which large gender differences were found (see Terman & Merrill, 1937, p. 34). In other words, Terman’s IQ test was developed to yield equal mean scores by fiat, not by appealing to the underlying construct of a representative sampling of cognitive abilities. Cognitive ability tests can be constructed to yield equivalent means for males and females or to yield higher mean scores for either sex. Omnibus tests of cognitive abilities based on some extant theories of intelligence could easily yield such different outcomes. However, without a general consensus on what abilities make up the universe of cognitive abilities, it is impossible to ascertain whether males or females have higher levels of mean cognitive ability.

The other component of the comment has to do with the scope of the discussion. One particular aspect of the cognitive ability repertoire ignored by Spelke (2005), however, is critically important to the determination of success in advanced study in mathematics and sciences. The perspective is based on Cattell’s distinction between fluid intelligence (*Gf*) and crystallized intelligence (*Gc*)—see McGrew and Flanagan (1998). Tests such as the SAT-Math have a substantial involvement of *Gf* (e.g.,  $r = .64$ , see Ackerman, Bowen, Beier, & Kanfer, 2001), and tests such as the SAT-Verbal have a somewhat larger involve-

ment of *Gc* (e.g.,  $r = .78$ ). The involvement of *Gc* for both SAT tests involves mostly what Cattell called “historical” *Gc*, that is, educational and experiential content that was acquired some years before the test is administered. (The SAT-Math test does not assess, for example, calculus content). Current sex differences on the SAT may be of modest magnitude, as noted by Spelke. However, the major sources of career-relevant differences in cognitive abilities for science and math are not found on the *historical Gc* content of the SAT but are clearly indicated on tests of *current Gc* knowledge, such as illustrated in Advanced Placement (AP) test performance. In the most recent report of AP testing statistics (College Board, 2005), the gender differences on math and science performance are both stark and compelling, in terms of both numbers of students taking the tests and the number of clear “passing” scores. Although females completed 155,849 more AP tests across all content areas than males, more males completed the Calculus AB test (7,439) than females, and a higher percentage of males (43.8%) than females (35.5%) had clear passing scores (of 4 or 5). For Chemistry, the results are even more pronounced (males completed 4,989 more exams and had a clear pass rate of 38.7%, compared with 26.1% for females). For Physics B, males completed almost twice as many tests (29,183 vs. 16,068) and had a clear pass rate of 36.4% (vs. 22.4% for females). Without comparable amounts of AP credit, females are at a clear disadvantage compared with males in getting ahead when matriculating in postsecondary education.

Moreover, similar sex differences in current *Gc* and domain knowledge are found beyond high school (see, e.g., Ackerman et al., 2001). Most important, however, is the fact that *Gc*/domain knowledge is a significantly more important predictor of graduate school success and success in the profession beyond graduate school than are general math and verbal abilities (see, e.g., Kuncel, Hezlett, & Ones, 2001). Spelke (2005) may be right that sex differences in basic cognitive abilities do not explain the “differential representation of

men and women in high-level careers in mathematics and science” (p. 950), but the mean differences in current *Gc*/domain knowledge provide a much clearer picture of why there is such a differential representation. There are data that suggest that gender differences in personality, interests, and/or motivation account for some of the differences in domain knowledge (see, e.g., Ackerman et al., 2001), but that issue goes beyond the scope of Spelke’s (2005) article and this comment.

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## There Is More to Aptitude Than Cognitive Capacities

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Spelke’s (December 2005) critical review is a research-based rebuttal (though implic-

itly) of Summers’s (2005) speech that posited a hypothesis that one of the reasons why women are underrepresented in math, science, and engineering may be sex differences in *intrinsic aptitude* for mathematics and science. Putting aside the question of whether the empirical evidence was sufficiently reviewed, the way Spelke conceptualized aptitude as a static rather than a dynamic quality (namely, cognitive capacities) rendered her critique of the “differences in intrinsic aptitude” hypothesis less effective in many respects.

Spelke (2005) decided to focus on the question of “Do men and women have equal cognitive capacities for math and science careers?” (p. 950). This question represents a narrow, perform-on-demand view of aptitude, as aptitude concerns not only what one *can* do when given a task (i.e., capacity) but also what one *will* do (i.e., conation) and *how* one will do (i.e., strategy deployment and style) given a situation. For example, Spelke identified gender differences in strategy use and then dismissed them simply because strategy use does not reflect capacity and is correctable with instruction (p. 954). However, as Lohman (1994) pointed out, the seemingly innocuous strategic and stylistic differences in female students’ tendency to use phonological-sequential-string processing and male students’ tendency to use analog-image processing may in the long run handicap female students for learning advanced mathematics. Here, aptitude manifests itself as propensity, not capacity, and is nonetheless important for learning and performance as well as their developmental trajectory.

Spelke (2005) also decided to leave out affective dimensions such as preferences, motives, and attitudes and to focus exclusively on cognitive capacities. The question is, how much remains when the affective component is left out? For example, Spelke reviewed the literature on whether infants and toddlers show sex differences in their preferences for objects versus people. Such a preference, either way, is not an issue of cognitive capacity, but an affective and conative one, what Panksepp (1998) referred to as the “seeking system” (p. 144) of the brain. Before we know anything about “capacity,” affect has already made choices as to what is attractive in an array of stimuli. A more dynamic, contextual conception of aptitude is theoretically more viable because molar-level intellectual functioning in real-life contexts is never a mechanical switching on and off of some invariable perform-on-demand capacity, but rather a dynamic interplay of cognition (both automatic and

controlled processes), affect, and conation (Snow, Corno, & Jackson, 1996). Affect and conation regulate attention and cognition not only quantitatively but also qualitatively (Dweck, Mangels, & Good, 2004), and they sometimes transform cognition. John Stewart Mill, for example, asserted that males excel on tasks that “require most plodding, and long hammering at single thoughts” (quoted by Darwin, 1896/1972, p. 564). Empirical support (or the lack thereof) aside, most of us would agree that such “plodding” and “hammering” reflect a motivational disposition rather than a cognitive capacity. Yet it can deeply influence the nature of cognition and its related developmental trajectory.

It was not accidental that Spelke (2005) retained the term *intrinsic aptitude* (p. 950) that Summers (2005) used in his speech, *intrinsic* meaning *biological*. Much of the “intrinsic aptitude” that Spelke reviewed involves putative *biologically primary abilities* for mathematics, to use the distinction Geary (1995) made between biologically primary and secondary abilities. This is understandable under the neonativist and evolutionary psychology theoretical frameworks. However, as Geary pointed out, for the most part, mathematical learning involves biologically secondary abilities, which build on biologically primary abilities yet can only be nurtured through cultural provisions. Indeed, Spelke (p. 954) cited Geary’s research showing that girls’ mathematical reasoning can be improved by telling them to use spatial strategy. This finding suggests that aptitude is likely developmental in nature, subject to both genetic and environmental influences. If so, insistence on finding or denying biologically based “intrinsic” sex differences seems unproductive as a research fixation. A more productive approach is to identify what might constitute *inaptitude* for mathematical or scientific ways of thinking and, when such inaptitude, if any, emerges in females (or males for that matter), what instructional strategies may remedy the condition. Empirically, the claim that purely biologically based differences in abilities were measured and investigated is itself misleading. Most, if not all, of the cognitive abilities empirically known to us are developed, rather than innate, ones. Posing the question of sex differences in terms of “intrinsic aptitude” will inevitably lead to a simplistic yes-or-no answer, when aptitude likely reflects a complex interplay of nature and nurture.

By focusing on “intrinsic aptitude,” Spelke (2005) also neglected another important consideration; that is, aptitude is relative to the level of task demands. A