A Cognitive-Process Taxonomy for Sex Differences in Cognitive Abilities

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ABSTRACT—*Females and males show different average patterns of academic achievement and scores on cognitive ability tests. Females obtain higher grades in school, score much higher on tests of writing and content-area tests on which the questions are similar to material that was learned in school, attain a majority of college degrees, and are closing the gap in many careers that were traditionally male. By contrast, males score higher on standardized tests of mathematics and science that are not directly tied to their school curriculum, show a large advantage on visuospatial tests (especially those that involve judgments of velocity and navigation through three-dimensional space), and are much more knowledgeable about geography and politics. A cognitive-process taxonomy can shed light on these differences.*

KEYWORDS—*cognitive abilities; sex differences; academic achievement*

As Bob Dylan wrote in 1964, "The times they are a-changin'." Every industrialized country in the world is on the cusp of one of the most profound social changes in history, with women entering and, in some cases, dominating professions that have been primarily male, including law, medicine, accounting, and veterinary practice. But women have been slow to enter jobs that require strenuous physical labor, as well as jobs in the technical fields and the physical sciences, and far fewer men are entering traditionally female occupations, such as clerical work, or occupations that require direct personal care, such as child care.

Predictions about future trends in employment can be made by looking at the statistics for educational pipelines. A substantial majority of college students are women; American women have received more college degrees than men every year since 1982, and the gap is widening every year. Among persons between 25 and 34 years old, 33% of women have completed college, compared with 29% of men. In addition, women get higher grades in school in every subject area. Women are still enrolled disproportionately in the humanities, social sciences, and education (Willingham & Cole, 1997).

These changes in the work lives of women and men raise the question: Why are some fields, such as engineering and physics, still dominated by men, while others, such as business, economics, veterinary medicine, and accounting, are now majority-female fields (among young adults)? At the heart of this question is the basic search to understand how women and men are similar and different. For cognitive psychologists, this is a question about intelligence and the relationship among cognitive abilities, academic achievement, being female or male, and career choice.

THE POLITICS AND PSYCHOLOGY OF GROUP DIFFERENCES

The "battle of the sexes"[1] has assumed center stage in the classroom as popular writers have advanced different social agendas by declaring that there is a "war against boys" (Sommers, 2000) or that "schools shortchange girls" (American Association of University Women, 1992). Psychologists who are contemplating research into this emotionally charged topic will learn an applied lesson about the pervasiveness of the bias to prefer research findings that confirm hypotheses consistent with one's own worldview (commonly known as confirmation bias), as well as about the social psychology of research. There are many psychologists who believe that research into the many questions about sex differences should not be conducted because the results will be damaging to women. But it is only through careful research that psychologists can separate false stereotypes from those that have a basis in fact (i.e., are supported by statistical data). Of course, no research is ever free from bias, but research, even though it is imperfect, is the best method we have for understanding emotionally charged social issues. All research takes place in a sociohistorical framework that determines the questions asked, the research methods used, and, most important, how results are interpreted. If we required

[1]Some authors prefer to use the term "gender" when referring to female-male differences that are social in origin and "sex" when referring to differences that are biological in origin. In keeping with the psychobiosocial model that I am advocating and with the belief that these two types of influences are interdependent and cannot be separated, I use only one term here. The two terms are often used inconsistently in the literature.

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that research be free from bias, psychologists could never study important social issues.

What Is the Meaning of Differences?

A finding that two or more groups differ with respect to some variable does not mean that one of the groups is inferior, especially as is the case here, with differences found across many different types of measures, sometimes favoring males and other times favoring females. Perhaps even more important, differences are not immutable. It would be difficult to argue that our understanding of scientific issues would be better if research was censored or that the world would be better if all groups were the same. Girls and boys, and women and men, are both similar and different—it is a false dichotomy to ask if they are similar *or* different. The theoretically interesting questions concern the ways in which they are similar and different and the contexts and reasons for the findings.

Why Are We So Afraid of Differences?

The potential for misuse of research on differences is a legitimate concern, but there is greater potential harm for claims made in the absence of data. There is also concern that research on differences obscures and minimizes the many ways males and females are similar, so that people come to exaggerate differences and think of females and males as so dissimilar that it is as though they come from alien planets. But research has shown that most people understand the fact that the ranges of abilities (within-group variability) for males and females overlap, and, in fact, most people underestimate the size of female-male differences (Swim, 1994).

Jensen (1998) reviewed several cognitive-achievement tests that, unlike traditional tests of intelligence, were not written to yield equal scores for females and males. He concluded that there are no overall sex differences in intelligence, but he did find sex differences on several of the individual tests. It is important to note that there are many cognitive tests and academic indicators that show no difference in the academic achievement and cognitive ability of males and females, but there are also measures that show large and consistent differences favoring females, and still others that show large and consistent differences favoring males. The size and direction of the sex difference depends on what and how you measure. The emerging picture is complex, but there are consistencies across time and place that suggest that the sex differences in cognitive abilities and academic achievement are systematic and not due to random variance.

A COGNITIVE-PROCESS APPROACH

A useful taxonomy for understanding cognitive sex differences is based on similarities and differences in underlying cognitive processes and offers a more fine-grained analysis than a simple comparison that sums across all tests—an analysis that considers how information is retrieved from memory, the nature of the representation of meaning in memory, and what females and males, on average, do when they work on different types of cognitive tasks. Older rubrics for understanding differences between females and males grouped cognitive tasks as though they were topics in a typical school curriculum (e.g., verbal, quantitative, and visuospatial). By contrast, a cognitive-process taxonomy relies on the understanding that information is acquired, stored, selected, retrieved, and used, and that each of these component processes has its own probability of being successfully completed and can vary in processing speed. For example, working memory (the portion of memory that is actively involved in the immediate task being performed, e.g., in performing arithmetic or processing language while you are listening to someone or figuring out a route from a map) is separated into multiple component processing subsystems—phonological, visuospatial, and meaning subsystems—and information stored in memory has different representational codes—visuospatial and verbal. The following differences between females and males, most of which have been documented early in childhood and across all industrialized societies, can be understood using a cognitive-process approach. Cognitive processes are categorized in the taxonomy as favoring women or men on the basis of the results of the preponderance of empirical studies (Halpern, 2000).

Compared with men, women have more rapid access to phonological, semantic, and episodic information in long-term memory, and obtain higher scores on tests of verbal learning and the production and comprehension of complex prose. A writing test was added to the standardized tests for college admissions because writing is an essential academic skill needed for every discipline, and the female advantage on writing tests increased the number of females who receive scholarships. Psychologists who have argued that the female advantage in fluent retrieval (writing and speaking) is small have overlooked those abilities for which females show the largest advantages—writing, retrieval from long-term memory, and speech articulation. Girls have the advantage on quantitative tasks in early elementary school, when math involves learning math facts and arithmetic calculations, showing rapid memory retrieval similar to that needed in language production and comprehension, and in later grades they perform better than males on algebra problems when the cognitive components of the solution strategy are similar to those of language processing (Gallagher, Levin, & Cahalan, 2002). By contrast, males have the advantage on tests of verbal analogies, which may seem to be verbal but at a cognitive-process level involve mapping relationships in working memory.

Males have large advantages on tasks that require transformations in visuospatial working memory; sex differences are found by age 4—probably the youngest age at which this ability can be measured reliably. The difference between males and females on mental rotation tests is very large (close to 1 standard deviation), so large that many statisticians maintain that tests of statistical significance are not needed. Males also excel at tasks that require velocity judgments about moving objects, tracking movement through three-dimensional space, and aiming at a moving or stationary target, and they show a large advantage in their knowledge of politics and geography (Willingham & Cole, 1997). The global consistency in female-male cognitive patterns is shown in Figure 1, which compares male and female achievement in reading literacy, science, and mathematics in 33 countries.

The Advantages of a Cognitive-Process Taxonomy

A troubling problem for psychologists who want to understand cognitive sex differences is the fact that females achieve better grades in school and on tests in all subject areas when the material closely resembles what has been taught in school, but boys achieve higher grades on standardized tests if the test questions are not tied to any

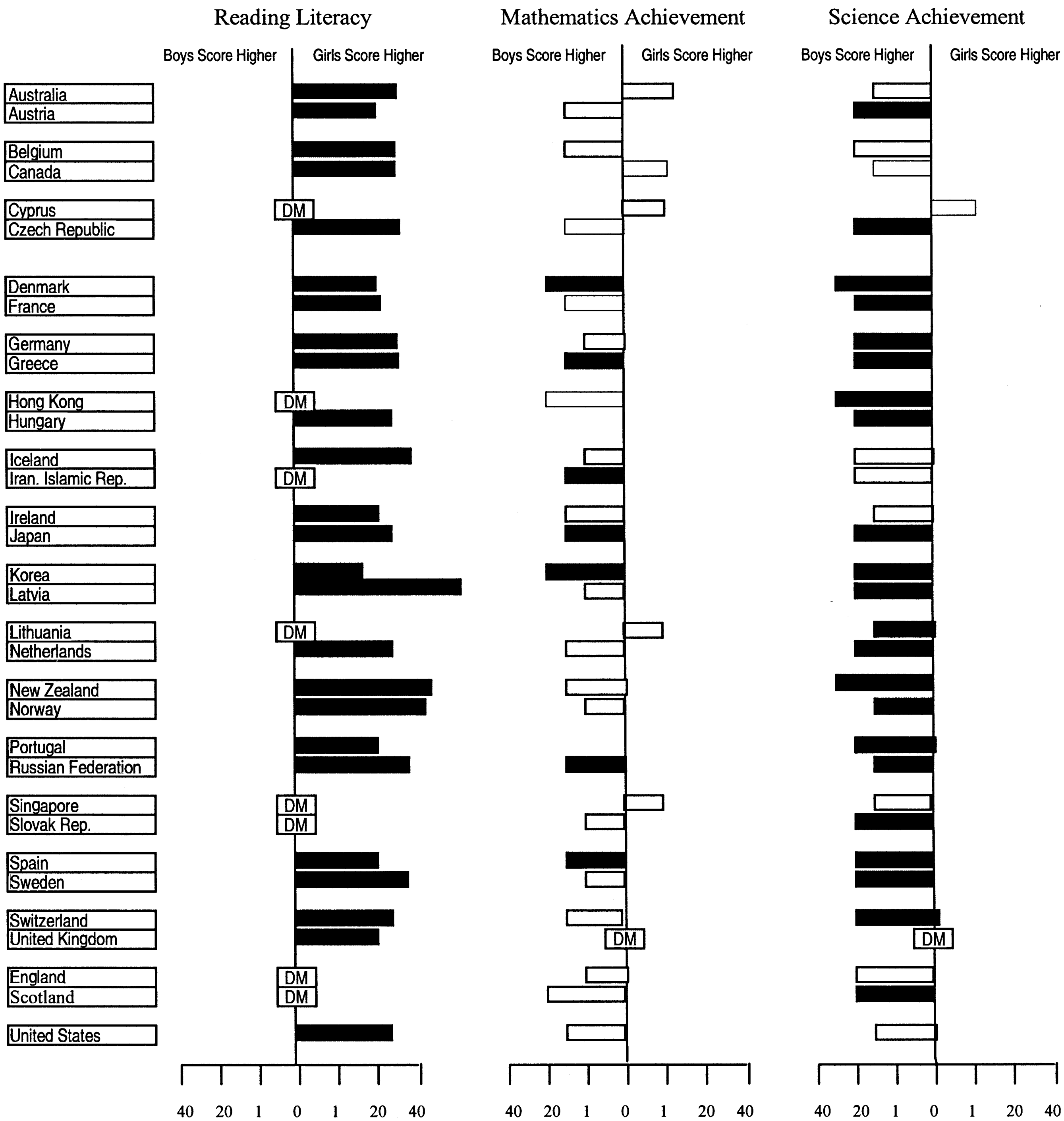

Fig. 1. Differences between male and female scores in reading literacy, mathematics achievement, and science achievement in 33 countries. The reading-literacy data are from 15-year-olds who participated in the Program for International Student Assessment (PISA; National Center for Education Statistics, 2002). The mathematics- and science-achievement data are from eighth graders who participated in The International Mathematics and Science Study (TIMSS; National Center for Education Statistics, 2000). Each bar represents the average score difference between boys and girls on combined tests. Black bars indicate statistically significant results. ''DM'' indicates missing data.

specific curriculum or in-class learning experience. These results can be partly explained by the fact that more women than men take advanced standardized tests like the Graduate Record Examination (GRE), so their overall mean on these tests would be expected to be lower than the mean for men (because the larger number of women test takers suggests that overall the group of women who take the tests is less select than the group of men who take them). However, this reasoning does not apply for tests taken by approximately equal numbers of females and males, for which similar results are found.

Kimball (1989) hypothesized that girls' learning is more rote than boys' learning, so girls' learning is assessed best with familiar problems, but this theory ignores the fact that writing is a highly creative act involving novel topics, and girls perform particularly well on writing tests. Other theories designed to explain why boys and girls have different (average) patterns of achievement depending on the type of test also overlook the fact that the differences are not easy to categorize. Other explanations have focused on learning preferences or styles. But girls' preference for cooperative learning activities and boys' preference for more competitive ones cannot explain the finding that girls and boys learn in a variety of classrooms and that differences are found as a function of the type of test that is used to assess learning and not as a function of the learning activities. The notion that girls perform particularly well in school because their temperament is better suited to sitting for long periods of time has achieved considerable popularity, but it is hard to see how the inability to sustain attention at a sedentary task would apply to students in advanced studies.

The cognitive-process taxonomy (Halpern, 2000) offers a solution to the puzzle of the mismatch between school grades and scores on standardized tests. In a recent study, Gallagher et al. (2002) examined cognitive patterns of sex differences in success at solving math problems on the GRE using the proposed cognitive-process taxonomy. They found the usual sex differences favoring males when there was an advantage to using a spatially based solution strategy (i.e., a strategy using a spatial representation), but not when solution strategies were more verbal or similar to the ones presented in popular math textbooks. Similarly, the usual male advantage was found with math problems that had multiple possible solution paths, but not problems that had multiple steps and therefore taxed working memory. Thus, the differences in the performance of males and females on GRE math problems lie in the recognition and selection of solution strategies and not in the load on working memory. Gallagher et al. found that average performance of different groups on standardized math tests can be minimized or maximized by altering the way problems are presented and the type of cognitive processes that are optimal for generating solutions.

The Psychobiosocial Model: Cause and Effect Are Circular

Psychologists and virtually everyone else who studies cognitive sex differences want to know the proportion of variability in performance that can be explained by innate (nature) or learned (nurture) variables. This is the wrong question because it rests on the assumptions that there are "true" values that exist "out there" for clever experimenters to discover and that variables can be divided into the mutually exclusive categories of "nature," "nurture," and their interaction. Research has shown that nature and nurture alter each other in sequentially interacting ways. What people learn influences the structure of their neurons (e.g., their branching and size); brain architectures, in turn, support certain skills and abilities, which may lead people to select additional experiences. Differences in the interests of females and males both derive from differences in the areas in which they have achieved success and lead to further differential success in these areas because of differential knowledge and experience. Learning is both a biological and an environmental variable, and biology and environment are as inseparable as conjoined twins who share a common heart. A diagram of this psychobiosocial model is shown in Figure 2.

Humans face pervasive and inescapable life experiences that teach appropriate sex roles and often punish violators. The influences range from explicit messages like the one spoken by that international

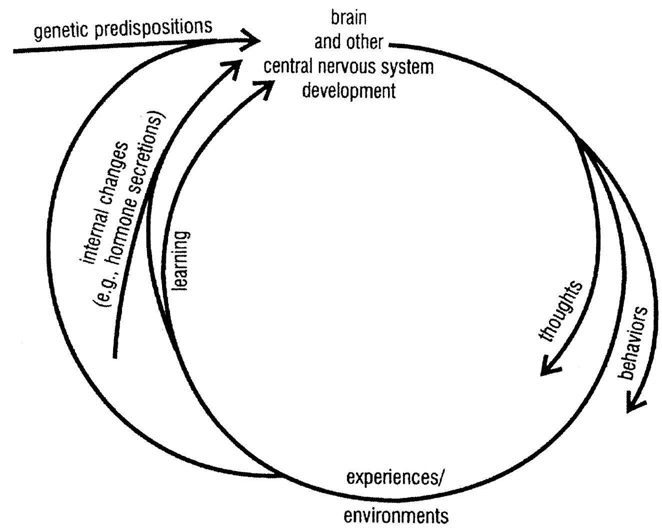

Fig. 2. A psychobiosocial model that can be used as a framework for understanding cognitive sex differences. It replaces the older idea that nature and nurture are separate influences and instead indicates that biological and psychosocial variables exert mutual influences on each other (graphically represented as a circle). From *Sex Differences in Cognitive Abilities*, 3rd ed. (p. 18), by D.F. Halpern, 2000, Mahwah, NJ: Erlbaum. Copyright 2000 by Lawrence Erlbaum Associates. Reprinted with permission.

spokesdoll for femininity, Barbie, who told little girls that "math is tough," to the implicit effects of common stereotypes that can depress test performance among members of groups that are expected to score low on a test (Steele, 1997), to the inductive lessons learned by realizing, for example, that the overwhelming majority of secretaries are female and engineers are male. But there is also considerable evidence for sex-related biological influences. The prenatal hormones that shape a fetus's developing genitals also influence the development of the fetus's brain in a female or male direction. Research has shown that cognitive abilities vary systematically over the menstrual cycle for women and over the daily and annual testosterone cycles for men (Kimura, 1996). Female-to-male transsexuals show changes in their results on cognitive tests from typical female patterns to typical male patterns soon after beginning cross-hormone treatments to prepare them for life as a man (Van Goozen, Cohen-Kettenis, Gooren, Frijda, & Van De Poll, 1995). Estrogen has a cumulative effect over a lifetime such that women who had greater exposure to estrogen (early menarche and late menopause) have higher scores on selected batteries of (mostly verbal) cognitive tasks than women with shorter exposures to estrogen (Smith et al., 1999), and gay men frequently show cognitive patterns that are more similar to those of females than to those of heterosexual men (Gladue, Beatty, Larson, & Staton, 1990). These effects have been confirmed using methodologically strong experimental designs with nonhuman mammals.

CAVEATS, CONCLUSIONS, AND CRITIQUES

There are still many unanswered questions about the cognitive abilities of females and males. Researchers do not know why girls and women excel on most long-term memory tests and why boys and men have the advantage on tasks with visuospatial components. The explanation that these differences are remnants from hunter-gatherer societies is appealing, but weak as an explanatory construct because any result can be explained post hoc, and the spatial skills used to solve math or physics problems are conceptually closer to those used for female-typical spatial tasks like weaving or fitting objects in small spaces than to those used to cross large distances. New work in testing shows that test scores can be manipulated by the way in which problems are posed and by whether there is an advantage to using verbal or visuospatial solution processes; these findings create new problems for researchers interested in test measurement (psychometricians), as well as for test developers.

What can we conclude from this complex picture? Given the seesaw nature of cognitive sex differences, there is no evidence that one sex is smarter than the other. Experimental results are based on group averages, and no one is average. Cognitive ability is a prerequisite for success in any field, but success depends on much more. Readers are urged to remember that everyone can improve in any cognitive area—that is the reason for education—and rapid changes in the proportion of men and women in some fields show that huge changes can occur across populations by changing educational opportunities and social expectations. People do not have to be the same to be equal.

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