Reconceptualizing Gender Differences in Achievement among the Gifted

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Introduction

Over the past 30 years, many of the unenlightened barriers preventing gifted women from achieving educational credentials and occupational status commensurate with their abilities have been removed. In many educational programs, comparable gender representation quickly ensued, especially in areas like law where many kinds of 4-year degrees are acceptable for admissions. Exceptional performances by women on bar exams, law school grades and honors followed, just as the protagonists who worked so hard to remove the aforementioned barriers had predicted all along. Gender-comparabilities in medical schools, both in representation and in performance, followed shortly thereafter. This trend served to reinforce further the well-grounded arguments for removing gender-discriminating educational barriers to begin with. That is, arguments initially stemming primarily from political–ideological concerns now became buttressed by economic *and* psychological justification: not only were women performing admirably in these areas, the disciplines themselves were benefiting from a more able student population. As a consequence of the greater number of women with exceptional academic credentials entering law and medicine, both disciplines have insured that their future leaders and practitioners will have greater competencies and sophistication.

With such progress in mind, the attention naturally has shifted to the physical sciences (our area of concentration), where pronounced gender disparities still remain (Dick & Rallis, 1991; Eccles & Harold, 1992; Maple & Stage, 1991). Could similar benefits accrue for these disciplines if more women entered and maintained a commitment to physical science educational/vocational tracks? Why has comparable representation in the math/science pipeline not been achieved? Have we completely removed from the physical sciences the barriers that previously prevented women from entering law and medicine? Are there factors unique to the math/science pipeline that discourage women from entering and excelling within it? These questions, among many others, are being investigated through our research. Here we focus specifically on factors relating to educational/vocational choice, exceptional educational/vocational achievements and gender differences within the gifted population. Our research, however, is also aimed at program experimentation and refinement of well-known educational interventions. That is, in working with intellectually talented students, individually and in groups, we attempt to find and provide environments wherein their talents can best blossom and come to their full fruition. Understanding what those environments consist of and learning how to provide them are two of the more central goals of our applied research. We shall draw upon that work as well.

Our work with mathematically and verbally precocious youth is particularly relevant to ascertaining the critical determinants of gender differences in math/science achievement. Noteworthy professional achievements in the sciences tend to be within the exclusive purview of the highly able—people located within the top few percentage points of the distribution of intelligence. Given this, our Study of Mathematically Precocious Youth (SMPY) provides a data bank especially well suited to speak to male/female differences in educational achievement and choice, inasmuch as it contains large proportions of individuals, of both genders, who possess

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the intellectual potential for educational and career excellence in engineering, mathematics and the physical sciences, as well as for a variety of other distinct professional careers.

It is the thesis of this chapter that the theoretical model guiding our research with the gifted, which is to be explicated, has implications for analyzing and better understanding the under-representation of women all along the math/science pipeline. Indeed, our empirical studies have revealed unique factors operating to preserve gender-disparities in math/science careers and these factors relate to choice. We propose here that gender differences in achievement are a reflection of choices and that these choices naturally emerge from a number of gender-differentiating attributes critical for a commitment to, and excellence in, math/science careers. Further, we suggest that it might be profitable to reconceptualize the professional and the public view of gender differences in math/science achievement, namely, as consequences of the different perspectives and personal qualities that males and females bring to situations.

In what follows, we shall draw on the longitudinal findings from SMPY to illustrate key antecedents to gender differences in the physical sciences. We shall first describe the design of our study and its theoretical framework. This is followed by a discussion of gender differences in actual achievement among the mathematically talented and some empirical findings involving gender differences on familiar as well as underappreciated variables critical for choosing to excel in math/science domains. Finally, we close with a brief discussion of the implications of our current state of knowledge and how these implications might be used to both guide and organize the direction of future research on gifted females (as well as males).

Study of Mathematically Precocious Youth (SMPY)

SMPY was founded by Julian C. Stanley in September 1971 at Johns Hopkins University and predicated on the philosophy of conducting research through service to intellectually talented students. SMPY was interested in first identifying adolescents who possess exceptional intellectual abilities and then to ascertain the factors that contribute to their optimal educational and vocational development. Special attention always has been devoted to math/science disciplines. One intervention, implemented from the start, was to provide these students, through acceleration and special classes, with better opportunities to develop their already exceptional quantitative skills. To facilitate the uncovering of other beneficial interventions and to answer basic research questions about intellectual giftedness more generally, SMPY established in 1972 a planned 50-year longitudinal study, now being conducted at Iowa State University. Through this study, which currently includes about 5000 talented individuals identified over a 20-year period, SMPY is beginning to bring into focus the factors that contribute to gifted students' educational, intellectual, personal, and vocational development.

Participants in SMPY were identified through a talent search, a concept developed by Stanley and initially limited to mathematical talent (cf. Cohn, 1991; Keating & Stanley, 1972; Stanley, 1973; Stanley, Keating, & Fox, 1974). The concept of a talent search has been refined over the past 20 years and extended from 450 students in 1972 to well over 140,000 on an annual basis and from a focus on mathematics only to include verbal and overall intellectual abilities. Yet the basic premise of the talent search has remained the same: students in 7th or 8th grade (12- to 13-year-olds) who are already known to have scored in the top 3% on national norms on standardized achievement tests (e.g., the Iowa Test of Basic Skills) administered routinely by American schools are invited to take the College Board Scholastic Aptitude Test (SAT) at regular administrations. The SAT measures mathematical reasoning (SAT-M) and verbal reasoning (SAT-V) ability and is designed for 11th and 12th graders who are planning to attend college. (This form of assessment is known as above-level testing (Stanley, 1990), inasmuch as the SAT was designed for students 4 to 5 years older than SMPY participants.) Nonetheless, the score distributions manifested by these gifted 7th or 8th graders are similar to those observed in random samples of high school students (Benbow, 1988; Keating & Stanley, 1972). It is through this mechanism, the talent search, that the SMPY subject pool for the longitudinal study was formed; all 5000 subjects, except for one group, were selected for high SAT scores that place them in at least the top 1% in intellectual ability. Although several "types" of gifted students are being studied, SMPY's emphasis has remained on the math/science disciplines.

SMPY's Longitudinal Design

Four SMPY cohorts of gifted students, initially identified at age 13, are being tracked longitudinally, as well as a fifth cohort comprised of graduate students in this nation's top math/science departments (see Table 1). Each cohort is separated by a few years. Collectively, the five cohorts span 20 years. Also, several comparison groups consisting of less able students are contained within the longitudinal study. Because the students in the first four cohorts were identified over a 20-year period, using the same criteria, our design allows us to assess historical influences to a degree (cf. Grinder, 1985). This is a great advantage. Lack of historical control is a problem associated with most longitudinal studies.

Another unique feature to the design of this present-day longitudinal study is the continued augmentation of Cohort 4, which is in the process of being formed. The influx of new students into the longitudinal study allows us to ask questions that were not possible in 1972 when the study began. The currency of the study is, therefore,

TABLE 1

The SMPY Longitudinal Study.
Its Cohorts of Subjects

Cohort	N	When identified	Age when identified	SAT criteria	Ability level
1	2188	1972–1974	12–13	Verb. ≥ 370 or Math ≥ 390	1%
2	778	1976–1979	12	Top 1/3 of Talent Search Participants	0.5%
3	423	1980–1983	<13	Math ≥ 700 Verb. ≥ 630	0.01%
Comparison Group		1983	12	SAT-M + SAT-V ≤ 540	5%
		1982	12	500–590 Math 600–690 Verb.	0.5%
4	≈ 750	1987	12	Math ≥ 500 or Verb. ≥ 430	0.5%

Cohort 5 includes 750 students enrolled in top-ranked graduate departments in the U.S. in various scientific disciplines; they were surveyed at age 23–25 in 1992.

maintained. Finally, as a validity check on our selection procedures, as well as enhancing the longitudinal design features of SMPY, we are conducting a retrospective study of the characteristics and developmental paths of graduate students in the top math/science departments in the U.S. As noted earlier, this is our Cohort 5. Do such students differ in substantive ways from the students in the SMPY longitudinal study? If so, we soon will be in a position to detect how.

Thus, over 5000 students are currently participating in the SMPY longitudinal study and soon will increase to over 6000. All of the students in the five cohorts are being surveyed at critical junctures throughout their youth and adult lives. Moreover, each cohort will be surveyed at the same age to ensure developmental comparability of our cross-cohort findings. This serves as a rough sketch of the composition of the SMPY database and how it constructed.

The Theoretical Structure Guiding SMPY Research

The conceptual framework for our research draws on three already existing theoretical perspectives (e.g., Dawis & Lofquist, 1984; Tannenbaum, 1983, 1986; Zuckerman, 1977). We also incorporate some of what is already known about the development of talent and personal preferences for contrasting educational/vocational paths. Primarily, our work is based upon a well-known model of vocational adjustment, the Theory of Work Adjustment (TWA), a model that has been developed over the last 30 years by Rene V. Dawis and Lloyd H. Lofquist (Dawis & Lofquist, 1984; Lofquist & Dawis, 1969, 1991) at the University of Minnesota. One especially attractive feature of this model is that it is readily extended to critical antecedents of vocational adjustment, such as choosing a college major.

According to TWA, to assess optimal learning and work environments it is useful to parse an individual's work personality and the environment into two broad, but complementary, subdomains. An individual's work personality is primarily comprised of his/her: (1) repertoire of specific skills or abilities and (2) personal preferences for the content found in contrasting educational/vocational environments. In contrast, different environmental contexts (educational curricula and occupations) are classified in terms of: (1) their ability requirements and (2) their capability to reinforce. Optimal learning and work environments are then viewed as requiring two levels of correspondence, labeled *satisfactoriness* and *satisfaction*.

Satisfactoriness denotes the degree of correspondence between abilities and the ability requirements of a particular environment (viz., occupation or educational curriculum), whereas satisfaction denotes the degree of correspondence between the preferences and the types of reinforcers provided by an occupation or educational track. Collectively, satisfactoriness (how the environment will respond to the individual) and satisfaction (how the individual is likely to respond to the environment) are useful for predicting the length of time individuals are likely to remain in various educational or career tracks. They are continuous as opposed to discrete concepts and one's psychological adjustment to any given environment at any point in time is, to a large degree, a joint function of these two broad correspondence dimensions (see Figure 1). One implication of the model is that assessing the environment

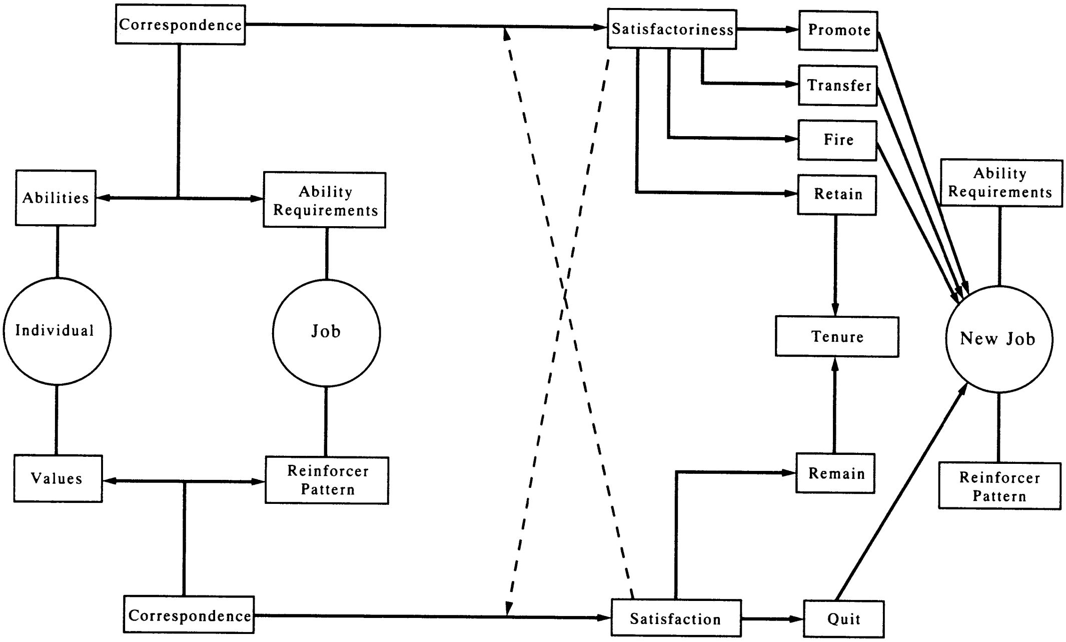


FIGURE 1. The theory of work adjustment — a depiction

for its requirements and reward capabilities is just as important as assessing the individual's learning and work personality (i.e., abilities and preferences). This model also stresses the importance of assessing *both* abilities and preferences, *concurrently*, to ascertain the readiness of a given individual for a particular educational or career track (cf. Lubinski & Thompson, 1986).

Personality Structure: Assessing Critical Dispositions for Learning Readiness and Efficient Work

ABILITIES

Before assessing abilities, one needs to determine how intellectual abilities are best conceptualized. There is actually a remarkable degree of consensus that intellectual abilities are quite adequately depicted by Guttman's (1954) early formulation of the Radex (cf. Ackerman, 1987; Carroll, 1985; Humphreys, 1979; Lubinski & Dawis, 1992; Snow et al., 1984); a Radex representation of intellectual abilities, taken from Snow's work, is provided in Figure 2. In this organization, cognitive abilities are differentiated along two dimensions, *complexity* (viz., sophistication of the intellectual repertoire, general intelligence, or "*g*") and *content* (viz., lower-order factors composed of three relatively distinct symbolic systems: verbal/linguistic, numerical/quantitative and spatial/pictorial). Both are important to assess. In our work with the gifted, for example, we have found it useful to assess the complexity dimension to determine the extent to which educational acceleration is warranted (to provide a more correspondent learning environment), plus lower-order factors to ascertain the precise nature of the acceleration required (thus providing a more individualized and optimal learning environment, responsive to students' unique strengths). Different "types" of gifted students, for example, verbally vs. mathematically precocious, assimilate certain course work at different rates and more optimal learning transpires if curricula are responsive to such individual differences.

PREFERENCES

In our research (and as part of our summer programs), the assessment of personal preferences is teamed with ability assessment to paint a more comprehensive picture of the unique aspects of each student and of how these features of their personality might factor into educational and career decision making. Students also have found this information useful in considering educational and career possibilities with high school counselors and parents. Two of the more useful schemes for analyzing educational/vocational interests and values are Holland's (1985) hexagon (consisting of **I**nvestigative, **A**rtistic, **S**ocial, **E**nterprising, **C**onventional, and **R**ealistic vocational interests; see Figure 3) and the Allport, Vernon, and Lindzey's (1971) Study of Values (SOV), which is comprised of six value dimensions (or evaluative attitudes), sharing appreciable

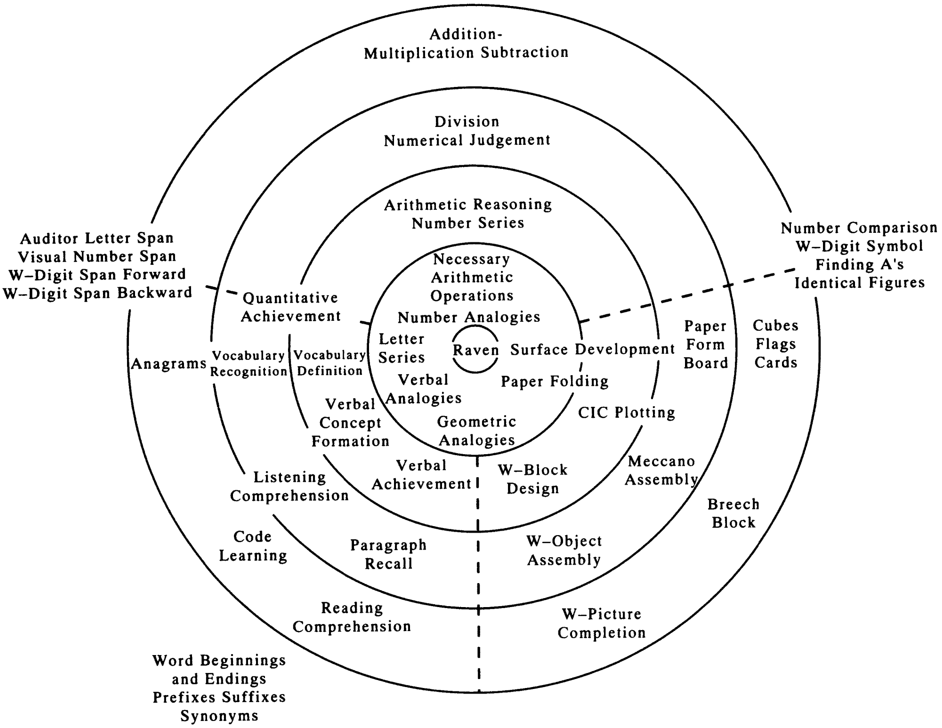


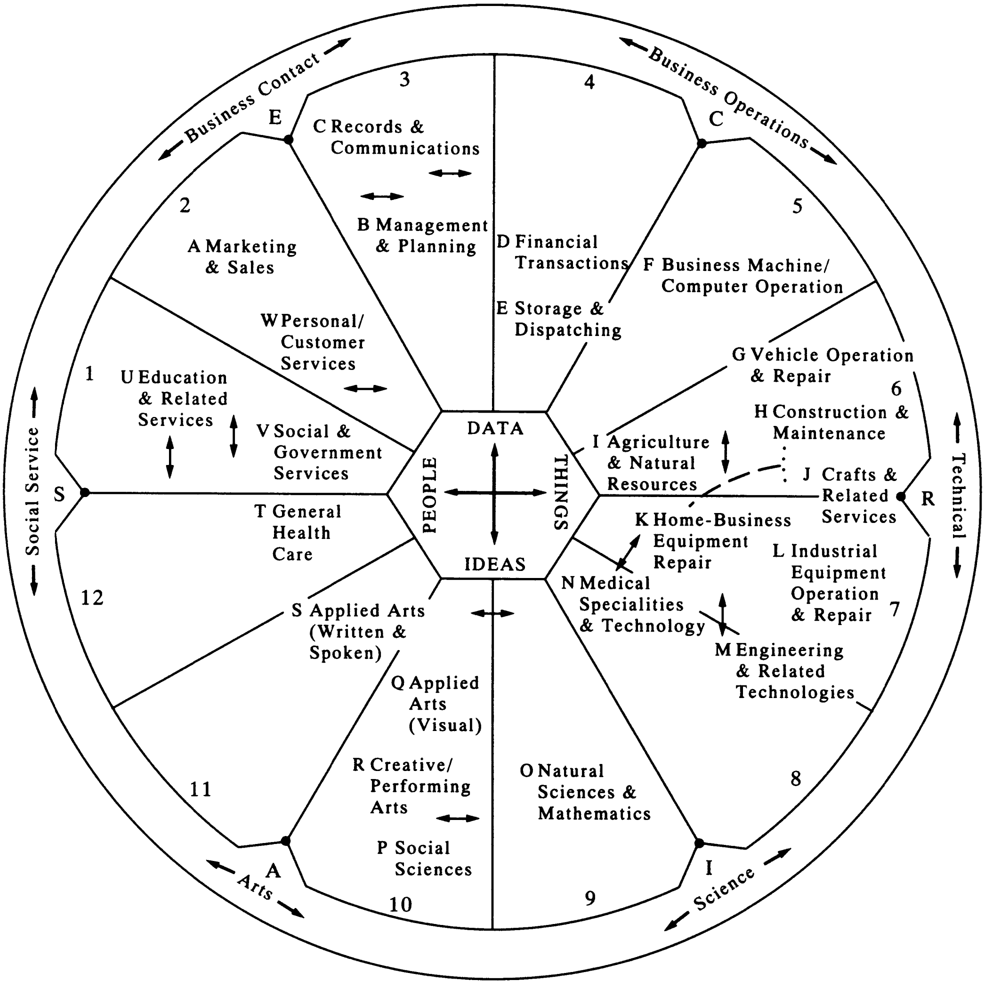
FIGURE 2. Hypothetical radex map showing suggested ability and learning simplexes and the content circumplex “w” identifies subtests of the Wechsler Adult Intelligence Scale. (After Snow, Kyllonen & Marshalek, 1984.)

overlap with Holland’s model (viz., theoretical, esthetic, social, economic, religious, and political). We assess these attributes as they are useful for identifying optimal learning environments (those likely to be most enjoyable and rewarding) for gifted students of comparable abilities but who differ in nonintellectual attributes ultimately related to career choice.

Environment Structure: Assessing Critical Features of Environmental Ecologies for Learning and Work

Up to this point we have talked about the personality structure of the individual (abilities and preferences). School and work environments also can be analyzed using analogous dimensions. Educational/vocational environments may be construed as molecular ecologies defined by: (1) their capability to reinforce certain preferences and (2) the response requirements (or the abilities) that they demand of individuals. In physical science environments the response requirements particularly involve high mathematical and spatial/mechanical reasoning abilities but also strong verbal ability, while investigative interests and theoretical values are among the most salient personal preferences for gravitating toward scientific environments, finding the content of these disciplines reinforcing (for developing one’s intellectual talent) and maintaining a commitment toward such disciplines (Dawis & Lofquist, 1984; Holland, 1985; Lubinski & Benbow, 1992; MacKinnon, 1962; Roe, 1953; Southern & Plant, 1968). These environments require intense abilities and preferences for manipulating and working with sophisticated things and gadgets for lengthy periods of time. Individuals with pronounced or relatively higher social values (or stronger need for people contact), in contrast, are not as readily reinforced in such environments.

The above is what we and others have found to be the person–environment correspondence structure for engineering and the physical sciences (Dawis, 1991; Dawis & Lofquist, 1984; Lubinski & Benbow, 1992; Holland, 1985; Roe, 1953). Although students are not formally selected for advanced scientific training based on their theoretical values, their investigative interests, or their spatial and mechanical reasoning abilities (but they are on mathematical reasoning ability), they appear to self-select scientific careers based on all of these attributes, whether they are explicitly aware of their abilities and preferences or not (Humphreys, Lubinski, & Yao, 1993). Moreover, an individual will remain in the sciences to the extent that congruence is established between (1) his/her abilities and preferences and (2) the skill requirements and reinforcers provided by the scientific environment, respectively. Satisfaction



- The World-of-Work Map arranges job families (groups of similar jobs) into 12 regions. Together, the job families cover all U.S. jobs. Although the jobs in a family differ in their locations, most are located near the point shown.
- A job family's location is based on its primary work tasks–working with DATA, IDEAS, PEOPLE and THINGS. Arrows show that work tasks often heavily involve both PEOPLE and THINGS (↔) or DATA and IDEAS (↕)
- Six general areas of the workworld and related Holland types are indicated around the edge of the map. Job Family Charts (available from ACT) lists over 500 occupations by general area job family, and preparation level. They cover more than 95% of the labour force.

FIGURE 3. World of work map

(need–reinforcer correspondence) *and* satisfactoriness (ability–ability requirement correspondence) are essential for optimal intellectual development; achieving both is the central goal of SMPY's programmatic work with gifted youth.

OPTIMAL EDUCATIONAL CORRESPONDENCE FOR THE EXTREMELY GIFTED

A proper response to this topic requires, first of all, a full appreciation of the range of interventions that need to be considered when creating optimal learning environments for the exceptionally gifted. That is, if giftedness is arbitrarily defined as being in the top 1%, individual differences in IQs among the gifted range from approximately 135 to over 200 (roughly one-third of the entire IQ range). Paralleling this vast ability range is an equally wide spectrum of ideal learning environments. Because learning environments can range from discorrespondent to optimally correspondent, a key component of our research is designed to uncover unique ways to enhance the learning experiences and intellectual development of the *exceptionally* able—to make it as optimally correspondent as possible. We suggest that the work of Harriet Zuckerman (1977) provides clues for how to enhance educational correspondence among the exceptionally able. For this part of our thinking, we blend Zuckerman's theory on the accumulation of advantage with Tannenbaum's (1983, 1986) work on the critical elements for world-class achievement.

Zuckerman (1977) studied the career paths of Nobel Laureates and occupants of the "forty-first chair" (scientists generally acknowledged to have done research of Nobel prize quality, but not awarded the prize). These individuals almost universally show promise extremely early in their careers and this evidenced precocity appears not only to respond to but also to create greater opportunities for intellectual development. For example, most Laureates receive an advantage in graduate work by attending the most distinguished universities (10 universities produced 55% of the laureates) and by studying with the best minds of the day—other Nobel Laureates or occupants of the 41st chair—thereby begetting a pattern of eminence's creating eminence. Zuckerman claims that the development of scientific taste, standards and self-confidence are the most beneficial results of the Laureate's apprenticeships (cf. Julian C. Stanley, 1992).

Moreover, future Noble Laureates obtain degrees and start publishing earlier and more copiously than other scientists. Soon, by the quality of their scientific contributions, they become distinguished from their age-equivalent peers. This opens up further opportunities for their development. Zuckerman suggested that the descriptions of Nobel Laureates' careers fits well with the model of "the accumulation of advantage: the spiraling of augmented achievements and rewards for individuals and a system of stratification that is sharply graded" (p. 249). Moreover, almost all future Nobel Laureates were "active" in creating this beneficial environment (cf. Scarr & McCartney, 1983).

Thus, among the gifted, it would seem that those who have the personal potentialities for manifesting exceptional achievement require special encounters with the appropriate environment to facilitate the emergence of world-class accomplishments. Consistent with this view, Bloom (1985) noted from interviews of talented performers in a variety of disciplines that special experiences, sometimes interventions, are important for the development of talent. Moreover, Tannenbaum (1983, 1986) postulated that great performance or productivity results from a rare blend of superior general intellect, distinctive special aptitudes, the right combination of nonintellectual traits, a challenging environment and the smile of good fortune at crucial periods of life. (The first three components seem to parallel the abilities and preferences discussed in the Theory of Work Adjustment and the latter two the work of Zuckerman.) According to Tannenbaum, success depends upon a combination of facilitators, whereas failure may result from even a single deficit. By virtue of its "veto" power, then, every one of the five qualifiers is a necessary requisite of high achievement and none of them has sufficient strength to overcome inadequacies in the others.

The above discussion presents the scaffolding for our work on the dispositional determinants of contrasting educational/career paths of the gifted and, thus, leads to the conclusion that individuals who are ideally suited for careers in the physical sciences are gifted individuals with highly developed mathematical and spatial/mechanical reasoning abilities and intense investigative/theoretical preferences. It is these individuals who will *choose* careers in the physical sciences and engineering and remain committed to them. Gifted individuals with other ability and preference profiles will choose careers in other areas. Given this line of reasoning, a natural consequence of educational and career counseling based on abilities *and* preferences will be disparate male/female ratios in academic and vocational choices, not only in the math/science disciplines but other disciplines as well. Moreover, these differences should intensify at the higher educational levels. Evidence supporting these conclusions is presented next.

Gender Differences in Abilities/Preferences: Their Implications According to TWA

Abilities

Recent reports seem to indicate that certain gender differences in cognitive abilities are steadily diminishing in normative samples (Feingold, 1988; Hyde, Fennema, & Lamon, 1990; Rosenthal & Rubin, 1982). That is, males and females appear to be converging toward a common mean on a variety of intellectual abilities. These trends, however, have not been noted among the most able (Benbow & Lubinski, 1992, in press; Benbow & Stanley, 1980, 1983; Lubinski & Benbow, 1992; Stanley et al., 1992). Among the gifted, there are sizable gender differences at age 13, favoring males, in mathematical reasoning and in spatial and mechanical reasoning abilities—the very abilities required of the physical sciences. Moreover, at the end of high school and college, these differences remain and accompany gender differences favoring males in math/science achievement test scores (as well as other test scores), whereas females tend to do slightly better than males on a number of verbally oriented achievement tests (Stanley et al., 1992). Before profiling these differences in some detail, we will address first the question: how can normative male/female means be converging while gender differences among the gifted remain pronounced? There are at least two possible explanations and probably both operate to a degree: test construction practices and gender differences in ability dispersion.

First, Stanley et al. (1992) have remarked that it is difficult to assess changes in group performance on cognitive tests over the last few decades, inasmuch as a number of test publishers may have routinely culled from their instruments items that characteristically generate the most conspicuous gender differences—a procedure that some refer to as correcting for "gender bias" or "equity in testing." Thus, it is possible that the apparent convergence of male/female group means is due to test construction practices as much as, or perhaps even more than, a genuine change in the cognitive attributes purporting to be assessed by these measures.

Second, if *meta*-analytic reviews are indeed detecting a degree of genuine gender-convergence, consumers of *meta*-analytic reviews must keep in mind that this methodology provides information only on group differences in *overall level* of the attribute under analysis. *Meta*-analytic reviews do not provide information on group differences in other statistics such as those indexing ability dispersion. There are other parameters on which the genders can differ and a critically important one is *variability* (cf. Benbow, 1988).

Many lines of evidence have converged to suggest that males are more variable than females on a variety of intellectual variables and, interestingly, this appears to hold even for variables on which females have superior means. This phenomenon has been observed over several decades in normative samples (cf. Feingold, 1992; Lubinski & Benbow, 1992; Lubinski & Dawis, 1992; Lubinski & Humphreys, 1990a, 1990b). Table 2, for example, consists of data from Project TALENT (Flanagan et al., 1962). Project TALENT contains data from a stratified random sample of U. S. high schools, collected back in 1960; this data bank contains four grades of students, 9 through 12, with approximately 100,000 students in each grade. A number of ability and preference measures were administered to these students over the course of several days of testing. Four composite measures (viz., English language, spatial visualization, mathematical reasoning, & general intelligence) are assembled in Table 2; each mean and standard deviation represents approximately 50,000 subjects. It is clear that even for the English language composite, on which females are clearly superior as a group, the males across all four grades were more variable on this measure as well as all the others.

A more contemporary example is provided by Stanley

TABLE 2

Means and Standard Deviations for Four Ability Composites. From Project TALENT for Grades 9–12 by Gender

	English language		*Mathematics*		*Spatial*		*Intelligence*	
	M_x	S_x	M_x	S_x	M_x	S_x	M_x	S_x
Grade 9								
Females	87.65	17.29	15.35	6.43	60.15	20.07	145.36	52.58
Males	79.51	18.11	16.01	6.98	69.18	22.54	142.48	54.22
Grade 10								
Females	92.29	17.43	16.65	7.08	63.42	20.80	157.35	52.69
Males	84.37	18.12	18.05	7.65	74.45	22.77	156.40	54.27
Grade 11								
Females	96.63	16.91	17.77	8.02	66.22	20.94	169.97	52.13
Males	89.28	17.89	20.69	8.90	79.01	22.96	173.56	53.95
Grade 12								
Females	100.27	16.55	18.60	8.15	68.49	21.31	180.08	51.56
Males	92.73	17.56	22.46	9.32	82.35	23.31	184.98	53.82

Sample sizes for each cohort by gender follow: grade 9, females = 49,393, males = 49,968; grade 10, females = 47,119, males = 48,543; grade 11, females = 45,428, males = 43,851; grade 12, females = 40,116, males = 38,392. Detailed descriptions of these ability composites may be found in Lubinski and Humphreys (1990a).

et al. (1992). These investigators again report that males tend to be more variable on measures of cognitive functioning, including tests for which females have higher means. For example, Stanley et al. (1992) noted that the largest gender difference favoring females on the Differential Aptitude Test (DAT) is observed in DAT-Spelling. Grade 12 females score approximately .5 standard deviations above the males on this measure. Alternatively, one may state that only 30% of males score above the female mean; yet, because of greater male variability, there is a comparable male/female proportion among students within the top 1% in "spelling talent." This finding and the general phenomenon of gender differences in ability dispersion has important implications for understanding male/female differences at exceptional levels of achievement (cf. Lubinski & Dawis, 1992). When assessing gender differences in achievement among the gifted, it is the upper tail of the ability distribution that we are evaluating; and this upper tail contains an inordinate number of males. Moreover, gender differences in dispersion and level often operate in concert to produce especially disparate male/female ratios at the extremes, as we will illustrate next by returning to SMPY's work with the mathematically talented.

In nationwide talent searches in the U.S., discussed previously, gifted students taking the College Board Scholastic Aptitude Test (SAT) have consistently generated the following pattern of scores. Gender differences in SAT-V are typically small. Yet on SAT-M the difference between means approximates .4 standard deviations, favoring males, and males are more variable than females. Together, these gender differences in level and dispersion produce the following male/female ratios for these 12- to 13-year-olds: SAT-M – 500 (average score of college-bound 12th-grade males), 2:1, SAT-M – 600 (83rd percentile of college-bound 12th-grade males), 4:1, and SAT-M – 700 (95th percentile of college-bound 12th-grade males), 13:1 (Benbow & Stanley, 1983). Comparable ratios have been replicated across the U.S. in a number of talent searches across several years, as well as in other cultures.* Score ranges at SAT-M – 500 are important for a 12-year-old to consider. They reflect important individual differences in quantitative sophistication (Benbow, 1992) and mark the level at which successful graduate work in the physical sciences at the very best universities begins to become probable.

The above gender difference in mathematical reasoning ability does not operate in isolation, however, to solely produce the profound gender disparities in educational attainment and pursuits along the math/science pipeline. Gender differences in other abilities required by the physical sciences, especially spatial and mechanical reasoning, amplify the disparities. These abilities are frequently overlooked by investigators trying to come to grips with the under-representation of women in engineering and the physical sciences. Table 3 contains data that bear on this issue. They were collected on Cohort 4 by SMPY at Iowa State University over the last 4 years. In addition to the SAT, students in Cohort 4 are administered a variety of nonverbal tests including Raven's Advanced Progressive Matrices, three-dimensional spatial visualization and mechanical reasoning. (A number of personal preference questionnaires are administered as well, see below.) Gifted students at or above the cutting score for the top 1% in overall mathematical reasoning ability display trivial gender differences in not only SAT-V but also in Advanced Raven scores. Yet significant gender differences are revealed for spatial ability and mechanical reasoning. This also parallels the findings of Stanley et al. (1992). These investigators analyzed gender differences on the Differential Aptitude Test (DAT) in effect-size units, taken from a national sample of over 61,000 students. The most pronounced gender difference in this battery was observed in Grade 12 on the Mechanical Reasoning measure, the male–female effect-size difference was almost a full standard deviation (.89) favoring males.

These gender differences in spatial and mechanical reasoning abilities, combined with the well-known gender differences in mathematical reasoning ability (Benbow, 1988), help explain why disparate male/female proportions are observed all along the math/science pipeline. The satisfactoriness criterion for engineering and many of the physical sciences is not as frequently met by gifted females as males. This is only part of the picture, however. There are gender differences in *non*ability personal attributes (vocational interests and values), in addition to life style preferences, that exacerbate disparities stemming from gender differences in satisfactoriness for the physical sciences. We turn to them next.

PREFERENCES

As noted earlier, physical scientists are characterized primarily by their high theoretical/investigative preferences (MacKinnon, 1962), coupled with a *relatively* low need for people contact. Both mathematically gifted males and females have, relative to their own sex norms, strong theoretical values and investigative interests. Yet, there are prominent gender differences in critical preferences for maintaining a commitment to careers in the math/science pipeline that mirror the aforementioned spatial/mechanical abilities among the gifted at age 13. Mathematically talented males are more theoretically oriented on the SOV (see Table 3). Further, their primary interests lie in the investigative and

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*Within Asian samples, male/female proportions at the extremes of mathematical talent are narrower than those reported for Caucasians (Stanley et al., 1989). For example, at SAT-M > 700, the male/female Asian ratio is closer to 4:1, whether students assessed live in the United States or not.

TABLE 3
Ability Profiles of Mathematically Gifted Students Attending a Summer Academic Program Across Five Separate Years by Gender

Year	Gender			Age-Adjusted SAT-M		SAT-V			Advanced Raven's			Mental Rotation Test			Bennett Mechanical Reasoning	
			N	X̄	SD	X̄	SD	N	X̄	SD	N	X̄	SD	N	X̄	SD
1992	*	M	72	494	93	398	91	72	24.6	4.1	72	31.3	7.7	72	49.8	7.1
		F	45	458	66	396	82	45	24.3	4.4	45	23.7	8.8	45	45.3	5.2
	†	M	84	486	91	395	88	85	24.4	4.2	83	31.6	7.5	83	49.9	7.0
		F	49	465	76	404	90	47	24.6	4.5	48	24.1	8.9	49	45.6	5.2
1991	*	M	68	532	101	426	78	68	25.1	3.9	68	29.9	8.1			
		F	51	480	87	418	87	51	25.8	4.3	51	25.1	10.2			
	†	M	107	579	101	413	81	92	25.2	4.2	95	30.0	8.1			
		F	67	472	85	418	80	58	25.9	4.2	63	24.1	10.0			
1990	*	M	69	537	100	415	79	69	24.5	6.5	69	29.2	9.1			
		F	48	487	74	422	76	48	25.3	4.4	48	22.5	9.7			
	†	M	87	545	96	415	79	82	24.6	6.8	80	29.8	8.8			
		F	61	487	71	419	80	57	25.1	4.1	56	21.6	9.4			
1989	*	M	20	585	86	441	98	20	27.3	4.4	20	24.9	9.9	20	40.2	9.4
		F	11	505	80	449	96	11	24.7	5.1	11	17.8	4.1	11	35.6	8.0
	†	M	43	593	95	446	78	21	27.0	4.4	40	23.8	9.7	42	42.2	10.0
		F	34	514	82	455	79	11	24.7	5.1	34	21.8	7.9	32	35.2	9.4
1988	*	M	57	562	81	435	59	57	26.6	3.8						
		F	32	491	65	424	80	32	25.1	5.3						
	†	M	72	571	85	440	62	66	26.8	3.7				8	39.3	6.5
		F	39	500	64	425	76	36	25.3	5.3				9	29.0	7.2

* Students who took all of the tests.
† All students who took any one test.

(secondarily) the realistic sectors of Holland's Hexagon (Benbow & Lubinski, 1992; Fox, Pasternak, & Peiser, 1976). In contrast, mathematically talented females are more socially and esthetically oriented and have interests that are more *evenly divided* among investigative, social and artistic pursuits (Table 3; Benbow & Lubinski, 1992; Fox, Pasternak, & Peiser, 1976). Females are more balanced and less narrowly focused in terms their interests and values. (One could also say this about their abilities, cf. Lubinski & Benbow, 1992.) Consequently, the TWA satisfaction criterion is less often achieved for females than males when considering the physical sciences.

Thus, at age 13 more males than females possess ability and preference profiles that are congruent with choices to pursue highly focused careers necessary for distinction in the physical sciences. Due to their more evenly distributed preferences and abilities, the career choices of mathematically gifted females and the amount of time they devote to scientific careers will be less distinguished than their male counterparts. Males will be more exclusively committed to the sciences, while females will have competing interests and will tend to develop their talents in relatively equal proportions across artistic, social, and investigative educational/vocational domains. That is exactly what is found in our educational programs designed for adolescents in the top 1% in ability. Females enroll in courses in math/science and English/foreign language in essentially equal proportions, whereas males were approximately six times more likely to enroll in math/science areas than in English/foreign languages. TWA would predict that the same pattern will reveal itself when career choices, made at a later age, are examined. Indeed, this is the case. Table 4 provides data on the secured educational credentials that mathematically gifted students in Cohort 1 achieved (or are intending to achieve) 10 years following their identification at age 13. Less than 1% of the females in the top 1% of mathematical ability are pursuing doctorates in mathematics, engineering, or physical sciences (Lubinski & Benbow, 1992). Eight times as many males are doing so. Benbow and Lubinski (1992) presented similar data just collected for SMPY's Cohorts 2 and 3.

An alternative way to capture the essence of these gender differences in preferences takes us back to Thorndike (1911) and one of the most celebrated dimensions of individual differences, "people versus things." In normative samples, females tend to gravitate toward the former, while males gravitate towards the

TABLE 4

Preference Profiles of Mathematically Gifted Students Attending a Summer Academic Program Across Five Separate Years by Gender

Year		Gender		Study of Values											
				Theoretical		Social		Economic		Aesthetic		Political		Religious	
			N	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
1992	*	M	72	46.7	7.1	35.7	6.8	43.7	7.1	36.7	7.1	44.0	6.7	33.2	10.9
		F	45	41.5	8.2	44.0	7.4	39.3	6.7	43.6	6.7	37.4	5.9	34.2	10.0
	†	M	73	46.7	7.1	35.7	6.8	43.6	7.1	36.6	7.1	44.0	6.7	33.5	11.0
		F	45	41.5	8.2	44.0	7.4	39.3	6.7	43.6	6.7	37.4	5.9	34.2	10.0
1991	*	M	68	47.7	7.0	37.1	7.3	41.6	7.2	36.4	8.2	42.9	6.6	34.2	10.4
		F	51	42.0	6.8	43.2	8.1	37.8	6.9	42.6	7.1	39.0	7.2	35.4	10.2
	†	M	77	47.6	6.9	37.1	7.0	41.8	6.9	36.5	8.3	43.1	6.8	33.8	10.1
		F	57	41.7	7.0	43.8	8.3	37.5	7.0	42.8	7.5	38.7	7.0	35.6	10.3
1990	*	M	69	46.6	8.8	38.4	7.8	40.4	8.2	38.4	8.4	42.5	6.9	33.4	11.14
		F	48	40.3	8.0	44.0	8.0	35.8	7.1	42.1	6.4	40.1	6.7	37.5	8.1
	†	M	73	46.6	8.7	38.3	7.6	40.4	8.1	37.8	8.7	42.7	6.8	33.9	11.3
		F	51	40.7	8.0	43.6	8.1	35.3	7.2	42.8	7.1	40.1	6.6	37.1	8.4
1989	*	M	20	49.3	7.4	35.4	5.9	40.3	9.4	37.3	8.0	45.0	7.8	30.8	11.1
		F	11	39.0	9.1	42.3	9.1	41.1	9.6	40.6	5.2	40.4	9.3	36.6	12.5
	†	M	43	50.0	6.8	34.8	7.5	42.2	8.2	37.0	7.7	44.1	8.2	30.9	10.7
		F	34	41.8	7.4	41.2	8.3	39.6	7.7	43.9	8.2	39.2	7.2	34.3	10.9
1988	*	M	57	48.0	8.5	34.4	7.8	44.9	7.6	35.3	8.1	45.2	8.2	32.4	12.8
		F	32	42.3	7.5	40.7	8.0	38.2	7.5	43.6	8.4	40.1	6.2	34.9	10.3
	†	M	61	48.3	8.5	34.5	7.6	44.7	7.4	35.0	8.0	44.8	8.3	32.9	12.7
		F	33	42.5	7.4	40.9	8.0	38.0	7.5	43.4	8.4	40.0	6.2	35.2	10.2

* Students who took all of the tests.
† All students who took any one test.

latter (cf., Lubinski & Humphreys, 1990a) and this parameter of individual differences operates among the gifted as well (Lubinski & Benbow, 1992). Given the female preference within the sciences for biology and medicine, however, compared to the physical sciences, as is evident in Table 4, perhaps it would be more precise to state that gender differences in vocational preferences are structured around "organic" versus "inorganic" content domains (Benbow & Lubinski, in press). It is not science, per se, that turns off many females, rather, it seems to be the inorganic nature of many of its content domains. We are currently investigating key value *configurations* (high theoretical values, relatively low social values), which we believe more precisely map the individual differences that contribute to these career decisions. Our preliminary findings indicate that the higher-order trend, theoretical *minus* social as assessed at age 13, has predictive validity for structuring choice of college major and areas of graduate concentration.

Life-style choices: Before leaving the domain of preferences, there is one critical gender difference in life-style preference that is essential to document (and one that is typically not assessed on standardized interest or values questionnaires). This gender difference is likely to exert a huge effect on gender differences even in disciplines in which male/female ratios in achieved educational credentials are comparable: commitment to full-time work as young adults. In our first three cohorts, for example, about 95% of mathematically talented males versus less than 60% of such females plan to work full-time until retirement, a percentage that has been stable over the past 20 years (Benbow & Lubinski, 1992, in press). This latter statistic would indicate that females, as a group, will tend to devote less time to their vocational development relative to males. Further, in most research in this area as in our previous research, questions to respondents are typically framed in terms of full-time versus various part-time options, not in terms of how much they are willing to work. Thus, we are currently assessing how the gifted feel about 50- to 70-hour work weeks, schedules more in line with people at the cutting edge of their discipline. This might reveal further gender disparities.

In sum, therefore, mathematically gifted females, in addition to having a more multifaceted interest profile *and* a more complex mixture of value orientations for evaluating their experiences and structuring their life-style, prefer to devote less time to vocational pursuits. They have more to balance, more competing needs at comparable intensities. Mathematically gifted males, however, are more focused on a theoretical/investigative style of life with fewer competing pulls and prefer to devote a greater amount of time to vocational pursuits.

Contemporary Research Trends: Viewed From the Context of TWA

We have illustrated above how the personal attributes of females compared to males will lead them to *choose* scientific careers less frequently, as a group, and to distribute their educational development across artistic, social and investigative areas more evenly. Of course, conventionally purported barriers (Eccles, 1985; Eccles & Harold, 1992; Kerr, 1985; Noble, 1989; Reis & Callahan, 1989; Silverman, 1986) might still remain. We suggest, however, that these and other purported barriers be evaluated from a broader context using TWA and its key components, satisfaction and satisfactoriness, to establish expectations on the degree to which comparable gender representation might be anticipated. According to TWA, because of their differing ability and preference profiles, highly able males and females achieve, as a group, satisfaction and satisfactoriness through different means. Consequently, they respond to the environment differently, as does the environment to them. Gender differences as a reflection of choice need to be factored into existing models and perceptions. Moreover, satisfactoriness and satisfaction baselines might be useful for appraising theoretical explanations of gender differences in achievement more generally.

For example, Eccles et al. (1983) introduced the expectancy-value model of motivation, which they proposed as a framework for understanding the relationship between values/personality attributes and academic achievement, as well as gender differences therein. This popular model describes two primary factors affecting achievement behavior: (1) expectations for success and failure and (2) subjective task value. Moreover, it conceptualizes gender differences in achievement, just as we do, from a *choice* perspective rather than a *deficit* perspective. It also views choices as being made from a variety of options presented within a complex social reality, wherein gender roles and stereotypes operate (see Eccles & Harold, 1992, for a discussion of this model as it pertains to the gifted). Yet to what extent do expectations and subjective task value reflect realistic personal estimates of the degree to which TWA's correspondence dimensions, satisfactoriness and satisfaction, respectively, are achievable in contrasting educational and work environments? Is self-confidence and self-efficacy, for example, merely a reflection of the extent to which one is in a correspondent environmental ecology in the TWA sense?*

Inadequate math/science preparation is another factor often mentioned as curtailing women's career options. Sells (1980), for example, perceived mathematics in high school as a "critical filter," screening out females from engineering and science majors. Indeed, the number of mathematics and science courses taken in high school is found to relate to choice of college major as well as career (Berryman, 1985; Ethington & Wolfe, 1986); gifted females, even mathematically gifted ones, do take somewhat less mathematics (and science) in high school compared to such males (Benbow & Minor, 1986; Benbow & Stanley, 1982). Consequently, it has been suggested that more females would enter and remain in the math/science pipeline if they were required to take more mathematics and science courses in high school. But to what extent is course-taking among mathematically gifted females a reflection of their preferences and/or abilities? Preference and ability profiles are in place long before high school. Can they be changed as a function of course-taking? Would *requiring* mathematically gifted females with intense preferences for social and artistic content to take more mathematics, chemistry, physics, and computer science in high school increase their representation in the math/science pipeline? Would *requiring* mathematically and spatially gifted boys with intense preferences for building and manipulating physical materials and inorganic things to take more high school courses in English increase their representation in the humanities?

Some of the other factors thought to attenuate the professional development of women include those that women "do to themselves." These are, among others, the Queen Bee Syndrome (Staines, Tavis, & Jayaratne, 1974), the Great Impostor Syndrome (Clance, 1985; Machlowitz, 1982; Warschaw, 1985), the Cinderella Complex (Kerr, 1985) and the Perfection Complex (Reis, 1987). The Queen Bee and Perfection Complex are similar in that females feel that they have to be perfect in every way and in how they handle the multiple roles of professional, mother, and wife. The Great Impostor Phenomenon captures how many successful women feel they achieved their success—not through their hard work and ability but rather through luck; and they are waiting to be found out. To avoid being "found out" they get caught in a circle of working even harder, achieving greater success and developing greater fear of being detected as the impostor they truly believe they are (Kerr, 1985, 1991). To what extent is this depiction characteristic of a gifted female with several competing interests at comparable intensities coupled with the greater conscientiousness of females in general (Schmidt & Hunter, 1992)? These questions and others like them will be pursued in our future research. In all of our research, however, detailed assessments of well-known personal attributes critical for satisfaction and satisfactoriness in specialized careers and advanced educational tracks are conducted, not only

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*Moreover, among the gifted, their self-concepts, especially academic ones, are so high in both males and females that measures derived on normative samples are psychometrically inadequate due to ceiling effects (Swiatek, 1992).

to establish expectations for gender representation in the math/science pipeline, but also the degree to which the self-perceptions of our students are reality based. Investigators in other areas of educational/vocational development, as well as theorists interested in indexing the magnitude of social psychological influences, might find this strategy profitable too.*

Conclusions

In this chapter, using TWA, we have organized data collected at SMPY with data of other investigators on key gender-differentiating attributes that channel the nature and degree of educational/vocational achievement among the gifted. We feel that this model is useful for conceptualizing and better understanding many different kinds of gender differences surrounding the manifestations of intellectual talent. We conclude with three points: one intended for researchers, another for theoreticians and finally one for educators and applied psychologists. While, to be sure, the expressed thoughts shared by these three categories possess appreciable overlap, they also reflect a unique emphasis.

First, for the researcher, if one thing is apparent from the last 20 years of research on the gifted and the ensuing gender differences uncovered therefrom, it is the need to conduct multi-attribute assessments of key characteristics relevant to criterion behaviors of interest. Our particular area of interest involves the determinants of educational and career excellence in engineering and the physical sciences. It behoves us, therefore, to incorporate measures of spatial and mechanical reasoning into our correlational and experimental designs, in addition to assessing critical vocational interests and values and life-style preferences. We simply cannot restrict investigations solely to abilities, preferences, *or* attitudes (or any "favorite" class of personal attributes) and expect findings to generalize with fidelity. There are simply too many gender differences observed in key variables relevant to multiple educational/vocational paths to make one-shot, one-variable designs unquestionably defensible.

Second, theoretical formulations must at least attempt to genuinely embrace all available evidence before casting highly integrative frameworks for interpreting research findings. Theorists certainly should not ignore relevant auxiliary data which speak to the tenability of certain conclusions. In another context, we have suggested that researchers employ the Total Evidence Rule for evaluating the verisimilitude of competing theoretical formulations. This rule of induction was formulated by Rudolph Carnap (1950). It maintains that consideration of all relevant information is essential when evaluating a proposed scientific assertion. There are multiple examples in the gifted literature for the relevance of this important rule, but the following two involving gender differences will suffice to illustrate its significance. First, if social influences are operating in isolation to attenuate the development of exceptional levels of mathematical reasoning abilities in females (as some have suggested), theorists must address why it is that females are superior to males in arithmetic computation and also tend to get better grades than males in high school math courses (cf. Benbow, 1988; Kimball, 1989). A second example involves sex-role identification. The masculine identification hypothesis has been used to explain the relative superiority of males compared to females in mathematical reasoning ability. This formulation must come to grips with the fact that regardless of how giftedness is defined (e.g., by selecting subjects based on exceptional levels of verbal, spatial, or mathematical ability), gifted adolescents of all "types" are less gender stereotyped than their average-ability peers in a variety of interests (Lubinski & Humphreys, 1990a), even though it is the gifted that display the largest gender differences in achievement. Moreover, in a recent *meta*-analytic review, covering the literature on parents' differential socialization practices as a function of their child's gender, Lytton and Romney (1991) observed many *in*significant effect sizes for a number of abilities and social behaviors.

Finally, we, like most vocational psychologists working with young adults, feel it is important that gifted adolescents are provided with the opportunity to develop in ways commensurate with their unique abilities and personal preferences. If this means that more gifted females *choose* to become biologists, lawyers, and physicians, relative to physical scientists, electrical engineers, or computer scientists, *as long as they are aware of their full potential* we are not concerned. We view gifted students as individuals first and try to be as

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*In applying TWA to programmatic interventions for the gifted, we have observed an interesting corollary phenomenon. Although we are only in the beginning stages of attempting to document this observation empirically, it might be profitable to alert practitioners and theorists to the following nascent (but we believe promising) line of empirical research: It appears that when interventions are implemented that are more optimal for the intellectual development of the gifted, the environments provided (relative to normative classrooms) are ideal for their social and emotional development as well. In correspondent educational environments, the gifted are simultaneously placed in environments composed of their age-mate intellectual peers and of individuals with shared academic *and* nonacademic interests. This is rarely the case for the gifted student placed in traditional educational settings. Thus, closer friendships are easier to cultivate in correspondent educational environments for the gifted. Moreover, their self-reports indicate that the experience of knowing that there are others "like them" and developing friendships with one another constitutes an invaluable support system that enhances their psychological well-being and personal development. We are now beginning to study the social and emotional effects of this kind of peer-support system more systematically, with students in our summer programs for the highly able.

responsive to their individual differences and uniqueness as possible. If one is to be all that one can be, to borrow Maslow's phrase, one must be responsive to one's true nature—a theme that cuts across many fulfillment theories and formulations aimed at construing optimal forms of human functioning, including those of Gordon Allport, Carl Rogers, and Carl Jung. It might be advisable for counselors and educators to keep the wisdom offered by these theorists in mind when working with clients and students searching for optimal direction for their educational and vocational development, and, perhaps also, to remind clients of Jane Loevinger's (1976) observation (contained in her treatment of ego development) that "personality develops by acquiring successive freedoms." Yet all of this actually can be encompassed by TWA, an empirically based model of personal fulfillment within the world of work (Dawis & Lofquist, 1984; Lofquist & Dawis, 1969, 1991).

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