TRAIT CONSTELLATIONS IN INTELLECTUALLY ABLE ADOLESCENTS: DISTINCT PREFERENCE PATTERNS AND EDUCATIONAL CHOICES AT CONTRASTING LEVELS OF SPATIAL ABILITY

By

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To my family,

Mark, Evelyn, and Alexander.

I am forever inspired by your presence in my life.

I am forever grateful for your love, support, and patience.

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CHAPTER I

INTRODUCTION

History of Talent Identification

Over the past 30 years, gifted education has grown, and it has become more sophisticated in many ways (Robinson, 1999). Prior to the 1970s, the identification of gifted students was conducted largely on a case-by-case basis, if at all; and assessments were usually unidimensional, measuring general cognitive ability (see, for example, Hollingworth, 1927, 1942; Pressey, 1949; Seashore, 1922; Terman, 1925-1959). In 1972, however, Julian C. Stanley implemented two important changes to the identification of intellectual giftedness: group testing and the assessment of specific abilities (Keating & Stanley, 1972; Stanley, 1996). These innovations transformed the face of gifted education permanently: They not only enabled talent searches to expressly identify large numbers of intellectually precocious youth, but they also afforded a better understanding of the breadth of psychological diversity within this special population.

The number of intellectually gifted youth identified annually through talent searches has grown from under 500 in 1972 to more than 300,000 currently (Lupkowski-Shoplik, Benbow, Assouline, & Brody, 2003). Talent searches typically begin by selecting seventh- or eighth-grade students who score in the top 3-5% of standardized achievement tests (e.g., the Iowa Test of Basic Skills) routinely administered in their schools. Because these students are all "bumping their heads" on the ceiling of these age-calibrated tests, little differentiation among them on the basis of those scores alone is possible. Therefore, following above-level testing procedures initiated by Stanley three decades ago, these students are then given college entrance exams designed for high school seniors [e.g., the College Board's Scholastic Aptitude Test, renamed the Scholastic Assessment Test in 1994, and now called the SAT I: Reasoning Test or simply the SAT (Lawrence, Rigol, Van Essen, & Jackson, 2002)]. These 12- and 13-year olds generate score distributions practically indistinguishable from those generated by students four to five years older (Barnett & Gilheany, 1996; Benbow, 1988; Wendler, Ninneman, & Feigenbaum, 2001), illustrating the intellectual diversity among this special population. Moreover, the SAT has demonstrated reliability (Benbow & Wolins, 1996; Brody & Benbow, 1990; Minor &

Benbow, 1996) and predictive validity along multiple dimensions of academic achievement (Benbow, 1992; Bleske-Rechek, Lubinski, & Benbow, 2004; Lubinski, Webb, Morelock, & Benbow, 2001; Shea, Lubinski, & Benbow, 2001), occupational success (Benbow, Lubinski, Shea, & Eftekhari-Sanjani, 2000;), and genuine manifestations of creativity (Lubinski, Benbow, Webb, & Bleske-Rechek, in press; Wai, Lubinski, & Benbow, in press) for gifted young adolescents.

Learned also from modern talent search procedures is that cognitive assessment tools, such as the SAT, that measure specific abilities rather than merely general cognitive ability, are useful for understanding differential development among intellectually precocious young adolescents. Distinctions in the relative strengths of quantitative and verbal abilities assessed in early adolescence, for example, portend distinctions in the educational and vocational pursuits of intellectually talented young adults as distant as twenty years later. For example, recent studies of gifted (top 1%) adolescents found that their scores on the mathematics and verbal subtests of the SAT (SAT-M and SAT-V, respectively) predicted their undergraduate majors (Achter, Lubinski, Benbow, & Eftekhari-Sanjani, 1999; Shea et al., 2001). A closer look at a subset of those participants – those with intentions of majoring in a math or science domain when they began their undergraduate studies – found that those who did complete a math or science undergraduate degree had higher SAT-M scores, on average, than those who eventually opted for undergraduate degrees outside math-science (Webb, Lubinski, & Benbow, 2002). Congruent findings were revealed through an independent study of profoundly gifted adolescents (top 1 in 10,000). This latter study compared the outcomes of three groups of adolescents: those with highly advanced mathematical reasoning ability, relative to their verbal ability (high-math participants); those with highly advanced verbal reasoning ability, relative to their mathematical ability (high-verbal); and those whose mathematical and verbal reasoning abilities were more uniformly advanced (high-flat). On a variety of outcome measures, including undergraduate and graduate majors, course preferences, and special accomplishments, high-math participants were more greatly represented in science, math, and technology domains; high-verbal participants were more greatly represented in the humanities and arts; and high-flat participants were intermediate (see Figure 1; Lubinski, Webb, et al., 2001).

Measures of specific abilities also provide educational counselors with critical information for designing and structuring developmentally appropriate environments for this

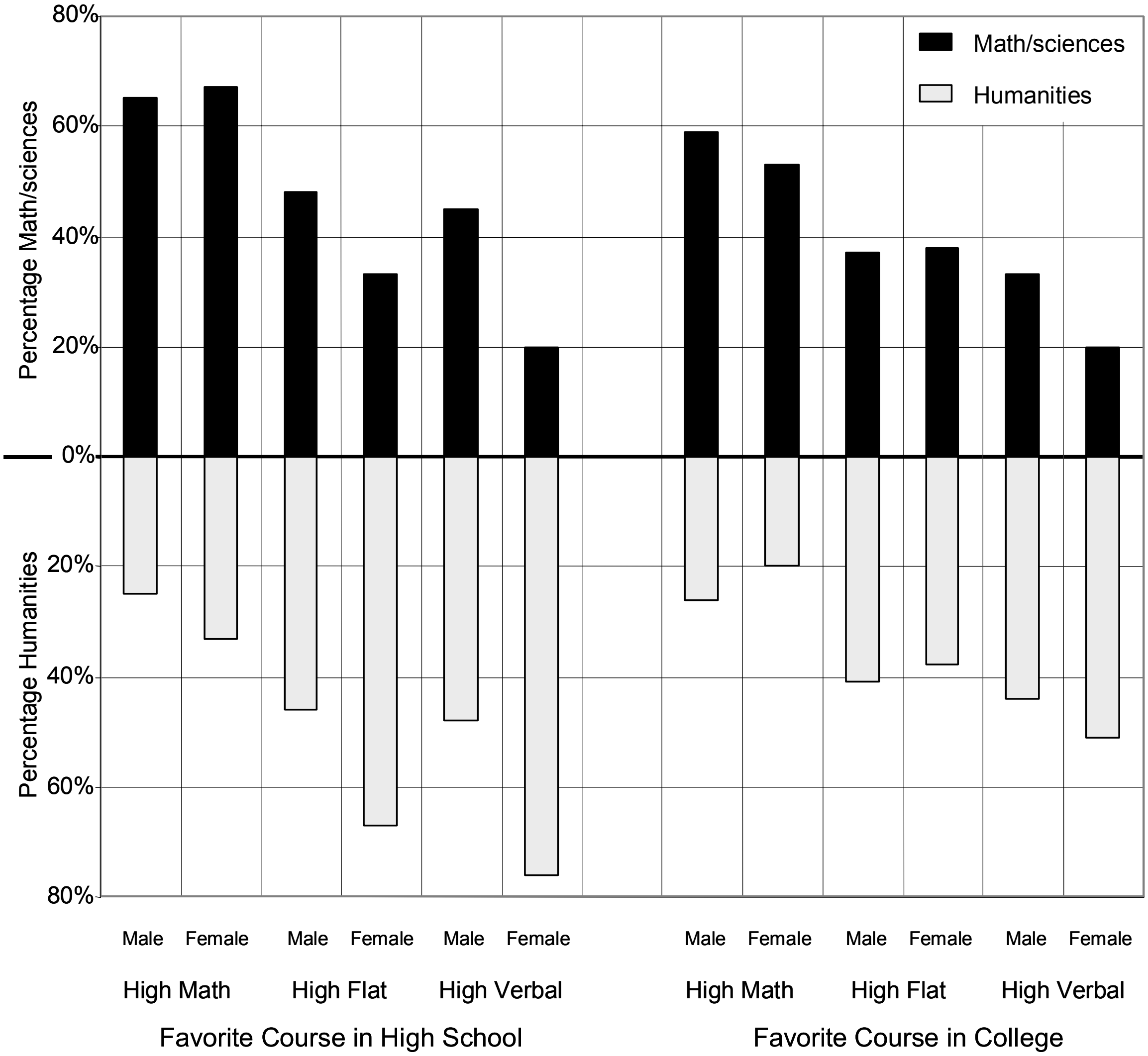


Figure 1. Participants' favorite course in high school and in college. Percentages in a given column do not necessarily sum to 100% because only participants indicating either math/sciences or humanities courses are displayed. Significance tests for differences among groups for favorite course are as follows: high school math/sciences χ^2 (df=2) = 20.7, p < .0001; college math/science χ^2 (df=2) = 18.2, p < .0001; high school humanities χ^2 (df=2) = 36.6, p < .0001; and college humanities χ^2 (df=2) = 30.2, p < .0001.

special population (Achter, Lubinski, & Benbow, 1996; Benbow & Stanley, 1996; Gallagher & Gallagher, 1994; Heller, Monks, Sternberg, & Subotnik, 2000; Lubinski, Benbow, Shea, Eftekhari-Sanjani, & Halvorson, 2001; VanTassel-Baska, 1998; Walsh, 2003). Armed with an understanding of individual students' strengths and relative weaknesses based on their specific ability profiles, counselors can appropriately tailor challenging educational opportunities congruent with the individuality of each student (Dawis, 1992, 2001). Across the country, for example, talent search participants have repeatedly demonstrated mastery of challenging curricula in rigorous, fast-paced (3-week) programs typically comprising a year of high school coursework or a semester of college coursework. Mathematically and verbally talented students have benefited from programs such as these for decades in courses such as chemistry, genetics, languages, and mathematics, among others (Benbow & Stanley, 1996; Colangelo, 2002, 2003; Colangelo, Assouline, & Gross, 2004; Stanley, 2000).

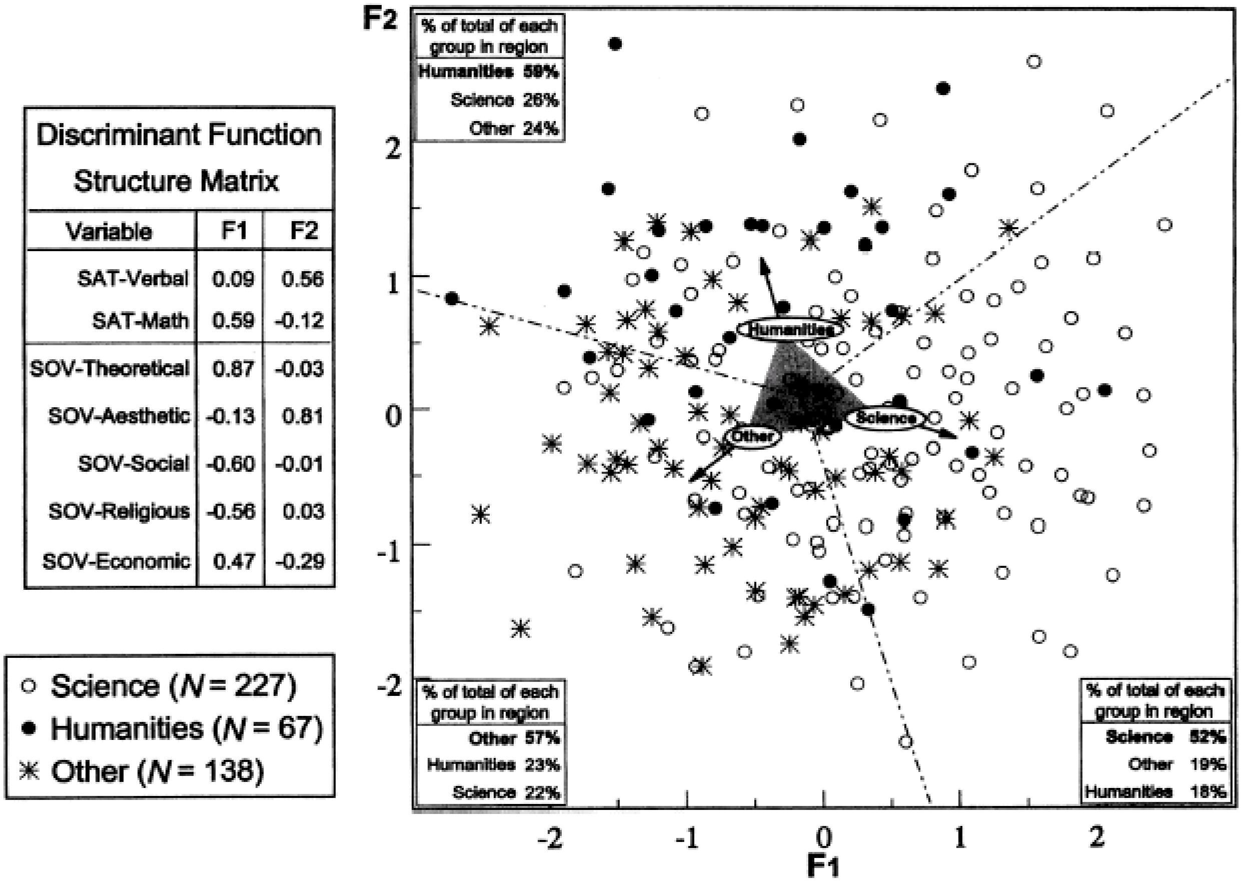
More recently, measures of noncognitive individual differences attributes have entered the talent development scene. Inasmuch as the cognitive development of intellectually gifted adolescents is characterized by unusually early development, perhaps intellectually talented adolescents exhibit preference patterns indicative of precocious development as well. If so, this could refine educational counseling and programming for this special population, akin to the manner in which interests and values refine vocational counseling and planning for young adults. Therefore, following the logic of out-of-level ability testing, preference assessments originally designed for adult populations have been utilized with intellectually precocious youth. This endeavor has proven fruitful: Preference assessments (of interests and values) have demonstrated longitudinal stability over 15 and 20 years (Lubinski, Benbow, & Ryan, 1995; Lubinski, Schmidt, & Benbow, 1996) and construct validity (Schmidt, Lubinski, & Benbow, 1998), including predictive validity (Achter et al., 1999), for intellectually talented youth.

In a sample of 695 gifted adolescents, for example, Schmidt et al. (1998) examined the convergent and discriminant validity patterns of two widely utilized and well validated (for adult populations) preference assessments, the Strong Interest Inventory (SII; Hansen & Campbell, 1985) and the Study of Values (SOV; Allport, Vernon, & Lindzey, 1970). They found that intellectually gifted adolescents exhibited relationships between the two preference assessments and a diverse assortment of external criteria that were remarkably in line with those exhibited by adult samples. Achter et al. (1999) extended the validity analysis of the SOV by examining its predictive utility in forecasting educational outcomes of 432 gifted adolescents identified by age 13. Using a discriminant function analysis, they found that abilities and values in combination accounted for 23% of the variance in three major classifications of earned undergraduate majors (math-science, humanities, and other). Furthermore, this study demonstrated that preference assessments provided incremental validity (13% of the variance) beyond the 10% offered by abilities alone in the prediction of these three groupings. The robustness of Achter et al.'s discriminant functions, which were derived by predicting age 23 undergraduate degrees from age 13 abilities and preferences, was examined recently by applying those functions to predict age 33 occupations (classified in commensurate groupings: math-science, humanities, and other). The predictive accuracy of these functions was maintained from educational to occupational contexts, reported 20 years after initial assessments (Wai et al., in press).

Beyond the evidence of predictive and incremental validity indicated by Achter et al.'s (1999) study, information regarding how cognitive and noncognitive attributes combine to predict external criteria can be gleaned from their research. Meaningful clusters of ability and preference measures were conspicuous in the discriminant structure. The first discriminant function was characterized by mathematical reasoning ability, theoretical values, and reversed (i.e., low) social and religious values, whereas the second was characterized by verbal reasoning ability and aesthetic preferences (see Figure 2).

The functions uncovered by Achter et al. (1999) correspond to C.P. Snow's (1965) two intellectual cultures, the scientific and the humanistic, respectively. Snow believed that intellectuals, broadly conceived, approach problems in one of two ways, between which lay a "gulf of mutual incomprehension" (Snow, p. 4). The first of these world views was characterized as scientific (exemplified by physical scientists); the second, humanistic (exemplified by literary intellectuals.) Although Snow described these competing value systems as operating across disparate fields, their influence can be identified within a given field as well. Their existence in psychology, for example, has been long observed (Boring, 1950; Cronbach, 1957); Lubinski (2000, 2004) has outlined how these different ideological approaches to psychology are manifested in the early history and systems of psychology which continue to the present day across the different divisions of American Psychological Association members (cf., Kimble, 1984).

Overall, the above review indicates that constellations of personal attributes form meaningful clusters that differentially attune people to different aspects of learning and working environments. After three decades of research with mathematically and verbally gifted youth, we understand a great deal about their talents and how to encourage their further positive development through programs that rely upon their individual strengths and interests (Benbow & Stanley, 1996; Colangelo, 2002; Colangelo & Davis, 2003; Heller et al., 2000; Stanley, 2000).



Discriminant Function Structure Matrix		
Variable	F1	F2
SAT-Verbal	0.09	0.56
SAT-Math	0.59	-0.12
SOV-Theoretical	0.87	-0.03
SOV-Aesthetic	-0.13	0.81
SOV-Social	-0.60	-0.01
SOV-Religious	-0.56	0.03
SOV-Economic	0.47	-0.29

Figure 2. Group centroids and discriminant structure matrix. Bivariate group centroids for the total sample were (F_1, F_2): math-science (.43, -.05); humanities (-.29, .60); other (-.57, -.21). Each bivariate point represents an average of two participants' discriminant scores, but percentages were computed using all individual data points. SOV = Study of Values; SAT = Scholastic Aptitude Test; F_1 = Function 1; F_2 = Function 2.

We know much about how contrasting patterns of intellectual and nonintellectual personal attributes relate to different educational and, ultimately, occupational experiences and outcomes. Educationally relevant and dispositionally stable personal attributes appear to operate in intellectually talented adolescents in educational settings much as the same attributes operate in more mature populations in a variety of learning environments and in the world of work. The question now becomes: Are other populations of gifted youth being missed with current talent search procedures, and, if so, what might be the implications for providing for their educational needs?

Spatial Ability

Although various conceptualizations of intelligence have been proposed, the predominant scientific and empirically-supported models organize cognitive abilities hierarchically (Carroll, 1993, 2003; Gustafsson & Undheim, 1996; Jensen, 1998; R. E. Snow & Lohman, 1989; Vernon, 1961). For example, Carroll's (1993) comprehensive factor analytic survey of over 460 cognitive ability datasets collected over the twentieth century found, at its apex, a general factor (*g*) that explained approximately half the common variance among heterogeneous collections of tests. This general factor was supplemented by several more specific abilities. This hierarchical organization has been replicated through multidimensional scaling, leading to the radex model of intelligence (see Figure 3), initially proposed by Guttman (1954) and more recently elaborated by the work of R. E. Snow and his students (R. E. Snow, Kyllonen, & Marshalek, 1984; R. E. Snow & Lohman, 1989).

At least three specific abilities—mathematical, verbal, and spatial—have surfaced as salient in the radex model, and each has demonstrated meaningful psychological import by providing incremental validity (relative to the others and beyond the variance explained by *g*) in the prediction of many educational, occupational, and life outcomes. These three specific abilities are especially relevant in predicting individual differences in performance across educational-vocational domains and for predicting educational-vocational niches into which people self-select (Gottfredson, 2003; Scarr, 1996; Scarr & McCartney, 1983). However, although mathematical and verbal abilities have been considered in talent searches and educational programming for intellectually talented youth for some time now, the importance of spatial ability in talent development has only recently begun to be appreciated (Silverman, 1998).

Spatial ability provides unique information in understanding development in educational and vocational contexts beyond that provided by general cognitive ability. In an examination of numerous job analysis datasets, for example, Gottfredson (1986, 2003) found that although the functional duties of jobs were characterized primarily by their cognitive complexity (i.e., the general intelligence demands), jobs requiring above-average intelligence were more dependent on profiles of specific abilities than were those jobs requiring average or below-average intelligence. Spatial-mechanical ability was found as a necessary component in several career clusters (e.g., physical, artistic) and, interestingly, as a reverse indicator in others (e.g., bureaucratic).

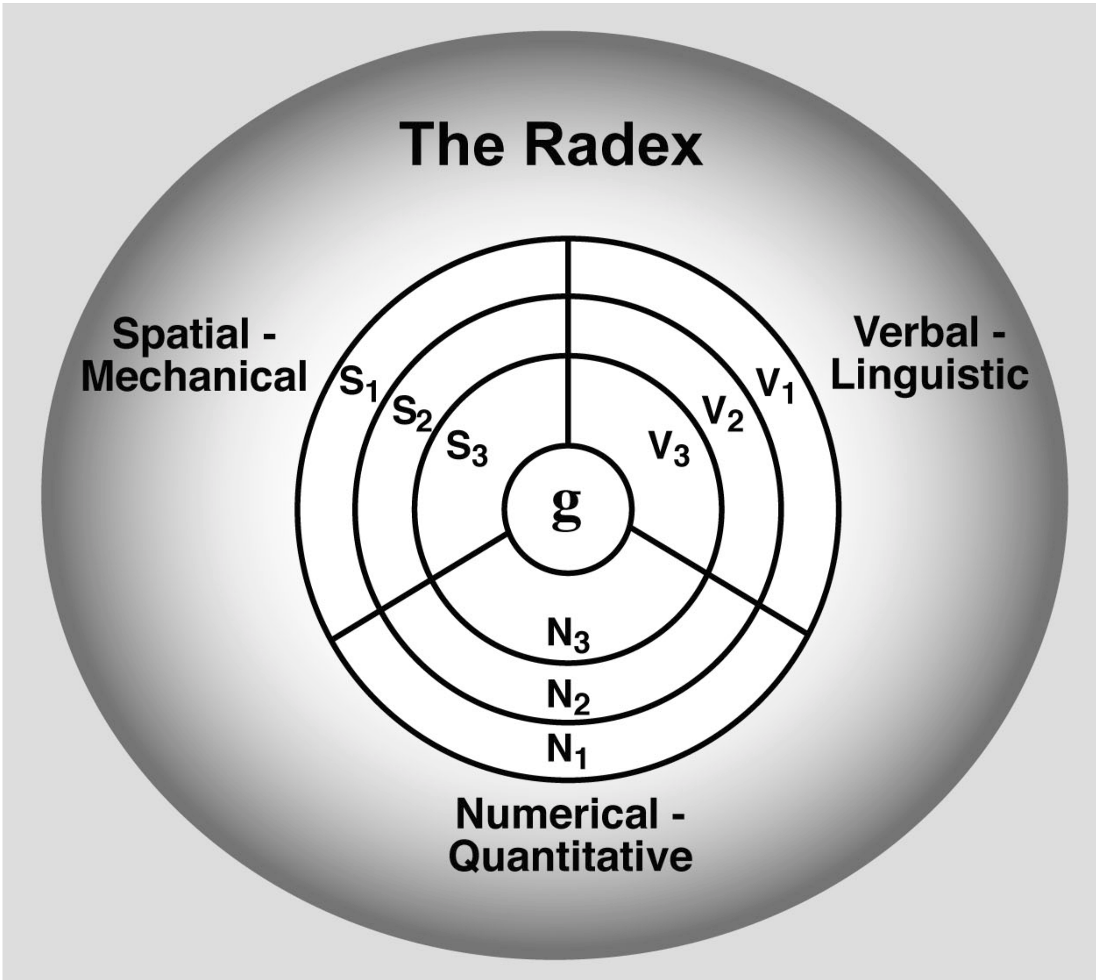


Figure 3. Radex model of intelligence. General cognitive ability, *g,* appears at the center of the organization. The letters within the cognitive ability arrangement denote different regions of concentration whereas level of complexity is represented by increasing subscripts.

Spatial ability has been examined extensively in general populations for decades; however, its importance has generally been presumed to be restricted to occupations below the professional level (Silverman, 1998; Smith, 1964). However, there is a growing body of evidence regarding its influence on a variety of educational and vocational choices and outcomes involving high-level professional careers (Gohm, Humphreys, & Yao, 1998; Humphreys, Lubinski, & Yao, 1993; Shea et al., 2001; Silverman, 1998). For example, in a 13-year longitudinal analysis of a stratified random sample of U.S. high school students (n > 400,000), Humphreys et al. compared the educational outcomes of two groups of intellectually able adolescents: The first group was comprised of students who scored in the top 20% of a verbal-mathematical composite that was designed to approximate the current selection instrument, the SAT, whereas the second group was comprised of students who scored in the top 20% of a spatial-mathematical composite designed as an alternative selection instrument, posited to be more sensitive to potential talent in engineering and physical science domains. Compared to the high verbal-mathematical group, the high spatial-mathematical group exhibited at least twice the proportion of undergraduate and graduate majors in the physical sciences, engineering, and the arts.

In another study, the developmental trajectories of more than 500 individuals identified as intellectually gifted in early adolescence were tracked across 20 years as a function of their specific abilities (Shea et al., 2001). In a developmentally sequenced series of outcomes using data collected from follow-ups at ages 18, 23, and 33, spatial ability assessed at age 13 exhibited predictive and incremental (over mathematical and verbal reasoning) validity in forecasting educational and vocational outcomes. Each panel of Figure 4 illustrates the differentiation between various criterion groups afforded by mathematical (x-axis), verbal (y-axis), and spatial (z-axis) abilities. Participants with preferences for math and science courses in high school exhibited higher spatial abilities relative to those who preferred humanities and social science courses, regardless of sex (panel A). Conversely, females who indicated a dislike for math or science courses in high school had lower spatial ability scores, relative to those who preferred humanities or social science courses. Males criterion groups of least favorite courses were not differentiated by their standing on spatial ability (panel B). Spatial ability also exhibited utility in predicting undergraduate degrees (panel C). Participants who earned degrees in engineering, mathematics, and physical and computer sciences tended to have much higher spatial ability scores than did those who earned degrees in the humanities, social sciences, and business. (A similar pattern was observed for graduate degrees, but is not presented in Figure 4.) Finally, this trend was maintained for occupations: Engineers, scientists, and mathematicians had higher spatial ability scores, relative to individuals working in business, social science, humanities, education, medical, and law fields (panel D).

The evidence strongly suggests that spatial ability is an important component for certain achievements, in particular, in many of the creative arts, engineering, and the physical sciences (Eliot, 1987; Gohm et al., 1998; Gottfredson, 1986, 2003; Humphreys et al., 1993; Shea et al., 2001). Given the frequently-heard calls to increase the numbers of potential scientists and

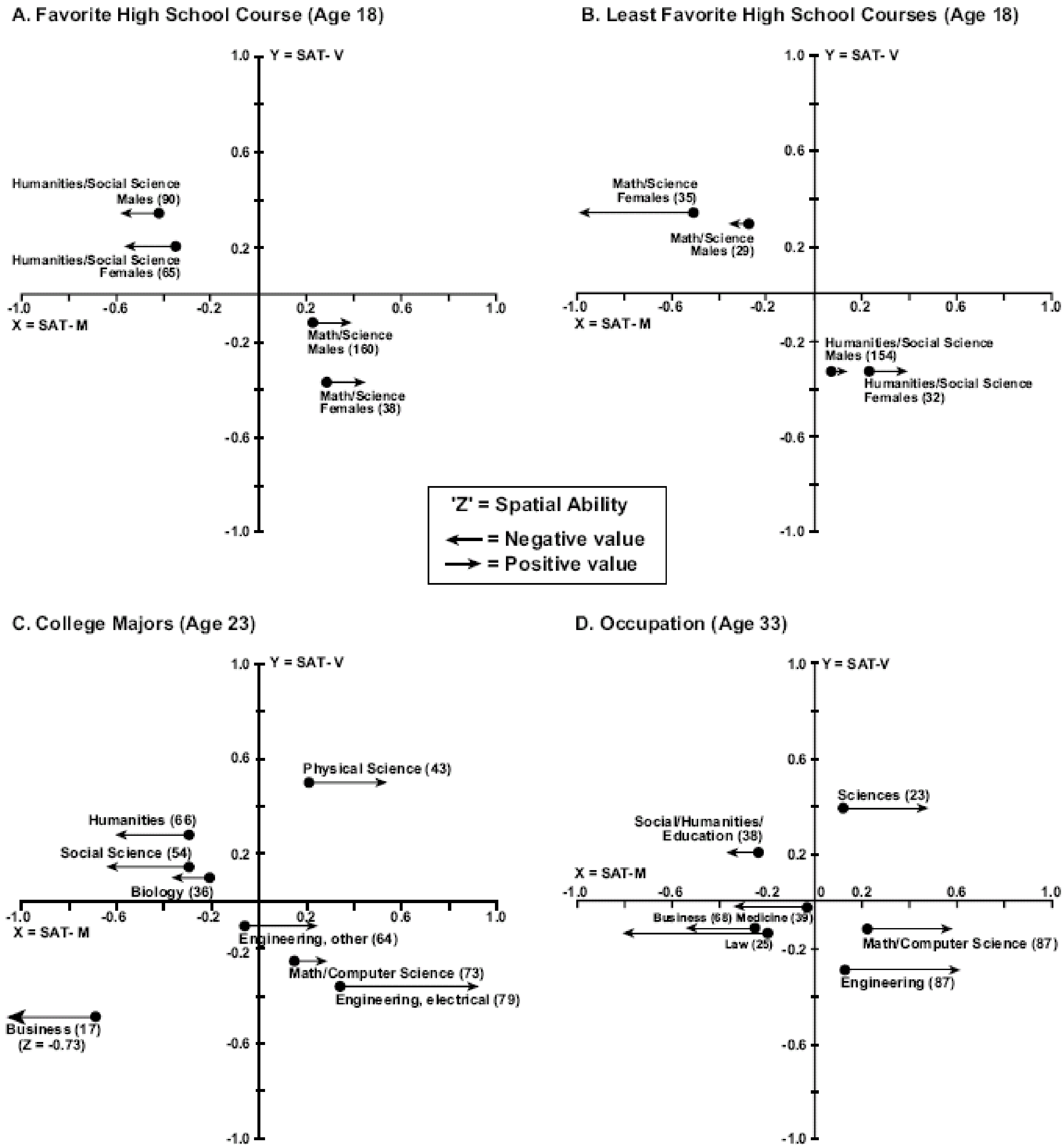


Figure 4. Trivariate means for favorite high school class, least favorite class, bachelor's degree, and occupation. Ability variables are scaled on a uniform metric. Mathematical (x-axis) and verbal (y-axis) mean scores for each group are plotted as bivariate points. Spatial ability (z-axis) mean scores for each group are represented by vectors projected from the bivariate points: Terminal points of the vectors represent the mean spatial scores for each group on the z-axis. Means are based on standardization using all participants and are 10% trimmed within groups. Sample sizes for untrimmed groups are in parentheses.

researchers in some of these fields (National Research Council, 2002; National Science and Technology Council, 2000), particularly to increase the representation of women in these often male-dominated career fields (National Science Foundation, 2004; Xie & Shauman, 2003), the potential to identify more future engineers and physical scientists is promising indeed (see especially panels A and B of Figure 4). The implication is clear: "If spatial-mechanical reasoning… is a component of achievement in some walks of science, then educators and program evaluators should be giving it direct attention" (Corno, Cronbach, et al., 2002, p. 73).

Spatially talented students, however, are not identified explicitly through current talent search models that rely upon identification through mathematical or verbal domains. Given that intercorrelations for highly reliable composite measures of mathematical, verbal, and spatial abilities range between .60 and .80 (Humphreys et al., 1993, Table 2, p. 254), some spatially talented youth are identified serendipitously by qualifying on mathematical or verbal abilities, but many more are missed entirely. It has been estimated that, by selecting the top 3% in mathematical and verbal abilities, more than half of the top 1% in spatial talent is lost (Gohm et al., 1998; Humphreys et al.; Shea et al., 2001). This suggests that spatially talented students may comprise one of the most unrecognized and perhaps underserved special populations of exceptional human capital in our educational system today.

Indeed, an examination of the top 1% of spatial talent and the top 1% of mathematical talent selected from a stratified random sample of approximately 100,000 high school seniors, for example, revealed distinct differences in the educational experiences of spatially and mathematically gifted students. Despite averaging more than 1.2 standard deviation units higher than the entire sample of seniors on a wide battery of cognitive tests, revealing high cognitive ability in general (comparable to that of the mathematically gifted students), spatially gifted students exhibited much lower educational aspirations and achievements than mathematically gifted students. Approximately three times as many high-space students, relative to high-math students, secured no educational degree beyond high school (32% and 41% of high-space males and females versus 7% and 16% of high-math males and females, respectively.) Conversely, less than half as many high-space students, relative to high-math students, secured graduate degrees (25% and 13% of high-space males and females versus 63% and 28% of high-math males and females, respectively.) Furthermore, high-space students reported less motivation to perform in school than high-math students on a variety of indicators, including attention in class, enjoyment of assignments, and actual time spent studying (Gohm et al., 1998).

Before any potentially effective intervention can be designed and implemented to address the underachievement of spatially talented students, however, their lower motivation and engagement in educationally-related contexts needs to be better understood. Just as efforts combining ability and preference dimensions were shown earlier to augment our understanding of the development of mathematically or verbally gifted adolescents, a more integrative approach may enhance our theoretical understanding of spatially gifted populations and contribute to awareness of how they may be better served by educational practice (Lohman, 1988; 2005). However, there is still much to be learned to fully understand how spatial ability works in conjunction with other features of psychological diversity to differentially attune spatially talented students to different developmental niches.

Correlates of Spatial Ability

The cognitive covariates of spatial ability have been examined in older populations. Eysenck (1995) has suggested that the intellectual repertoire can be adequately represented by a general factor and a bipolar verbal-spatial dimension, indicating a reciprocal relationship between verbal and spatial abilities. Lohman (1994) has noted an inverse relationship between verbal and spatial abilities among talented youth also in an article incisively entitled: "Spatially gifted, verbally inconvenienced." However, these observations might reflect, at least in part, systematic sources of individual differences in nonintellectual personal attributes that are carried along with verbal or spatial abilities.

There is some initial evidence of the nonintellectual covariates of spatial ability in both adult and gifted adolescent populations. Visual perception, one component feature of spatial ability, has exhibited positive correlations with working with "things and gadgets" and scientific interests in adult samples (Ackerman & Heggestad, 1997), and spatial ability was found to be positively correlated with realistic interests and negatively correlated with social interests in a sample of intellectually gifted youth (Schmidt et al., 1998). This pattern of nonintellectual covariates suggest that spatially talented individuals are likely to be psychologically quite distinct from individuals identified as gifted in other areas.

To illustrate this idea, consider the following: In Schmidt et al.'s (1998) study of gifted adolescents identified as having either exceptional mathematical or verbal ability, spatial ability was correlated approximately .25 with realistic interests and -.25 with social interests. If individuals were selected on the basis of high spatial ability, the resulting sample would be characterized by having a high attraction to working with things (i.e., realistic interests) and a relatively low attraction to working with people (i.e., social interests). More specifically, spatially talented students (top 2-3%) would exhibit interest in working with things one half standard deviation above the mean of the normative population and interest in working with people one half standard deviation below the mean of the normative population. This group of individuals would look very different from a group selected for high verbal ability, who would exhibit the opposite pattern of interests (relatively little interest in working with things, but highly interested in working with people.) These two groups, each selected for a high specific ability (spatial or verbal), would differ by a full standard deviation, on average, on the people-versus-things dimension (see Figure 1) and are likely to appear so distinct that they could prompt observers to categorize them as qualitatively different types (e.g., scientists and humanists, respectively, C. P. Snow, 1965).

In the previous sections, constellations of dispositionally stable personal attributes—both abilities and preferences—were shown to operate in educational settings for verbally or mathematically gifted adolescents similarly to the way they operate in learning and working environments for adult populations. In the current section, the relevance of spatial ability in certain educational and occupational outcomes for adult, adolescent, and gifted adolescent samples was reviewed, and some evidence of the noncognitive correlates of spatial ability was presented. Given these findings from earlier research, one might expect that differences in spatial ability among intellectually talented youth would carry with them systematic sources of individuality that are nonintellectual in nature. Yet many questions remain: If adolescents with high spatial ability were selected in talent searches, how might they look psychologically? Could a richer appreciation of their cross-attribute psychological profiles inform programmatic changes that might serve to more fully engage spatially talented students in the educational process? How do their cognitive and noncognitive personal attributes team to predict educationally- and occupationally-related outcomes? Are constellations of traits stable enough in adolescence to yield meaningful psychological insight for predicting various life outcomes? These are some of the questions that the current study is motivated to inform.

Cross-Attribute Models of Talent Development

One way to gain a psychological appreciation of spatially talented young adolescents is to examine the salient nonintellectual attributes related to spatial ability, rather than viewing spatial ability as an intellectual attribute operating in isolation. It has been proposed that the specific content of educational and vocational development operates through interests and other personological attributes (Ackerman, 1996; Gottfredson, 1986, 2003). This multivariate approach is aligned closely with R. E. Snow's (1987, 1992, 1994, 1996) concept of aptitude. Snow calls for a more integrative and comprehensive view of aptitude than is usually implied by the term. He suggests that we elaborate aptitude to represent not only intellectual factors, but also nonintellectual components of personality like interests, motivation, and values. The current study draws upon this idea and other existing theoretical ideas that model how cognitive and noncognitive attributes operate jointly in adults; these conceptualizations include aptitude complexes (R. E. Snow, 1987, 1992, 1994, 1996), trait clusters (Ackerman, 1996; Ackerman & Heggestad, 1997), and taxons (Dawis & Lofquist, 1984; Lofquist & Dawis, 1991).

In theory, Ackerman's (1996) model of adult intellectual development is particularly useful here. This approach integrates cognitive abilities, interests, and personality dimensions into a system that describes developmental changes in cognitive processes and content. The cornerstones of Ackerman's theory are intelligence-as-*p*rocess, *p*ersonality, *i*nterests, and intelligence-as-*k*nowledge (PPIK). Intelligence-as-process regulates the complexity and density of the knowledge assimilated whereas the development of intelligence-as-knowledge is guided by interest and personality attributes. Thus, intelligence-as-process, through interactions with interests and personality, fosters intelligence-as-knowledge.

Moreover, his examination of the intercorrelations among various components of the three major domains of individual differences reveal specific trait clusters comprised of across-domain attributes. Four of these trait clusters have been documented in adult samples: science-math, intellectual-cultural, social, and clerical-conventional (Ackerman & Heggestad, 1997). The science-math trait complex is characterized by correlations among mathematical reasoning and visual perception, and realistic and investigative interests. The intellectual-cultural trait complex includes crystallized intelligence and ideation fluency, artistic and investigative interests, and the personality traits of typical intellectual engagement and openness to experience. The social trait complex includes social and enterprising interests, and the personality traits of extraversion, social potency, and well-being. The clerical-conventional trait complex includes perceptual speed, conventional interests, and the personality traits of control, conscientiousness, and traditionalism.

Of these clusters, the first two, science-math and intellectual-cultural, have particular relevance to the current study. These clusters will be relied upon to guide the formation of criterion groups that will be examined in the longitudinal component of this study. More details regarding these criterion groups are forthcoming. Moreover, because these two clusters mirror C. P. Snow's (1965) scientists-humanists distinction, they have particular relevance to the development of talent along the math-science pipeline (Xie & Shauman, 2003).

Moves to extend models of adult development to organizing how abilities and interests operate collectively in intellectually precocious youth have only recently started to appear (Lubinski & Benbow, 2000). One such extension was based on the theory of work adjustment (TWA; Dawis & Lofquist, 1984; Lofquist & Dawis, 1991). TWA was originally designed to organize the interplay among the characteristics of the individual and the characteristics of the work environment to understand job tenure within adult populations, but it has proven useful in conceptualizing talent development in intellectually precocious youth. According to TWA, positive adjustment is comprised of two dimensions of correspondence: satisfactoriness and satisfaction. Satisfactoriness refers to the degree of correspondence between the abilities of an individual and the ability requirements of the environment (i.e., a person's competence to perform in a given situation). Satisfaction refers to the degree of correspondence between the preferences (e.g., interests, needs) of an individual and the reinforcer systems utilized by the environment (i.e., the fulfillment one experiences in a given position). When a person both performs satisfactorily and feels satisfied, the person-environment fit is maximized and the person-environment relationship is maintained (see Figure 5). If either satisfactoriness or satisfaction are not achieved, the relationship will likely be discontinued: The environment may end the relationship if satisfactoriness is low, whereas the individual may end the relationship if satisfaction is low.

One of the strengths of TWA is its equal emphasis on both the person and the environment in its evaluation of person-environment fit. In isolation, there is no such thing as an ideal environment, any more than there is an ideal individual – they must be taken in conjunction and viewed as an ideal environment for a particular individual (or an ideal person for a given

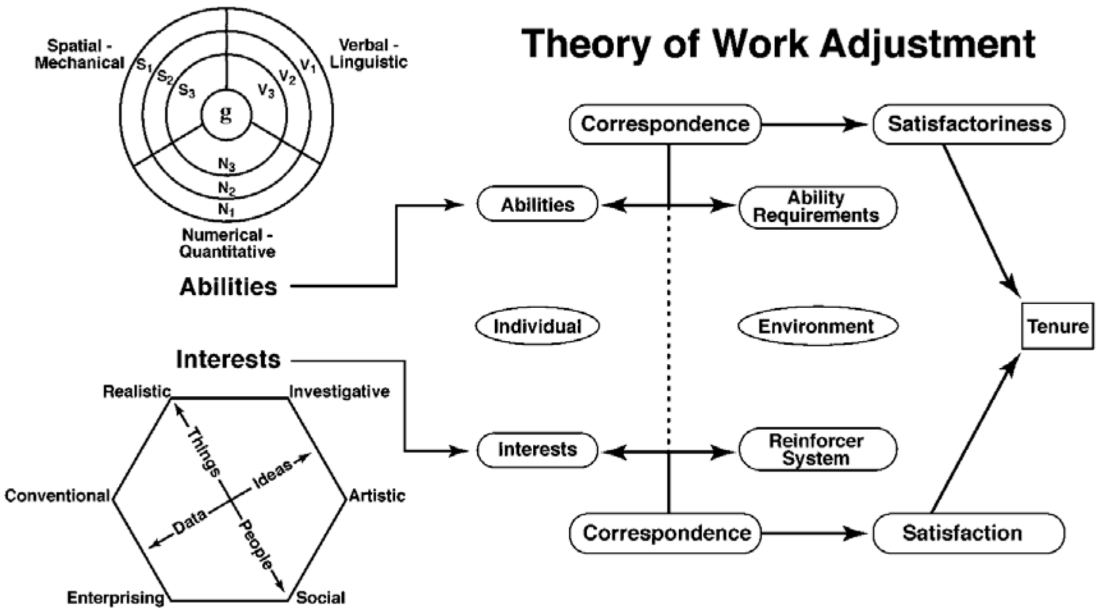


Figure 5. Theory of work adjustment. The theory of work adjustment (right) is combined with the radex scaling of cognitive abilities (upper left) and the RIASEC hexagon of interests (lower left) for conceptualizing personal attributes relevant to learning and work. The letters within the cognitive ability arrangement denote different regions of concentration whereas their accompanying numbers increase as a function of complexity. Contained within the RIASEC hexagon are two bipolar dimensions of interest: people-versus-things and data-versus-ideas (Prediger, 1982).

environment). How correspondent the salient features of an environment (ability requirements and rewards) are with the salient features of a person's individuality (abilities and preferences) defines the person-environment fit. As the TWA model illustrates, this is true for work environments, but it also can be extended to learning environments. TWA has provided the framework for much of the study of how mathematical and verbal abilities operate in tandem with interests to explain educational and vocational choice in young gifted individuals. In this study, the guiding structure of TWA will be utilized to examine spatial ability (see Figure 5).

Current Research Questions

Given what we know about the importance of spatial ability in educational and vocational development in high school students and adult populations, coupled with recent longitudinal findings on intellectually precocious youth, it is only a matter of time before spatial ability will be employed to augment modern talent search procedures. However, it is not clear that our educational system is prepared to handle the unique educational needs of spatially gifted students. This study is designed, in part, to uncover the distinct nonintellectual attributes that characterize members of this special population and to inform future educational and vocational counseling and the design of educational programming. To that end, a comprehensive psychological profiling of spatially talented students will be undertaken.

This study is designed also, in part, to investigate the potential for development along the math-science pipeline for spatially talented students. Previous research clearly implicates spatial ability as an important component of development in math and science, but does early identification on the basis of spatial ability hold promise for the identification of future scientists? To answer this question, two groups of intellectually able adolescents, distinguished by having either relatively high or relatively low spatial talents, will be compared to an independent sample of world-class scientists-in-training across an array of nonintellectual personological attributes (i.e., values and interests).

To further our understanding of this special population and their potential for development along math-science trajectories, intellectually able participants will be examined to determine if differences in spatial ability, assessed in adolescence, portend differences in outcomes and aspirations assessed in early adulthood. In a five-year longitudinal phase of this study, the developmental choices of students distinguished by their level of spatial ability will be compared using several educationally- and vocationally-relevant criterion variables, arranged according to C. P. Snow's (1965) two cultures—scientists and humanists—and further informed by Ackerman and Heggestad's (1997) science-math and intellectual-cultural trait clusters.

CHAPTER II

METHODS

Participants

Participants in this study were taken from the Study of Mathematically Precocious Youth (SMPY), a longitudinal study of the development of intellectual talent throughout the lifespan (Lubinski & Benbow, 1994; Stanley, 1996). The primary participants studied throughout both phases of this study were adolescents identified through talent searches; a comparison group of exceptional mathematics, science, and engineering graduate students also were included in the first phase. Each group of participants is described below.

Talent search participants. The SMPY participants included here were identified during 1992-1997 through annual talent searches for (primarily) seventh and eighth grade students scoring at or above the 97th percentile on any subtest of the routinely administered standardized achievement tests in their schools. Ninth and tenth grade students who had been identified by earlier talent searches were eligible to participate also. Participants were drawn primarily from Midwestern states. Students identified through the talent searches were invited to attend summer residential academic programs, and, in turn, summer program enrollees were invited to participate in the longitudinal research study. At time-1 (approximately age 13), 1060 research participants (617 males, 443 females) were included in the study. See Table 1 for sample sizes for each grade level, by sex.

Table 1
Last grade completed, by sex (frequency)

	Males	Females
7th grade	208	120
8th grade	226	162
9th grade	136	121
10th grade	47	40
Total	**617**	**443**

Approximately five years after participants were identified for the study, they were followed up by mail survey. Most participants completed this survey during their first year of college (approximately age 18). Approximately 93% of the original participants were located for the 5-year follow-up. Follow-up questionnaires were returned by 547 participants (281 males, 266 females). The overall response rate for this follow-up was 52%; the response rate corrected for lost and deceased participants was 57%. (In some of the analyses, participants with time-1 but not time-2 data will be utilized to replicate the covariance structure uncovered from participants with data at both time points.)

Graduate student participants. These participants were identified by SMPY in 1992 as graduate students enrolled in highly-ranked (top 15) U.S. mathematics, science, and engineering programs; most were completing their first or second year of graduate studies. These graduate students are some of the nation's most able scientists-in-training. One benchmark of their ability level, their mean Graduate Record Exam scores, is reported in Table 2. Because men outnumbered women in many programs but equivalent representation by sex was sought for this sample, women were deliberately over-sampled by identifying all qualifying females in the department and selecting an equal number of randomly selected males. This over-sampling of women resulted in 368 men and 346 women, a total of 714 participants. Further descriptive details, including the full identification procedure for these participants, have been reported previously (Lubinski, Benbow, et al., 2001).

Table 2

Mean (SD) scores on Graduate Record Exams of graduate students, by sex

	Males	Females
Verbal	622.3 (87.4)	615.5 (99.1)
Quantitative	747.6 (60.3)	734.4 (58.0)
Analytical	701.5 (87.3)	711.0 (79.1)

Note. Statistics are based on at least 314 males and 290 females who reported their GRE scores.

Instruments for Talent Search Participants

Following Cattell's (1957) recommendation to gather information from three major sources (test data, questionnaire data, and life record data), several different instruments were utilized. Moreover, to facilitate a more comprehensive understanding of these adolescents, both normative and idiographic variables were examined. At time-1, a background questionnaire was completed by participants, and their cognitive abilities and nonintellectual attributes were assessed using several measures, described below. At time-2, approximately five years later, participants were asked to complete a follow-up survey, also described below.

Assessment of abilities. The Mental Rotation Test (MRT; Vandenburg & Kuse, 1978) assesses three-dimensional spatial visualization. The test is comprised of twenty multiple choice items in which the examinee is supposed to match a criterion figure to two of four response options. Two response options are correct alternatives, identical to the criterion but rotated in space, whereas the other two response options are incorrect, including one mirror image of the criterion and one rotated image from another test item. The test was administered timed, with a limit of 10 minutes. Test-retest reliabilities over one year were .83 and .70 (Kuse, 1977), and internal consistency reliability was .88 for the original standardization sample (Vandenberg & Kuse, 1978). Schmidt et al. (1998) found the one-year test-retest reliability of this instrument was .73 for intellectually talented adolescents.

The Mechanical Comprehension Test (MCT; Bennett, 1969) assesses the understanding of the relationships of mechanical elements and physical forces in practical settings. It is comprised of 68 multiple choice items, each of which includes three response options, only one of which is correct. Each item requires the examinee to make a judgment about a pictorially-represented practical or mechanical situation. The test was administered timed, with a 30 minute limit. Bennett reported a split-half reliability of .84 for a sample of ninth-grade boys. Test-retest reliability over one year was .85 for intellectually talented adolescents (Schmidt et al., 1998).

Raven's Advanced Progressive Matrices (APM; Raven, Court, & Raven, 1977) is a widely used non-verbal measure of abstract reasoning and is considered to be one of the best cross cultural measures of general intelligence available (Jensen, 1998; Sattler, 1992). The test is comprised of 36 multiple choice items, each of which includes eight response options, only one of which is correct. Each item presents a three by three array of patterned geometric designs with the bottom right cell blank and requires the examinee to determine which of the eight response options would correctly complete the array. The test was administered untimed. Test-retest reliabilities over 6-8 weeks were .91 for adult students and .86 for 12-year-olds (Raven et al.). Test-retest reliability over one year was .60 for intellectually talented adolescents (Schmidt et al., 1998). Mean scores (and standard deviations) for participants, by sex and grade, are presented in Appendix C.

Assessment of values. The Study of Values (SOV; Allport et al., 1970) assesses ipsatively the relative prominence of personality-related values based on Spranger's (1928) types. The SOV includes six dimensions: theoretical (values discovery of truth; may be empirical, critical, and rational), economic (values utility; prefers knowledge to be practical and useful), aesthetic (values form and harmony; may be artistic, individualistic, and self-sufficient), social (values altruistic or philanthropic love of others; may be kind, sympathetic, unselfish), political (values power; desires to lead and influence others), and religious (values unity; seeks to comprehend their place in the cosmos).

The reliability and validity of the SOV for intellectually talented adolescents has been examined over a 20 year interval (age 13 to 33). The median inter-individual test-retest correlation among the six SOV dimensions was .34, and the median intra-individual correlation among SOV profiles across 20 years was .39 (Lubinski et al., 1996). An extensive examination of its construct validity for gifted adolescents revealed a pattern of external correlates similar to that generated by adult samples (Schmidt et al., 1998). Moreover, for intellectually talented youth, the SOV has demonstrated predictive validity beyond quantitative and verbal reasoning abilities in forecasting college majors over 10 years (age 13 to 23; Achter et al., 1999) and occupational group membership over 20 years (age 13 to 33; Wai et al., in press).

The SOV is an empirically sound instrument which has been relied upon heavily for several decades [dating back to the original version (Vernon & Allport, 1931)] in both pure research and applied settings. Following the 1970 revision, it was the third-most frequently cited non-projective personality test in use, but its use has declined greatly over the past two decades (Kopelman, Rovenpor, & Guan, 2003). This decline is largely due to the dated and non-inclusive language used in some items. We addressed this issue by slightly updating the language in a few questions in the current study and the aforementioned studies which examined the reliability and validity of this instrument. However, a revision has recently been undertaken to modernize the instrument; initial investigations indicate that this revision has similar psychometric properties to the 1970 version (Kopelman et al., 2003).

Assessment of interests. The Strong Interest Inventory (SII; Hansen & Campbell, 1985) assesses the relative normative strengths of general occupational interests. The SII is arranged according to Holland's (1985, 1996) organization of occupational interests in a hexagonal manner with one primary theme at each vertex in the hexagon. Following the calculus assumption underlying this model, adjacent themes are more highly correlated to one another, and opposite themes are the least correlated. This structure is commonly referred to as the RIASEC model, an acronym for each of the six general occupational themes defining the hexagon. The six themes include realistic (working with things and tools), investigative (scientific pursuits), artistic (aesthetic pursuits and self-expression), social (contact with and helping people), enterprising (buying, marketing, and selling), and conventional (office practices and well-structured tasks) interests.

The six general occupational themes of the SII may be further broken into 23 basic interest scales. These scales allow finer distinctions among educational and occupational interests than the six broad themes permit (Armstrong, Smith, Donnay, & Rounds, 2004). Although the SII has been slightly revised recently (Harmon, Hansen, Borgen, & Hammer, 1994), including some changes to the basic interest scales, assessment of interests for most SMPY participants relied on the earlier version (Hansen & Campbell, 1985), so it is described here. The realistic theme includes agriculture, nature, adventure, military activities, and mechanical activities, whereas investigative includes science, mathematics, medical science, and medical service. The artistic theme is comprised of music/dramatics, art, and writing, and the social theme includes teaching, social service, athletics, domestic arts, and religious activities. Enterprising is comprised of public speaking, law/politics, merchandising, sales, and business management, whereas conventional includes one basic interest scale, office practices. To differentiate between the two organizational levels on the SII, the general occupational themes and the basic interest scales will be referred to as RIASEC and BIS, respectively.

The RIASEC model has emerged repeatedly in large and diverse samples, and its generalizability has held up cross-culturally (Day & Rounds, 1998; Day, Rounds, & Swaney, 1998). Moreover, these interest dimensions remain relatively stable throughout adolescence (Low, Yoon, Roberts, & Rounds, in press). Among intellectually talented youth, test-retest reliability has been examined over 15 years (ages 13 to 28). The median inter-individual correlation among the RIASEC dimensions was .46, and the median intra-individual correlation among the RIASEC profiles was .57. Analyses of the test-retest stability of the BIS subscales of the SII revealed a median inter-individual correlation of .44 and a median intra-individual correlation of .51 (Lubinski et al., 1995). Evidence of the construct validity of the RIASEC dimensions has been demonstrated across a wide range of external criteria for intellectually talented adolescents in a manner observed in adult populations (Schmidt et al., 1998).

Background questionnaire. In addition to the psychometric scales that were administered at time-1, participants were asked to complete a 10-page background questionnaire (Appendix A). This questionnaire included demographic, familial, attitudinal, educational, and social items. Participants were also asked about their future educational and vocational plans.

After high school follow-up survey. After participants had completed high school, they were mailed their first follow-up questionnaire (Appendix B). This survey primarily questioned participants about their high school experiences and their future educational and vocational plans. Several criterion variables reflecting the educational and vocational plans and preferences of participants will be examined as the longitudinal component of this study; these are drawn from this survey.

Instruments for Graduate Student Participants

Instruments utilized to assess graduate student participants' standing on numerous dimensions of nonintellectual personal attributes included the Study of Values and the Strong Interest Inventory. In addition to the psychometric assessments, graduate students completed a background questionnaire. Each of these instruments was described above.

Procedure

As illustrated by the variability in their scores on the three ability measures—the APM, MRT, and MCT (see Appendix C)—the talent search sample secured for this study is more intellectually diverse than typical samples of gifted adolescents. This heterogeneity is largely due to less stringent selection criteria: Talent searches usually identify the top 1% or the top 0.5% in ability by utilizing above-level testing among students scoring within the top 3-5% of their grade-level tests. Rather than including only students who met the top 1% criterion that typically defines gifted or the top 0.5% criterion that typically qualifies talent search participants for summer residential programs for intellectually talented youth, the participants identified here qualified by scoring at the 97th percentile on *any* single subtest. These broader selection criteria are ideal for this study, however, inasmuch as they allow for the identification of many spatially talented students who would be missed using conventional selection criteria (viz., measures exclusively restricted to mathematical or verbal reasoning). Moreover, the heterogeneity of this sample provides an opportunity to compare intellectually able students with high spatial abilities to intellectually able students with relatively low spatial skills.

Scores on a spatial composite were derived by standardizing, within grade, scores on the two spatial measures, the MRT and the MCT. Standardized scores on these two measures were then averaged to yield a spatial composite score for each participant. High and low space comparison groups were determined on the basis of their standing on the spatial composite. The highest 25% and the lowest 25% of each grade, by sex, were selected to form, respectively, a high space group and a low space group. See Table 3 for sample sizes for each of the extreme comparison groups, by grade and sex. Participants ranged from just having completed seventh grade through tenth grade; therefore, participants were split by grade and sex for their classification as high or low space. Otherwise, because their cognitive abilities are developing further every year at this age, a high space-low space distinction based on the entire sample would be confounded with age.

Table 3

Sample sizes for each extreme space group, by sex and grade

	Males		Females	
	High space	Low space	High space	Low space
7th grade	52	52	30	30
8th grade	58	57	40	41
9th grade	33	34	30	31
10th grade	11	11	10	10
Total	**154**	**154**	**110**	**112**

Design and Analysis

In Phase I of this study, the nonintellectual attributes of high and low space talent search participants (bottom versus top quartile) will be compared, by sex, with those of incumbents in top mathematics, science, and engineering graduate programs. In Phase II, the longitudinal component of this study, the utility of spatial ability in predicting a variety of outcomes, aspirations, and preferences assessed approximately five years after their initial identification will be evaluated.

Phase I: Comparison of talent search and graduate student participants. Intellectually able students who exhibit high versus low standing on spatial ability are hypothesized to manifest distinct constellations of nonintellectual attributes. Therefore, among the sample of talent search participants, the top and bottom quartiles of spatial ability will be profiled, by sex, along the six values assessed by the SOV and the two levels of generality of the SII (RIASEC and BIS).

It is hypothesized that adolescents with high spatial ability constitute an untapped pool of future scientific and technical talent with interests congenial to the math-science pipeline. Therefore, the preference profiles of two talent search groups distinguished by extreme standing on spatial ability will be compared with the preference profiles of same-sex young adults attending world-class graduate training programs. Inasmuch as graduate students enrolled in top-ranked mathematics, engineering, and physical science programs across the U. S. are an ideal group of incumbents for this purpose, this latter group of participants will serve as a criterion reference group (Lubinski, Benbow, et al., 2001). Specifically, it is hypothesized that male and female talent search participants in the high space group will exhibit educationally- and vocationally-relevant personal preferences more similar to their same-sex graduate student counterparts than the low space group will.

Rather than contrasting individual preference dimensions or comparing profiles using one of many congruence coefficients [e.g., C index (Brown & Gore, 1994), r_c (Gorsuch, 1983), correlation (Hansen & Swanson, 1983)], a different approach will be taken here. Mean SOV, RIASEC, and BIS profiles of high and low space groups will be compared to the mean profiles of the graduate students, by sex, using generalized distances in n-dimensional space. Conceptually, the use of the full profiles of these participants is advantageous in that it allows a more comprehensive psychological understanding of the groups' likes and dislikes, than would be allowed by a less comprehensive profiling. Methodologically, the use of generalized distances, rather than other congruence measures, has the advantage of maintaining three aspects of profile similarity commonly examined in profile analysis, elevation, scatter, and shape, for the normative RIASEC and BIS and the latter two aspects for ipsative measures (e.g., the SOV).

However, because the themes in both the SOV and the SII are not orthogonal, Mahalanobis, rather than Euclidean, distance measures have an advantage here (Cronbach & Gleser, 1953; Rao, 1948). The Mahalanobis distance measure is preferable to Euclidean distance because it takes into account the covariation among the various dimensions in the profile. Cronbach and Gleser recommend the use of Mahalanobis distances for correlated variates, explaining that it "yields the same results as would be obtained if one factored the correlation matrix into *k* orthogonal factors, computed the person's scores on these components, and then applied the [Euclidean distance] formula to measure similarity" (p. 467).

Cronbach and Gleser (1953) further suggest that Mahalanobis distances are appropriate for evaluating the profile similarity between groups. However, an extensive literature search failed to uncover an empirical example of this methodology used in this manner. Attempts to locate an empirical application began with literature searches in PsycInfo and WorldCat for reports including any reference to "Mahalanobis distance" measures; these searches yielded 22 and 37 reports, respectively. All abstracts from these databases were reviewed, and original articles were retrieved and reviewed for any study that did not eliminate the possibility of a group comparison in the abstract. No instance of profile comparison of groups was located. To broaden the scope of this review, a similar search was conducted using Google Scholar. However, because "Mahalanobis distance" yielded an unmanageable number of hits (>5000), this search parameter was joined with "profile similarity" to reduce the number of irrelevant matches, resulting in more than 400 hits. An examination of these, with particular attention paid to journal articles, revealed no examples of profile analyses of groups based on Mahalanobis distances.

Several uses of Mahalanobis distance measures were encountered in this literature. Occasionally, Mahalanobis distances are used to compare the profiles of two or more individuals (Harris, 1955). However, they are more frequently utilized to compare an individual profile to that of a group for purposes of identifying outliers in various multivariate analytic techniques (Rasmussen, 1988), assigning individuals to groups in both agglomerative and divisive cluster analyses (Overall, Gibson, & Novy, 1993), or assessing the fit of a measurement model to an individual (Reise & Widaman, 1999). In a manner similar to the current study, Mahalanobis distance measures are commonly utilized to compare the profiles of new individual observations to existing criterion groups; empirical examples of this type abound in the literatures of many disciplines [e.g., chemistry (Lleit, Sarabia, Ortiz, Todeschini, & Colombini, 2003), aeronautical engineering (Howell & Howell, 1994), geology (Holmes & Harbottle, 2000), and genetics (Diaz et al., 2003)]. Although this approach is similar to that used in this study, it is still based on the profile of the individual, rather than a group mean profile. Therefore, the use of this technique in the current study is an opportunity to provide an empirical example of this extension.

To test the hypothesis that the high space groups are more similar to their gender equivalent graduate student counterparts than are the low space groups, the degree of profile similarity of each extreme space group's mean profile to the same-sex graduate student mean profile on SOV, RIASEC, and BIS dimensions will be computed as Mahalanobis squared distances, that is,

$$\left(MD_{spacegroup-gradgroup}\right)^2 = \left(\bar{\mathbf{x}}_{spacegroup} - \bar{\mathbf{x}}_{gradgroup}\right) \times \mathbf{C}^{-1} \times \left(\bar{\mathbf{x}}_{spacegroup} - \bar{\mathbf{x}}_{gradgroup}\right)'$$

where $\bar{\mathbf{x}}_{spacegroup}$ is the mean vector of the relevant extreme space group, $\bar{\mathbf{x}}_{gradgroup}$ is the mean vector of the same-sex graduate student group, $\mathbf{C}^{-1}$ represents the inverse of the covariance matrix of the relevant (same-sex) graduate student group, and $\left(\bar{\mathbf{x}}_{spacegroup} - \bar{\mathbf{x}}_{gradgroup}\right)'$ represents the transpose of the difference between the aforementioned mean vectors. The squared distance between pairs of Mahalanobis squared distances will be calculated by taking the square of the difference between the Mahalanobis distances (i.e., the positive square roots of each relevant Mahalanobis squared difference) in the comparison, by sex; that is,

$$\left(MD_{difference}\right)^2 = \left(MD_{highspacegroup-gradgroup} - MD_{lowspacegroup-gradgroup}\right)^2$$

where $MD_{highspacegroup-gradgroup}$ is the Mahalanobis distance between the high space group mean and the same-sex graduate student mean, and $MD_{lowspacegroup-gradgroup}$ is the Mahalanobis distance between the low space group mean and the same-sex graduate student mean. Because Mahalanobis squared distances are distributed as an F-distribution (Bose & Roy, 1938; Roy, 1938), the statistical significance of each squared distance (or squared distance between pairs of squared distances) may be tested using a standard F-test (Cacoullos, 1962).

Phase II: Longitudinal assessments of talent search participants. The anticipated differences in nonintellectual attributes between high space and low space intellectually able adolescents are expected to translate into systematic differences in longitudinally assessed developmental choices and preferences such as course preferences, academic majors, and occupational plans. These choices can be arranged meaningfully according to C. P. Snow's (1965) scientists-humanists distinction, allowing for an examination of the construct validity of spatial ability using the group membership approach (Rulon, Tiedmen, Tatsuoka, & Langmuie, 1967; Tatsuoka, 1988), to isolate constellations of personal attributes specifically indicative of the "two cultures" (viz., humanists or low space, and scientists or high space).

Each of the five primary criterion variables examined in the longitudinal component of this study are described below, along with all possible values for each criterion (i.e., criterion groups). The guiding framework for the selection of criterion groups was inspired by C. P. Snow's (1965) distinction among scientists and humanists and was further informed by Ackerman's (1996; Ackerman & Heggestad, 1997) science-math and intellectual-cultural trait clusters.

Participants responded to open-ended questions at the time of their time-2 follow-up survey (after high school) that asked them to list their favorite high school courses and their least favorite high school courses. Their responses to each of these items were grouped into one of three categories: science-math, humanities, and other. The science-math category included all physical and biological sciences, mathematics, and computer science classes. The humanities category included all literature, languages, history, music, and other humanities. All other classes were included in the other category; these were primarily in business, social science, and areas of physical, domestic, or vocational education (Table 4 reports sample sizes, by sex, for each of these categories).

Participants responded to another open-ended question that asked them to list their favorite leisure activities. Again, their responses were coded as falling into one of three categories: science-math, humanities, and other. The science-math category included primarily computer-related activities such as programming and gaming. The humanities category included reading, writing, and various cultural activities (e.g., music, drama, dance, art). All other activities were included in the other category; these were primarily social, entertainment, athletic, or outdoor activities (see Table 5).

Table 4

Favorite and least favorite high school courses, by sex (frequency)

	Favorite course		Least favorite course	
	Males	Females	Males	Females
Science-math				
Science	76	63	37	43
Mathematics	50	29	56	75
Computer science	18	0	6	2
Total	**144**	**92**	**99**	**120**
Humanities				
English or literature	31	72	66	27
History	26	25	33	49
Music or theater	28	20	3	3
Languages	7	9	24	10
Creative arts	10	18	3	3
Total	**102**	**144**	**129**	**92**
Other				
Business	4	4	9	13
Physical education	1	0	13	16
Social science	6	10	6	5
Domestic-vocational ed.	10	1	9	6
Miscellaneous courses	14	15	12	11
Total	**35**	**30**	**49**	**51**
Grand total	**281**	**266**	**277**	**263**

Also at the time-2 follow-up, participants reported their expected undergraduate major. Their open-ended responses were coded according to the College Board's Educational Testing Services' list of academic majors which were, in turn, categorized into one of three categories: science-math, humanities, and other. The science-math category included all physical and biological sciences, mathematics, computer science, and engineering. The humanities category included majors in literature, languages, history, music, and other humanities. All other majors

Table 5

Favorite leisure activities, by sex (frequency)

	Males	Females
Science-math		
Computer-related	26	1
Gaming	22	1
Total	**48**	**2**
Humanities		
Reading or writing	40	75
Music or arts	36	26
Total	**76**	**101**
Other		
Sports or outdoor activities	86	56
Social activities	50	77
Television or movies	15	14
Domestic-vocational activities	2	6
Miscellaneous	3	5
Total	**156**	**158**
Grand total	**280**	**261**

were included in the other category; these were primarily in business, social science, or education (see Table 6).

Participants reported their intended occupation at the time-2 follow-up. Their open-ended responses were coded according to Stevens & Hoisington (1987) scale of occupations and occupational prestige, which were then grouped into three categories: science-math, humanities, and other. The science-math category included engineers, scientists, computer programmers, and various occupations in the biological and physical sciences. The humanities category included writers, professors of various humanities, and theology. All other occupations were included in the other category; these were primarily managerial and business positions, teaching, health professions, or the law (see Table 7).

Table 6

Anticipated undergraduate majors, by sex (frequency)

	Males	Females
Science-math		
Biological science	39	57
Engineering	69	19
Computer science	34	5
Physics or chemistry	13	9
Mathematics	14	6
Other natural sciences	7	9
Total	**176**	**105**
Humanities		
Humanities or arts	23	27
English	8	14
History	6	10
Religion or theology	3	4
Languages	1	2
Total	**41**	**57**
Other		
Business	14	18
Political science	9	15
Communications	6	15
Psychology	3	14
Education	6	10
Economics	5	2
Other social sciences	1	3
Other majors	9	7
Total	**53**	**88**
Grand total	**270**	**250**

Table 7

Anticipated occupational field, by sex (frequency)

	Males	Females
Science-math		
Engineering	51	13
Natural science	18	16
Math or computer science	20	5
Professor, science or math	7	9
Total	**96**	**43**
Humanities		
Author or writer	5	5
Professor, English or language	2	5
Professor, humanities or arts	4	1
Professor, theology or history	3	2
Total	**14**	**13**
Other		
Medicine	30	30
Executive or managerial	27	23
Entertainment or public relations	13	31
Teacher	8	13
Lawyer or judge	6	13
Social or public service	7	8
Professor, other areas	6	7
Psychologist	3	9
Health support fields	2	10
Sales	6	2
Other fields	10	13
Total	**118**	**159**
Grand total	**228**	**215**

Snow's scientists-humanists bifurcation and its parallels to Ackerman and Heggestad's (1997) science-math and intellectual-cultural trait clusters stimulated the following hypotheses. High space groups are expected to report more frequently than low space groups a math or science course as their favorite in high school. Conversely, low space groups are expected to report a dislike for math and science courses more frequently than high space groups do. Also, high space groups are expected to report anticipating an undergraduate major and eventual occupation in math and science domains more frequently than low space groups do. To extend the breadth of criterion variables beyond that of strictly educationally- and vocationally-related criteria and to obtain a more comprehensive picture of what spatially talented students are like, the preferred leisure activities of high and low space groups also will be compared: High space participants are expected to report preferences for scientific, mathematical, and technical leisure pursuits, relative to low space participants.

To expand upon the extreme group comparisons on these longitudinally assessed preferences and choices, each of the five criterion variables also will be examined in multiple discriminant function analyses (DFA). Participants' group memberships for each of the criterion variables for each DFA will be organized into the three groups (science-math, humanities, or other) arranged according to Ackerman's (1996; Ackerman & Heggestad, 1997) trait clusters and Snow's (1965) two cultures (see Tables 4-7). Each external criterion variable will serve as the criterion in two separate DFAs: the first will use the spatial composite and five of the six scales of the SOV (because the SOV is an ipsative measure, the sixth scale is redundant and is therefore eliminated from the analysis); the second will include the spatial composite and the six RIASEC themes of the SII.

Initially, the incremental validity (Sechrest, 1963) of spatial ability over preferences in the classification of group membership for the five criterion variables will be evaluated. A series of hierarchical DFAs will be performed, with each preference inventory (SOV or RIASEC) in the first step and the spatial composite added in the second step, to test the hypothesis that spatial ability offers an improvement over preferences alone in the prediction of group membership on each of the criterion variables. The change in the proportion of the between-groups variance that is explained by the inclusion of spatial ability in the DFA over preferences alone will be examined for statistical significance.

If spatial ability does evidence a unique contribution in the prediction of group membership in these analyses, the structure matrices of the derived functions will be examined directly. Although many methodological approaches (e.g., factor analysis) do not allow for a direct interpretation of variables, the structure matrix of a DFA affords an opportunity to examine the relationship of each variate to the composite function. Each structure matrix includes, for each of its functions, a vector of correlations between scores on that discriminant function and each of the predictor variables (Betz, 1987). The pattern of correlations observed in each structure matrix will also be examined for stability across the array of external criterion variables.

It is hypothesized, for the DFAs based on spatial ability and the SOV, that spatial ability, theoretical values, and reversed social values will define a function that will discriminate members of the science-math criterion groups from the other participants along a developmentally sequenced series of external criteria arranged according to Ackerman's (1996; Ackerman & Heggestad, 1997) trait clusters and Snow's (1965) two cultures. Similarly, it is hypothesized, for the DFAs based on spatial ability and the RIASEC dimensions, that spatial ability, and investigative, realistic, and reversed social interests will define a function that will discriminate members of the science-math criterion groups from the other participants along the external criterion variables described above. A second function, defined largely by aesthetic values (on the SOV) or artistic interests (on the RIASEC), is expected to discriminate members of the humanities groups from other participants.

CHAPTER III

RESULTS

Phase I: Comparisons of Talent Search and Graduate Student Participants, by Sex

Descriptive statistics. Preference profiles on the SOV, RIASEC dimensions, and the BIS of the SII appear in Figures 6-8 for graduate students, high space participants, and low space participants, by sex. Some noteworthy features of these mean profiles were observed. As anticipated, high space groups, regardless of sex, exhibited high theoretical values. Both male and female high space groups were well above the normative mean on the theoretical dimension; however, the male high space adolescents were particularly distinguished by their standing on this value (nearly a full standard deviation above the normative mean). Although findings from the general occupational themes of the SII were ambiguous, a clear pattern emerged for both males and females on the SII's basic interest scales. High space adolescents, regardless of sex, exhibited markedly high interests in science and mathematics. This more detailed level of organization of the SII allows for a more refined examination of the interests assessed by this instrument. Both science and mathematics are included as subscales of the investigative general occupational theme, yet high space groups were not particularly distinguished by their investigative interests. However, medical science and medical service are components of the investigative general occupational theme also, both of which exhibited inconsistent trends across the space groups. Means and standard deviations, by sex, for graduate students and each of the extreme space groups, in addition to those for talent search participants in general, are provided in Appendix D.

Profile similarity. The profiles of each extreme spatial ability group (i.e., high space and low space) were compared to the criterion reference group of math, science, and engineering graduate students, by sex. The similarity of each of the space groups to the graduate students was assessed using Mahalanobis squared distances between group means; the results of each of these comparisons appear in Table 8. To test, within sex, whether the mean profile of each high space group was in closer proximity to the mean profile of the MSE graduate student comparison group than was the mean profile of each respective low space group, the difference between pairs of Mahalanobis squared distances was calculated and tested for statistical significance.

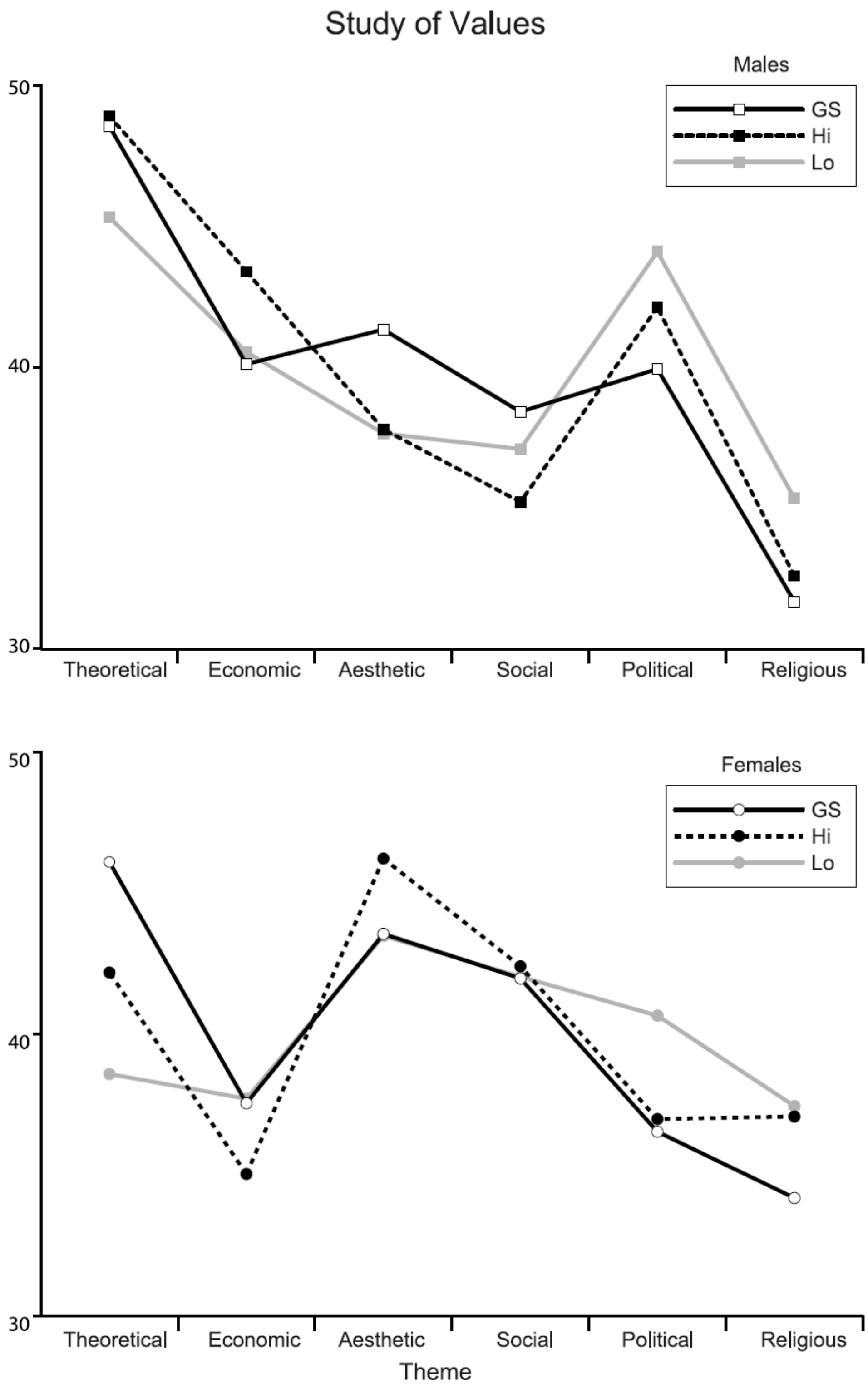


Figure 6. Study of Values. Means on the SOV for extreme spatial groups and graduate student comparison groups, by sex. GS = graduate students, Hi = high spatial ability adolescents, and Lo = low spatial ability adolescents.

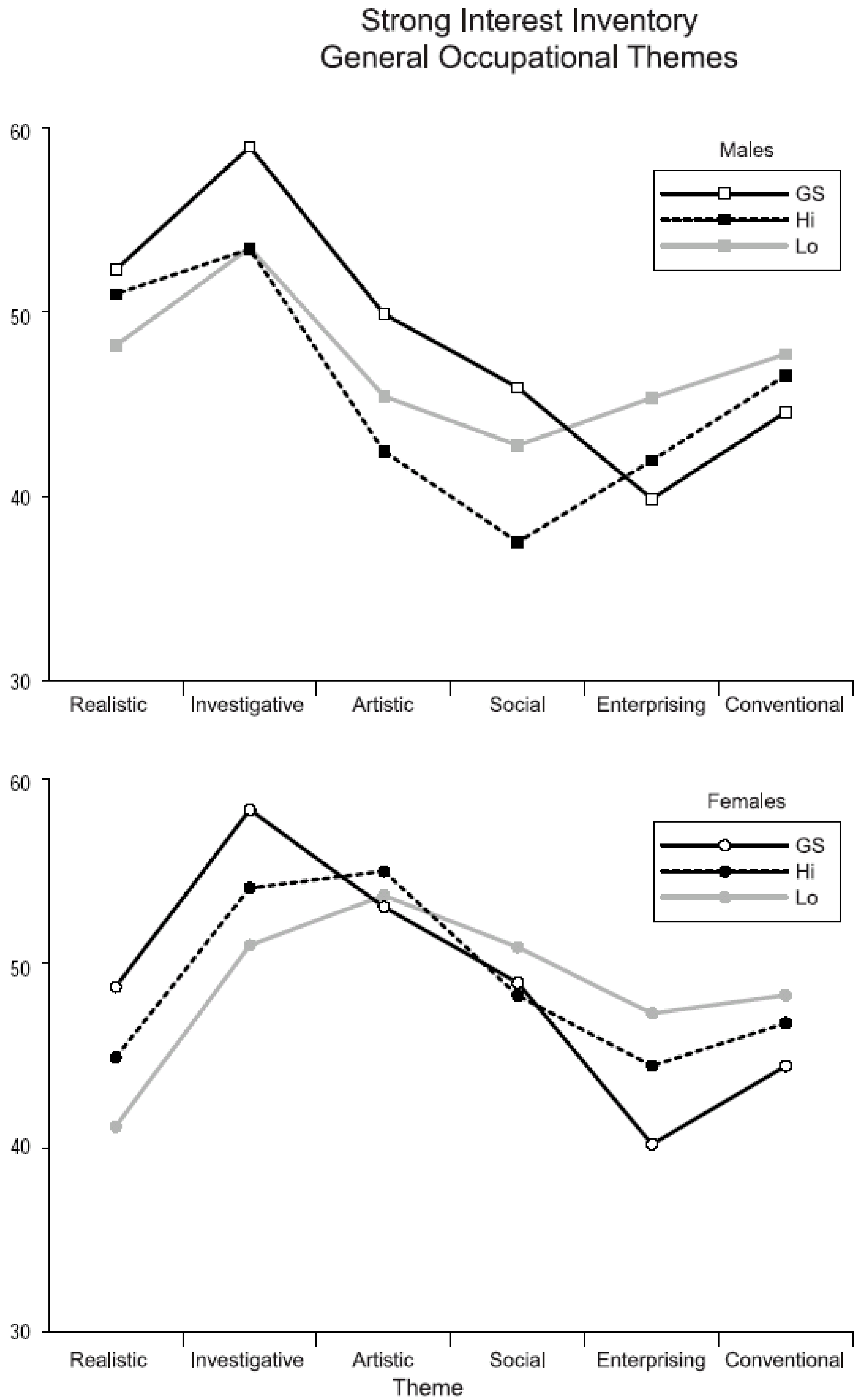


Figure 7. Strong Interest Inventory General Occupational Themes. Means on the RIASEC for extreme spatial groups and graduate student comparison groups, by sex. GS = graduate students, Hi = high spatial ability adolescents, and Lo = low spatial ability adolescents.

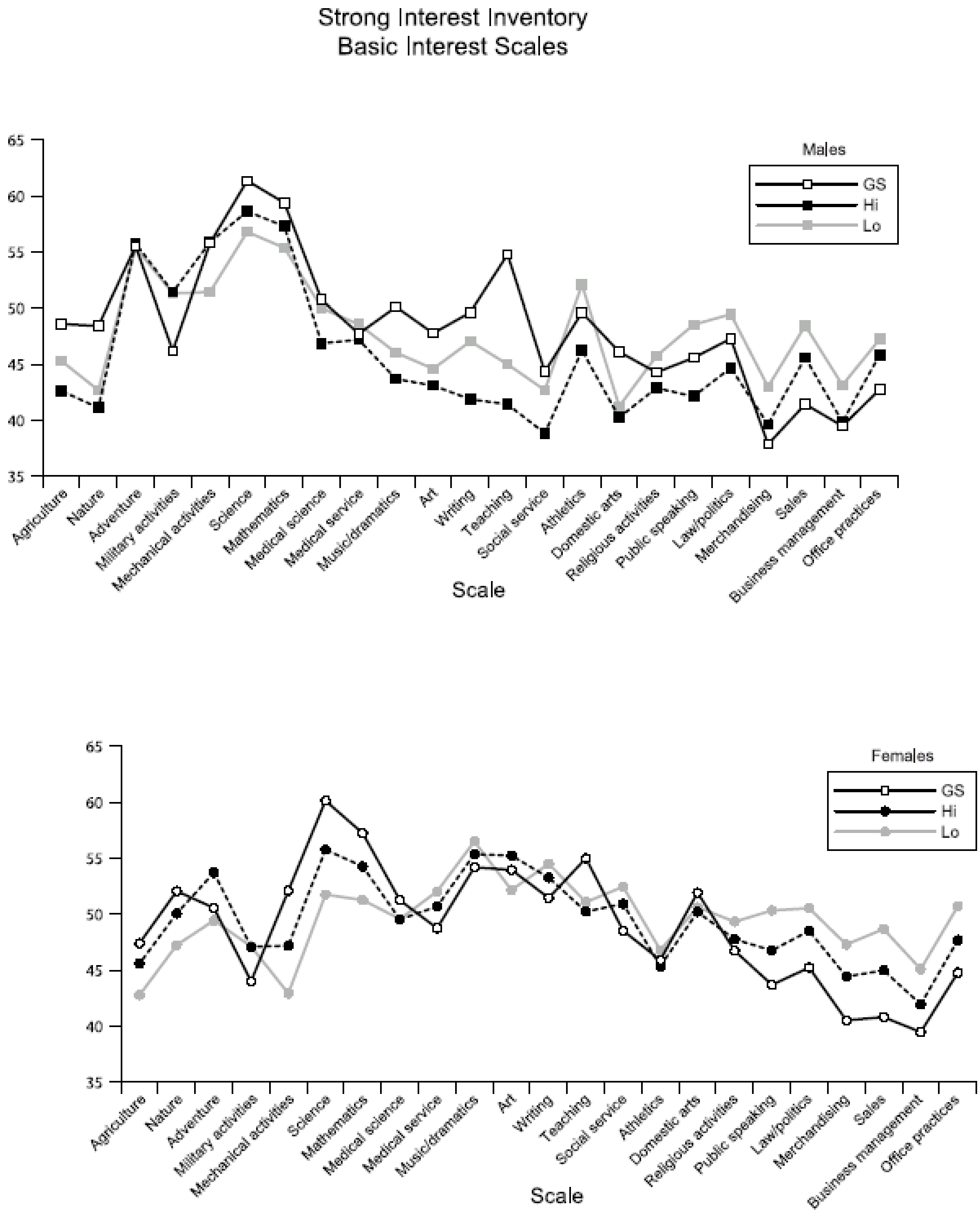


Figure 8. Strong Interest Inventory Basic Interest Scales. Means on the BIS for extreme spatial groups and graduate student comparison groups, by sex. GS = graduate students, Hi = high spatial ability adolescents, and Lo = low spatial ability adolescents.

Table 8

Mahalanobis squared distances of mean profile of each extreme spatial group to mean profile of graduate student criterion group, by sex

	Males	Females
Study of Values		
High space	0.46	0.59
Low space	0.82	1.62
RIASEC		
High space	1.96	1.28
Low space	2.02	3.26
BIS (23 scales)		
High space	6.65	2.59
Low space	5.80	6.47

High space females, as compared to low space females, exhibited more similar profiles to the MSE graduate students on the SOV [$F(5, 208) = 5.99$, $p < .01$], on the RIASEC [$F(6, 180) = 10.50$, $p < .01$], and on the BIS [$F(23, 163) = 20.26$, $p < .01$]. However, these results were not maintained for the males. Although the direction of the comparisons was in the predicted direction for each of the measures, there were no statistically significant differences between the profile similarities of each space group to the MSE graduate students: SOV [$F(5, 286) = 1.63$, *ns*], RIASEC [$F(6, 244) = 0.02$, *ns*], and BIS [$F(23, 227) = 0.92$, *ns*][1].

To further evaluate profile similarity, mean graduate student profiles were correlated with each of the extreme space groups, by sex, on each of the three preference measures, the SOV, RIASEC, and BIS. These correlations are presented in Table 9. The pattern of results was very similar to the pattern of results using Mahalanobis squared distances to compare profiles: stronger correlations between graduate student and high space females than between graduate student and low space females, but ambiguous results for the males[2].

[1] MD^2 based on medians, rather than means, also were calculated, and the pattern of results was similar to that based on means. Because there was no clear advantage to the median-based method, these findings are not presented but are available from the author upon request.

[2] Correlations based on medians, rather than means, also were calculated, and the pattern was similar to that based on means. Because there was no clear advantage to the median-based method, these findings are not presented but are available from the author upon request.

Table 9

Correlations of mean profile of each extreme spatial group to mean profile of graduate student criterion group, by sex

	Males	Females
Study of Values		
High space	.90	.78
Low space	.91	.55
RIASEC		
High space	.73	.85
Low space	.76	.42
BIS (23 scales)		
High space	.72	.86
Low space	.69	.46

Phase II: Longitudinal Assessments of Talent Search Participants, by Sex

Univariate analyses. To examine whether differences in the spatial abilities of intellectually able adolescents translate into long-term systematic differences in developmental choices and preferences, high space and low space groups were compared, by sex, on a series of criteria including course preferences, preferred leisure activities, undergraduate majors, and occupational plans assessed five years after their talent search identification. Table 10 reports the proportion of high space and low space participants, by sex, who indicate preferences and developmental choices along math- and science-related trajectories. For both males and females, a greater proportion of high space, relative to low space, participants reported a math or science course as their favorite in high school (males: $z = 2.63$, $p < .01$; females: $z = 1.87$, $p < .05$). Conversely, a greater proportion of low space, relative to high space, participants reported a math or science course as their *least* favorite course in high school, regardless of sex (males: $z = 4.63$, $p < .001$; females: $z = 3.44$, $p < .001$). High space males reported preferences for scientific, mathematical, and technical leisure pursuits ($z = 3.33$, $p < .001$), but neither high nor low space females indicated similar preferences (tests of statistical significance were unwarranted because of low proportions). Compared with low space males, high space males more frequently reported

Table 10

Proportions of extreme spatial groups who indicated math-science preferences, by sex

	Males	Females
Favorite course		
High space	59%	43%
Low space	38%	28%
Least favorite course[a]		
High space	21%	37%
Low space	57%	66%
Preferred leisure activity		
High space	28%	0%
Low space	7%	2%
Undergraduate major		
High space	74%	49%
Low space	52%	36%
Anticipated occupational field		
High space	59%	26%
Low space	19%	10%

[a.] Note that this variable is scaled differently than the other four, in that low space participants report a math or science course as their *least* favorite more frequently than do high space participants.

plans to major in math or science domains (z = 2.62, p < .01); females exhibited a similar trend, but the difference was not statistically significant (z = 1.52, p = .06). Finally, both male and female high space participants reported plans for a math- or science-related occupation more frequently than low space participants did (males: z = 4.77, p < .001; females: z = 2.34, p < .01).

Multivariate analyses. To test the hypothesis that spatial ability provides incremental validity over preferences in the prediction of group membership for each of the five criterion variables, a series of hierarchical discriminant function analyses (DFA) was performed. In each of the first five of these DFAs, five of the six scales of the SOV were entered in the first step and spatial ability was added in the second step. Next, each of these analyses was repeated using the RIASEC interest inventory in the first step and spatial ability in the second. The incremental validity of spatial ability was assessed by examining the difference in the proportion of variance explained at each step; that is, the difference between Pillai's trace estimates of the preference-alone model and the preference + spatial ability model. Summary information for each of these models appears in Table 11. In every case, the addition of spatial ability to the model provided a statistically significant improvement over preferences alone[3].

Given that spatial ability consistently exhibited incremental validity over preferences in the prediction of group membership for these criterion variables, the structure matrices of each of the discriminant functions were examined directly. The structure matrix is comprised of correlations between each predictor variable and scores on the discriminant functions. These discriminant loadings can be examined for content and psychologically interpreted. (See Appendix E for another way to evaluate the utility of these analyses.)

Scores on the first function (F_1) of each of the DFAs based on five values from the SOV and spatial ability, regardless of criterion variable, consistently exhibit strong positive correlations with spatial ability and theoretical values and consistent negative correlations with social values, as hypothesized (see Table 12). Additionally, the first functions exhibited consistent positive correlations with economic values and negative correlations with aesthetic values. Similarly, for DFAs based on RIASEC interest dimensions and spatial ability, F_1 was defined by strong positive correlations with spatial ability and consistent negative correlations with social interests for all criterion variables, as predicted. However, the hypothesized positive correlations with investigative and realistic interests were less consistent. No pattern is clear for F_2; in fact, although statistically significant (due to the large sample size), very little additional variance was explained by any of the second functions. Across all ten DFAs (those based on either preference instrument), the first functions accounted for 86% of the total variance explained, on average, whereas the second functions accounted for only 14% of the explained variance, on average.

[3] Some specific preference-ability interactions were hypothesized and tested, including theoretical values * spatial ability, social values * spatial ability, investigative interests * spatial ability, realistic interests * spatial ability, and social interests * spatial ability. Although a few reached statistical significance due to the large sample size and the number of criterion variables examined, the additional variance explained by their inclusion was inconsequential; therefore, they were not investigated further. Although the theory of work adjustment (Dawis & Lofquist, 1984; Lofquist & Dawis, 1991) predicts interactions between satisfaction and satisfactoriness, corresponding interactions between preferences and ability failed to be identified in this study. These findings speak to Dawes' (1979; Dawes & Corrigan, 1974) observation of the "robust beauty of main effects" as illustrated by their ubiquity across analyses.

Table 11

Incremental validity of spatial ability beyond preferences in discriminant function analyses

	Pillai's Trace	Δ	*p*
Favorite course			
SOV	.11		
SOV + SA	.14	.02	.01
RIASEC	.16		
RIASEC + SA	.18	.01	.05
Least favorite course			
SOV	.06		
SOV + SA	.10	.05	.0001
RIASEC	.11		
RIASEC + SA	.14	.02	.01
Preferred leisure activity			
SOV	.08		
SOV + SA	.11	.03	.001
RIASEC	.13		
RIASEC + SA	.14	.02	.03
Undergraduate major			
SOV	.20		
SOV + SA	.23	.03	.01
RIASEC	.26		
RIASEC + SA	.28	.02	.01
Anticipated occupational field			
SOV	.15		
SOV + SA	.18	.04	.0001
RIASEC	.15		
RIASEC + SA	.17	.03	.01

Note. The first row of each set of two rows reports the Pillai's trace statistic (explained variance) for the DFA based on preferences alone; the second reports Pillai's trace for DFA based on preferences and spatial ability, the incremental validity of the second model (Δ), and the *p*-value of the significance test for additional variance explained. Values of Δ may not equal the differences between reported Pillai's trace statistics due to rounding. SOV = Study of Values, RIASEC = general occupational themes of Strong Interest Inventory, and SA = spatial ability.

Table 12

Two sets of discriminant functions (Values + Spatial Ability and Interests + Spatial Ability) for five criterion variables across three criterion groups (science-math, humanities, other)

Values + Spatial Ability

	F_1					F_2				
	Fav.	Least	Leis.	Major	Occ.	Fav.	Least	Leis.	Major	Occ.
Theoretical	.69	.49	.61	.71	.73	.48	.06	.42	.25	-.03
Economic	.72	.39	.69	.52	.57	.08	-.60	-.53	-.63	-.56
Aesthetic	-.60	-.55	-.34	-.61	-.56	.46	.20	.52	.59	.32
Social	-.46	-.24	-.51	-.39	-.50	-.67	.56	-.07	.12	.40
Religious	-.38	-.03	-.46	-.07	-.16	-.39	.43	.07	.02	-.00
Spatial ability	.68	.87	.79	.62	.70	-.04	-.11	.23	.41	-.62
Pillai's Trace	**.13**	**.09**	**.09**	**.17**	**.17**	**.01**	**.01**	**.02**	**.06**	**.01**

Interests + Spatial Ability

	F_1					F_2				
	Fav.	Least	Leis.	Major	Occ.	Fav.	Least	Leis.	Major	Occ.
Realistic	.30	.35	-.04	.51	.42	.31	.58	-.28	.24	.05
Investigative	.24	.31	-.26	.55	.27	-.53	.00	-.27	.38	.47
Artistic	-.72	-.45	-.66	-.52	-.51	-.32	-.29	.51	.67	.69
Social	-.41	-.19	-.87	-.22	-.60	.15	.17	.04	-.03	.52
Enterprising	-.18	-.14	-.55	-.14	-.24	.34	.34	-.39	-.14	.13
Conventional	.31	.49	-.27	.35	.19	.16	-.07	-.03	-.09	.47
Spatial ability	.61	.66	.64	.59	.75	-.18	.25	-.15	.38	.19
Pillai's Trace	**.15**	**.12**	**.10**	**.19**	**.16**	**.03**	**.02**	**.04**	**.09**	**.02**

Note. Arguments in table are the weights for each preference dimension and spatial ability in each of five discriminant functions based on a preference measure (either SOV or RIASEC) and spatial ability with favorite course, least favorite course, preferred leisure activity, undergraduate major, and expected occupation as the criterion variables. The proportion of variance in group membership (science-math, humanities, or other) that is explained by each function (Pillai's trace) is reported in bold for each function.

F_1 = first discriminant function, F_2 = second discriminant function, Fav. = favorite course, Least = least favorite course, Leis. = preferred leisure activity, Major = undergraduate major, and Occ. = anticipated occupation.

Table 13

Correlations between discriminant function scores across five criterion variables

DFAs based on SOV and Spatial Ability

		F_1					F_2				
		Fav.	Least	Leis.	Major	Occ.	Fav.	Least	Leis.	Major	Occ.
F_1	Fav.		**.89**	**.95**	**.92**	**.95**	-.06	-.22	-.06	-.09	.07
	Least	**.87**		**.87**	**.88**	**.90**	-.27	.00	.06	.14	.38
	Leis.	**.95**	**.83**		**.83**	**.90**	-.04	-.26	.04	.08	.23
	Major	**.92**	**.88**	**.82**		**.99**	.01	.12	.19	.07	.02
	Occ.	**.95**	**.90**	**.90**	**.99**		.06	.01	.19	.11	.09
F_2	Fav.	-.01	-.25	.13	.00	.08		**.00**	**.63**	**.42**	**-.20**
	Least	-.25	.02	-.32	.08	-.03	**-.14**		**.66**	**.58**	**.25**
	Leis.	-.11	.06	.01	.12	.14	**.57**	**.62**		**.92**	**.40**
	Major	-.16	.10	.00	-.01	.03	**.37**	**.55**	**.93**		**.72**
	Occ.	-.04	.31	.11	-.05	.01	**-.17**	**.31**	**.47**	**.76**	

(table continues on next page)

The stability of the first functions across these analyses may be more fully appreciated by correlating participants' scores on the functions that were derived from analyses based on the five unique criterion variables within each set of predictors. Scores on each of the discriminant functions were calculated for all talent search participants. Correlations among the function scores of individuals for whom longitudinal data were available appear below the diagonal in Table 13 (SOV and spatial ability in the first panel; RIASEC and spatial ability in the second panel). Correlations among the function scores of individuals for whom longitudinal data were not available appear above the diagonal in Table 13 (SOV and spatial ability in the first panel; RIASEC and spatial ability in the second panel).

The bold entries in Table 13 represent the cross-correlations among the first functions (across the five different analyses of each set) and among the second functions (across the five different analyses of each set). The average intercorrelation among the first functions based on

Table 13, continued

DFAs based on RIASEC and Spatial Ability

		F_1					F_2				
		Fav.	Least	Leis.	Major	Occ.	Fav.	Least	Leis.	Major	Occ.
F_1	Fav.		**.92**	**.66**	**.92**	**.89**	.02	.17	-.44	-.23	-.16
	Least	**.92**		**.58**	**.89**	**.87**	-.08	.05	-.18	.01	.20
	Leis.	**.69**	**.56**		**.48**	**.81**	-.23	-.17	-.07	.13	-.16
	Major	**.92**	**.89**	**.50**		**.86**	-.06	.26	-.46	-.04	-.04
	Occ.	**.89**	**.85**	**.82**	**.87**		-.19	.05	-.17	.19	.00
F_2	Fav.	.00	-.07	-.17	-.13	-.21		**.73**	**-.48**	**-.64**	**-.59**
	Least	.14	.00	-.14	.20	.02	**.65**		**-.75**	**.31**	**.48**
	Leis.	-.38	-.11	-.01	-.39	-.17	**-.32**	**-.73**		**.31**	**.48**
	Major	-.21	.00	.06	.00	.19	**-.66**	**-.29**	**.49**		**.68**
	Occ.	-.10	.27	-.22	.05	.02	**-.54**	**-.46**	**.58**	**.65**	

Note. Arguments in table reflect correlations between discriminant function scores across five criterion variables: favorite course, least favorite course, preferred leisure activity, undergraduate major, and anticipated occupation. Correlations below the diagonal are based on subsets of the 547 talent search participants for whom 5-year follow-up surveys were secured: 540 cases were used in the analyses based on the SOV and spatial ability, and 463 cases were used in the analyses based on RIASEC and spatial ability. Correlations above the diagonal are based on subsets of the 513 talent search participants for whom 5-year follow-up surveys were *not* secured: 476 cases were used in the analyses based on the SOV and spatial ability, and 418 cases were used in the analyses based on RIASEC and spatial ability. Although theoretically, F_1 and F_2 of the same criterion variable should be orthogonal, because of a small degree of item nonresponse, these cross-correlations diverged from zero somewhat.

F_1 = first discriminant function, F_2 = second discriminant function, Fav. = favorite course, Least = least favorite course, Leis. = preferred leisure activity, Major = undergraduate major, and Occ. = anticipated occupation.

the SOV and spatial ability was. 90 for the subsample with longitudinal data and .91 for the subsample without longitudinal data, and the average intercorrelation among the first functions based on the RIASEC and spatial ability was .79, regardless of subsample. This observed pattern of high correlations among the first functions imply that they are functionally equivalent and that they are converging on the same external criterion space. As indicated by their lower intercorrelations, the second functions are markedly less robust.

Overall, the first functions of each of the two sets of five DFAs appear as functionally equivalent and empirically interchangeable, regardless of the criterion variable used to derive it (favorite course, least favorite course, preferred leisure activities, undergraduate major, or anticipated occupation). These five functions appear to draw on the same constellation of personal attributes that are conducive to math-science pursuits. Because the integrity of both sets of five second functions was markedly more frail, attention was focused on the covariance structure of F_1 across both sets of five DFAs.

In addition to the first functions drawing upon the same constellation of traits regardless of the *external criterion* used, these functions appear to draw on the same constellation of traits regardless of the *preference instrument* used (SOV or RIASEC dimensions of the SII). To examine this systematically, participants' scores on the first functions derived from the DFAs based on the SOV and spatial ability were correlated to participants' scores on the first functions derived from the DFAs based on the RIASEC and spatial ability. These correlations appear in Table 14. The correlations among the scores on the first functions across instrument averaged .70 among participants for whom longitudinal data were available (top panel) and .71 among participants for whom longitudinal data were not available (bottom panel).

The power of the first discriminant functions to predict group membership may be further appreciated by examining the distributions of scores on each of those functions for each of the criterion groups. Scores on each first discriminant function were standardized and categorized according to their group membership (science-math, humanities, or other) on each relevant criterion. Then the distributions of standardized scores for each of the three criterion groups for each of the ten DFAs were graphed, by sex (see Figure 9). The distributions of scores for science-math groups appear in red, humanities in blue, and other in gray, by sex, for each of the five DFAs based on the SOV and spatial ability (top two rows) and each of the five DFAs based on the RIASEC dimensions and spatial ability (bottom two rows). The discriminant functions illustrated in Figure 9 showed that the science-math criterion group was much more readily distinguished from the other two groups (humanities and other) than the latter two were from each other.

Members of the science-math criterion group exhibited higher scores on the first discriminant function (F_1), on average, than members of the humanities or other criterion groups; in other words, participants with higher F_1 scores were more likely than participants with lower

Table 14

Correlations between first discriminant function scores for analyses based on the SOV and spatial ability versus RIASEC and spatial ability across five criterion variables

F_1 scores of participants with longitudinal data

		F_1 (RIASEC + SA)				
		Fav.	Least	Leis.	Major	Occ.
F_1 (SOV + SA)	Fav.	.78	.69	.66	.72	.77
	Least	.74	.73	.61	.71	.75
	Leis.	.73	.67	.72	.66	.80
	Major	.71	.64	.57	.70	.70
	Occ.	.74	.67	.64	.72	.77

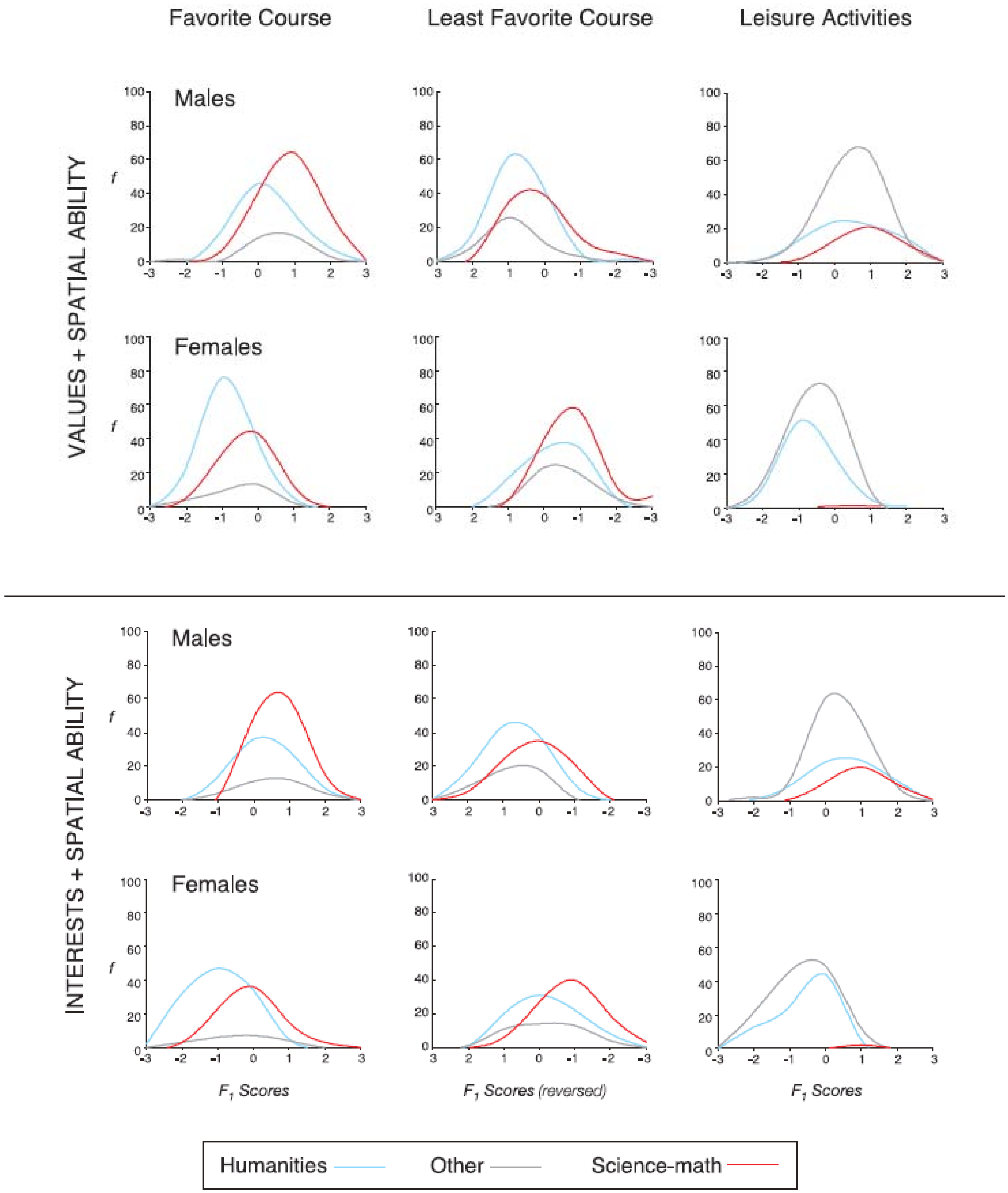
F_1 scores of participants without longitudinal data

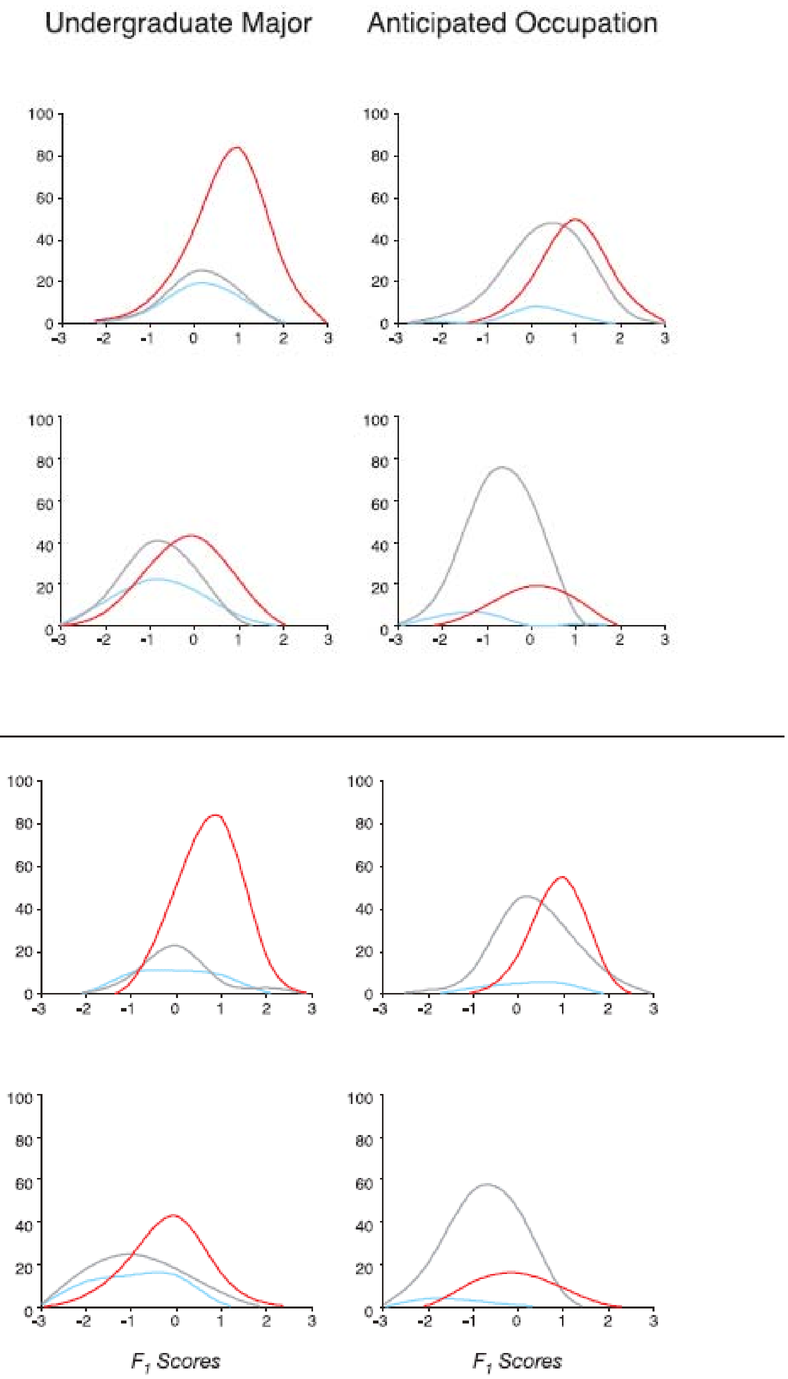
		F_1 (RIASEC + SA)				
		Fav.	Least	Leis.	Major	Occ.
F_1 (SOV + SA)	Fav.	.79	.73	.66	.73	.78
	Least	.71	.73	.62	.68	.75
	Leis.	.74	.73	.72	.68	.81
	Major	.71	.68	.56	.70	.71
	Occ.	.75	.72	.63	.73	.77

Note. Arguments in table reflect correlations among participants' scores on the first functions derived from the DFAs based on the SOV and spatial ability (along left) were correlated to participants' scores on the first functions derived from the DFAs based on the RIASEC and spatial ability (along top). F_1 = first discriminant function, Fav. = favorite course, Least = least favorite course, Leis. = preferred leisure activity, Major = undergraduate major, and Occ. = anticipated occupation.

F_1 scores to have reported a math- or science-related course as their favorite course in high school. This was true for both males and females. This pattern of results was replicated across all five criterion variables within both sets of analyses (based on spatial ability and either the SOV or RIASEC). Note that the abscissa has been reversed for the column representing least favorite course to reflect the nature of this variable—rather than representing a *preference* for something (as in favorite course, preferred leisure activities, major, and occupation), this variable reflects a *dislike* for something. Therefore, the second column of Figure 9 illustrates that participants with higher F_1 scores tended to report a math- or science-related course as their least favorite less frequently than did participants with lower F_1 scores. The observed stability of the first function across five distinct criterion variables is exhibited similarly in the analyses based on the RIASEC dimensions and spatial ability. The second discriminant functions were not examined in this manner for any of the analyses because of the instability exhibited in their structure matrices.

Figure 9. Distributions of scores for each criterion group, by sex, on first discriminant functions. Individuals were categorized according to their group membership (science-math, humanities, or other) on each relevant criterion and graphed, by sex, according to their scores on each of the first discriminant functions. The top two rows represent functions based on values and spatial ability; the bottom two represent functions based on interests and spatial ability.


Favorite Course
Least Favorite Course
Leisure Activities
VALUES + SPATIAL ABILITY
INTERESTS + SPATIAL ABILITY
Males
Females
f
F_1 Scores
F_1 Scores (reversed)
F_1 Scores
Humanities
Other
Science-math


Undergraduate Major
Anticipated Occupation
100
80
60
40
20
0
-3
-2
-1
0
1
2
3
F_1 Scores
F_1 Scores

CHAPTER IV

DISCUSSION

Spatial Ability in Talent Development

Spatial ability, although long ignored in talent development, has recently gained the attention of educational researchers. It is gaining recognition as a vital component of the intellectual repertoire. Given this, it is only a matter of time before talent searches incorporate spatial ability into their identification procedures, and when they do, our educational systems need to be prepared to meet the learning needs of spatially talented students, which are likely to be distinct from those of other populations of gifted youth. To better understand their educational needs, this study set out to psychologically profile spatially talented students to enrich our appreciation of their individuality.

Understanding the personal preferences of spatially talented adolescents is critical information for educational and vocational counselors (Colangelo, 2002; Colangelo & Davis, 2003; VanTassel-Baska, 1998; Walsh, 2003). The counseling literature and the models used therein advocate the use of multiple indicators of a person's strengths and salient preferences to maximize person-environment fit in learning and working environments (Dawis, 1991, 1992, 2001; Dawis & Lofquist, 1984; Holland, 1997; Lofquist & Dawis, 1991). Armed with a more comprehensive understanding of a person's individuality, counselors are better equipped to identify environments in which a person is likely to perform competently and experience personal fulfillment.

Spatially talented students in this study, relative to intellectually able students with less remarkable spatial skills, tended to exhibit strong theoretical values, as measured by the SOV (Allport et al., 1970). The SOV has long been utilized in counseling contexts; its ipsative nature yields a particular advantage over normative instruments, in that an individual's salient values are contrasted to other values within the individual. Although reliance on the SOV in research has diminished in the past years, a recent revision holds promise for a revitalization of this instrument (Kopelman et al., 2003).

Adolescents with high spatial abilities, regardless of sex, also were characterized by prominent scientific and mathematical interests on the basic interest scales (BIS) of the SII (Hansen & Campbell, 1985). Both scientific and mathematical interests are included as components of the investigative general occupational theme at a more general level of organization of the SII, which is directly comparable to the theoretical theme of the SOV. However, the investigative general occupational theme did not exhibit this pattern of results. This is likely due to the other BIS that comprise the investigative theme (medical science and medical service) in the version of the SII utilized here (Hansen & Campbell, 1985); the subscales have been reorganized somewhat in the latest version of the SII (Harmon et al., 1994), and the investigative theme no longer includes medical service. It is likely that this reorganization will yield a more purified investigative theme in studies utilizing the revised version. However, this situation illustrates that the BIS allow for much more fine-tuned vocational counseling than the general occupational themes (Armstrong et al., 2004). In this study, both of these salient personal preferences may be viewed as markers of enthusiasm and motivation for development along the math-science pipeline.

These findings need to be viewed in light of what we already know about the kinds of environments to which older spatially talented individuals are drawn. Humphreys et al. (1993) reported preferences in high school students for "building, working with, making, [and] repairing" (p. 258), among other activities, all of which had the common elements of providing the individual with opportunities to create or manipulate things. Although these interests are conducive to development in many technical and trade fields, as spatially able students have been steered in the past (Smith, 1964), they are also relevant to high-level development in scientific and engineering domains (Silverman, 1998). These professional level career options may provide spatially talented individuals with opportunities for development that may increase both their career satisfaction and satisfactoriness (Dawis & Lofquist, 1984; Lofquist & Dawis, 1991).

These findings fit well with other cross-attribute studies of young adults and intellectually precocious youth. Educators and counselors should be comfortable using this information, albeit cautiously, with students talented in spatial visualization. That a number of the high space students would not have been identified by conventional talent search procedures presents a challenge to existing talent search models. Hence, a distinctive "type" of intellectually precocious student is currently underserved by our educational system in general and modern talent search models in particular.

In his commentary on expanding the breadth and depth of admissions testing, R. E. Snow (1999) remarked, "There is good evidence that [visual-spatial reasoning] relates to specialized achievements in fields such as architecture, dentistry, engineering, and medicine. Given this plus the longstanding anecdotal evidence on the role of visualization in scientific discovery, it is incredible that there has been so little programmatic research on admissions testing in this domain" (p. 136). The same could be said for existing talent search models that are exclusively restricted to verbal and quantitative reasoning abilities. A large segment of truly exceptionally talented students are missed by these procedures, those who are particularly gifted in nonverbal ideation.

Spatial Ability in the Math-Science Pipeline

Spatial ability has repeatedly exhibited its importance in educational and vocational development along math- and science-related trajectories, in both normative and gifted populations (Gohm et al., 1998; Humphreys et al., 1993; Shea et al., 2001). This study has extended the examination of spatial ability to young adolescents using psychometrically sound preference dimensions, revealing interest patterns indicative of nascent physical scientists. The preference profiles of intellectually able adolescents distinguished by their standing on spatial ability were compared to the preference profiles of young adults seeking advanced training in math, science, and engineering graduate training programs, by sex. Some of the resulting findings regarding congruence on particular preference dimensions merit attention.

The notably high standing of high space groups on theoretical values and on mathematical and scientific interests is remarkably aligned with that of the math, science, and engineering graduate student comparison group. These scientists-in-training were further removed from the normative population on these dimensions than they were on any other preference dimension. That high space adolescents display these conspicuous markers of nascent scientists suggests potential for development along the math-science pipeline. Moreover, the high space adolescents shared low standing with the graduate students on several preference dimensions, including political and religious values (on the SOV) and enterprising and conventional interests (on both the RIASEC and BIS levels of the SII).

This is an often underappreciated point: Relative weaknesses and dislikes can be as important to consider in educational-vocational counseling contexts as are relative strengths and preferences. Although the latter clearly influence the educational-vocational niches that people self-select into, the former influence the niches that people select out of (Gottfredson, 2003; Scarr, 1996; Scarr & McCartney, 1983). The three specific abilities found in the radex are especially relevant in predicting individual differences in performance across educational-vocational domains and for predicting educational-vocational domains that people approach *and* avoid. This often neglected point is illustrated well here.

Examinations of overall profile similarity revealed that, across all measures, female adolescents with high spatial abilities exhibited more similar preferences to graduate student females than did female adolescents with relatively low spatial abilities. However, findings for males were ambiguous. This pattern of results was found regardless of method of profile analysis used. The lack of consistent findings for the males may have multiple roots and will require further investigation to be more fully understood. However, these findings are relevant to the extensive literature on the difference in male and female representation in the math-science pipeline, in that they may facilitate targeting of girls at promise for positive development in these fields. To be clear though, given the well-known sex differences in spatial visualization (Geary, 1998; Hedges & Nowell, 1995; Kimura, 1999), it is not realistic to expect identification on the basis of spatial ability to bring male-female representation in these fields to equivalent proportions. It is likely, however, to enable us to identify some girls at promise for development in math-science domains who might otherwise be missed.

It is important to keep in mind that, in this study, boys exhibited higher spatial abilities than girls, overall. This is consistent with sex differences observed in the normal population. Although general cognitive ability exhibits no consistent sex differences, specific abilities do—some with a female advantage, others with a male advantage (Benbow, 1988; Geary, 1998; Halpern, 2000; Hedges & Nowell, 1995; Kimura, 1999). The mean sex difference, favoring males, in the normal population on spatial ability is higher than for other gender-differentiating abilities—nearly a full standard deviation in some visuospatial tasks, especially those involving mental rotation (Geary, 1998; Halpern, 2000; Hedges & Nowell, 1995; Kimura, 1999; Loring-Meier & Halpern, 1999; Masters, 1998; Parsons et al., 2003). There is at least one visuospatial task that favors females—object location—but it is less clear that this component of spatial ability is relevant to development in math-science domains than is mental rotation, one of the primary tasks utilized to assess spatial ability here. In this study, for example, there was very little difference between the cut-off scores on the spatial ability composite for the high space girls and the low space boys (less than .03 standard deviation units), whereas high and low space cutoffs within each sex were more than one standard deviation removed from one another. This could, at least in part, explain why more men than women enter the math-science pipeline.

Although more men than women are observed at all levels of development along the math-science pipeline, the ratio becomes more disparate at rising levels along the continuum (Webb et al., 2002). For example, a recent National Science Foundation (2000) study reported that 37% of bachelor's degrees in the physical science were earned by women, but only 22% of doctoral-level degrees were. These differences are even more extreme in the faculties of math and science departments. It is clear that women are exiting the math-science pipeline in greater proportions than men, and understanding sex differences in specific abilities is critical to understanding why. Recall that Gottfredson (1986, 2003) has observed that, relative to importance of *g*, the importance of specific abilities in job performance increases as the cognitive complexity of occupations increases. This implies that at higher levels of educational-vocational development in math-science, the cognitive demands for performance will rely increasingly more on specific abilities (namely, spatial ability). Given the extraordinarily disparate male-female ratios one would observe in the upper tails of distributions offset by a mean difference like that observed for spatial ability, the number of spatially talented women available to draw upon for these advanced positions would be small indeed, relative to the number of men at a comparable level of spatial ability.

Similar to the different pattern of findings across sex documented here, Shea et al. (2001) found that spatial ability predicted course dislikes for girls, but not for boys. It is possible that the two extreme groups of boys in this study are more similar to one another than are the two groups of girls. This possibility is supported by observations in an earlier study that compared the graduate students to another group of talent search participants, by sex (Lubinski, Benbow, et al., 2001). They found that both male and female math, science, and engineering graduate students and male talent search participants were quite similar in their psychological profiles (on abilities and preferences) but the female talent search participants were clearly distinguished from the other three groups.

Prediction of Math- and Science-Related Choices

The second vein of investigation in this study took two approaches within a longitudinal framework. First, the power of spatial ability alone to discriminate temporally remote developmental choices and preferences was assessed using, again, an extreme group comparison methodology. Relative to low space adolescents, high space adolescents, regardless of sex, more frequently indicated math- and science-related preferences and choices across a series of developmentally sequenced criterion variables, spanning educational, vocational, and leisure domains. These effects were consistent across both retrospective (favorite course, least favorite course, and preferred leisure activities) and prospective (undergraduate major, anticipated occupation) reports. Interestingly, some rather striking sex differences also were apparent. For all of the longitudinal criteria examined here, males reported math- and science-related choices and preferences more frequently than their female counterparts, regardless of spatial group.

The power of spatial ability to predict temporally remote developmental paths in conjunction with personal preferences also was examined among these adolescents initially selected for their ability in quantitative or verbal reasoning. Previous research has shown that spatial ability provides incremental validity over quantitative and verbal reasoning abilities in the prediction of similar, long-term outcomes (Shea et al., 2001). Moreover, age 13 assessments of personal preferences and quantitative and verbal reasoning abilities exhibit incremental validity over one another in the prediction of undergraduate degree at age 23 (Achter et al., 1999) and occupational group membership at age 33 (Wai et al., in press). Therefore, it was expected that spatial ability might explain some unique variance left unexplained by preferences alone. As hypothesized, spatial ability exhibited incremental validity over both interests and values in the prediction of group membership along a diverse array of criteria. This method had the advantage of using all talent search participants with available longitudinal data, rather than the extreme groups of the previous method, allowing for a more detailed analysis.

An examination of the structure matrix of each of the discriminant functions revealed a stable function that distinguished math-and science-related developmental choices from other choices across all ten analyses. This ubiquitous function was defined by strong positive correlations with spatial ability and theoretical values and consistent negative correlations with social interests and values. Again, it is likely that the more purified investigative general occupational theme of the more recent revision of the SII would yield stronger and more consistent positive correlations with this function. As in other studies aimed at identifying the personal attributes factoring into differential development along advanced educational-vocational paths for young adults (Austin & Hanisch, 1990) and intellectually precocious participants (Achter et al., 1999), a dominant math-science discriminant function surfaced in the present study. This function was defined by ability and preference patterns indicative of adult engineers and physical scientists.

Although there were some fluctuations in the correlations found across F_1 structure matrices for each salient individual differences dimension, it is important not to assign much significance to small changes in these values. These small fluctuations may reflect variation specific to each criterion variable or, perhaps to a lesser extent, sample-specific variance (due to item missingness, the samples varied slightly across analyses). The meaningfulness of the individual variate is best appreciated as an aggregate across criterion variables.

The examination of the structure matrices suggested that the first functions in each of the two sets of five DFAs appeared to be converging on the same psychological space, regardless of external criterion variable. That these functions appeared to be empirically interchangeable was further illustrated by the intercorrelations (some approaching unity) of function scores in both the group of individuals on which the analyses were originally based and in the replication of the correlation matrix in the group of participants for whom longitudinal data were not available.

Moreover, the first discriminant functions appeared to be converging on this same psychological space regardless of preference measure used! Across all five criterion variables, the first functions, uncovered using either spatial ability + SOV or spatial ability + RIASEC, were functionally equivalent, with an average intercorrelation of .70. Psychologically, the SOV and RIASEC appear to team with spatial ability in the same way—combining competency and preference attributes—to identify students with affinities for math-science degrees and careers.

Particularly striking was the ability of those similar first functions to distinguish the distributions of math- and science-related longitudinal outcomes from the others, as illustrated across all 20 panels of Figure 9. Regardless of sex, type of preference measure, or criterion variable, the distribution of members of the science-math criterion group were distinguished by having higher F_1 scores, on average, than either the humanities or other criterion groups. Those individuals with math-science affinities (as measured by favorite and least favorite course, leisure activities, college major, and anticipated occupation) consistently possess higher scores on these functions. To the extent that one has high standing on these functions, as a collective, individuals are more likely to sustain commitment to the development of math-science competencies as learning and work environments become more challenging.

These density curves also provide a glimpse into the nature of sex differences and differences in male-female representation in the math-science pipeline. It is particularly interesting to note the sex differences on the scores on the first functions in the science-math criterion groups. Across all sets of analyses, regardless of type of preference instrument or criterion variable, males in the science-math criterion groups exhibited a distribution of scores higher than that exhibited by females in the science-math criterion groups.

Although this study has the potential to inform methods of identifying young women and men at promise for math and science educational and vocational development, we see fewer females than males in the MS-related groups across the board. These sex differences again suggest that fewer women than men might be identified using these methods. A greater proportion of men than women were members of the science-math criterion groups across all criterion variables, a sex difference that was particularly striking for leisure activities, where only 2 females reported math-science activities during their free time. Moreover, the ratio of males and females in the science-math criterion groups appears to vary as a function of level of spatial ability. When the extreme groups (high space and low space groups) are viewed as a comparison across sex, rather than across spatial ability group, the male-female ratio of science-math group membership is higher for the high space group than for the low space group.

Implications

This study reinforces the need for spatial ability to be incorporated into current talent search models and may inform attempts to better serve spatially gifted students. That they are underserved in our educational system is demonstrated, in part, by their underachievement, relative to students gifted in other content domains (e.g., mathematics; Gohm et al., 1998). The frequent observations of lower motivation and engagement in educationally-related activities by spatially gifted students may be better understood in light of the findings from this study regarding their personal preferences. More generally, improving our understanding of the psychology of spatially talented students could inform educational programming and curriculum development with the potential to more fully engage them in the educational process.

This aptitude complex approach may be used to hypothesize explanations for their underachievement and, in turn, posit potentially effective interventions. It seems that spatially talented students could be dissuaded from pursuing post-secondary education because of the strong verbal and mathematical orientation of K-12 curricula (Silverman, 1998). Spatially talented students might be better served by a curriculum that relied more upon reasoning with figures and shapes, their preferred medium of ideation, and less upon words and numbers, the media typically preferred by verbally and mathematically talented students, respectively. Just as mathematically or verbally gifted students learn best in a learning environment designed with their particular strengths and preferences in mind, spatially talented student stand to benefit from educational programming designed explicitly to complement their unique aptitudes. There is a need to fine-tune the curriculum for spatially talented students. Examples of possible programmatic changes that might serve to more fully engage them in the educational process might include increased lab work in science classes or reading biographies of scientists and inventors in literature classes.

Given the considerable national attention given to the observation of lesser representation of women in math, science, and engineering (National Research Council, 2002; National Science and Technology Council, 2000; National Science Foundation, 2004), these findings may have important ramifications for identifying those women at promise for positive development in these fields. For the reasons reviewed above, however, it is not realistic to consider spatial ability to be a panacea for the male-female disparities observed along the math-science pipeline. The benefit of identifying talent on the basis of spatial ability is to better foster the development of this population of exceptional human capital.

In addition to the potential benefits of identifying a valuable pool of talent with the potential to become tomorrow's much needed scientists, incorporating spatial ability into current talent identification methods may serve another interesting purpose. Spatial ability tends to have a weaker association with socioeconomic status than do either of the major methods currently utilized—mathematical or verbal abilities (Austin & Hanisch, 1990). In light of this observation, it is reasonable to expect broadening talent identification procedures to include spatial talent will serve to identify more lower SES students than identification on mathematical and verbal abilities alone.

Limitations and Future Directions

Although the longitudinal component of this study was successful in identifying functions that were able to discriminate science-math from other criterion group membership, the same could not be said for the humanities criterion group. This is likely due to the under-determination of the model in this study. Previous research has shown that verbal ability and aesthetic values predict humanities undergraduate degrees (Achter et al., 1999), and, indeed, somewhat consistent aesthetic and artistic themes were observed in the second functions of many of the analyses. However, they were not consistent enough to draw any solid conclusions. The addition of verbal ability in future research would increase their potential to distinguish humanities-related outcomes[4].

There is another advantage to incorporating measures of other specific abilities into future studies. Measures of specific abilities cannot measure their specificity in isolation from general cognitive ability (Gustafsson, 2002; Gustafsson & Snow, 1997). Including markers of all three major specific abilities (i.e., quantitative reasoning, verbal reasoning, and spatial abilities) would allow a general ability factor to be extracted and the unique contribution of each specific ability to be examined directly. Teaming this approach with comprehensive noncognitive assessments is likely to allow a fuller appreciation of how these dimensions of individual differences operate collectively.

[4] Indeed, an initial investigation of a subset of these participants for whom markers of the three major specific abilities were available (they were assessed on the SAT-Math and SAT-Verbal as well) suggests that spatial ability makes a unique contribution beyond preferences and verbal and mathematical abilities. Although there were insufficient sample sizes to reach statistical significance across many of these analyses (sample sizes ranged from 159 to 211), a clear-cut pattern emerged (see Appendix F). Averaged across all ten analyses, spatial ability explained an additional 2.4% of the variance in group membership (science-math, humanities, or other), beyond that explained by preferences and verbal and mathematical abilities. These findings do seem to indicate that spatial ability will enrich our understanding and modeling of educational-vocational development among intellectually precocious youth above and beyond those based on verbal and mathematics alone.

Conclusion

This study investigated the relevance of spatial ability in talent development with a particular emphasis on predicting outcomes along the math-science pipeline. Findings support the conclusion that spatial ability is an important factor related to pursuing math-science domains and that spatial ability provides unique information beyond preferences in understanding math-science development. The relations among the ability and preference dimensions examined here that are relevant to math- and science-related development are in place in early adolescence. These constellations of intellectual and nonintellectual attributes appear to work in conjunction to predict developmental choices and preferences. Incorporating spatial ability into talent identification and development, in tandem with a more thorough understanding of the nonintellectual attributes that tend to covary with spatial ability, should enable educators and counselors to better serve the unique needs of this special population of under appreciated students.

The findings from this study underscore the importance of normal science and its reliance upon the gradual, incremental accumulation of knowledge in accordance with well-established theory (Kuhn, 1962). Just as Julian C. Stanley stood on the shoulders of Leta Hollingworth and Lewis Terman to reveal the importance of going beyond the construct of general intelligence by measuring the specific mathematical and verbal reasoning abilities of intellectually precocious youth, it is time for modern procedures to take the next logical step. It is clear that measures of spatial visualization, initially designed for high school students and young adults, have construct validity for intellectually precocious youth. The evidence is clear that seeking out this special population in the environments where they are found, and implementing a talent search, using measures of spatial visualization, will pay high dividends. At the very least, we need to identify the approximately 50% of the top 1% of spatially talented students who are lost currently by modern talent search procedures. This will not only better meet the needs of this special population, but also, by facilitating their development, the human capital needed to maintain and advance our ever-changing technical world will be insured. Finally, on a more basic theoretical level (Lubinski & Benbow, 2000), launching such an effort is likely to contribute to a more comprehensive understanding of exceptional forms of intellectual precocity and lifelong learning.

Appendix A

Talent search background questionnaire

Background Questionnaire

1. Gender: ◯ Male ◯ Female Age: ________

Race:

◯ 1. White or Caucasian
◯ 2. Black or African-American
◯ 3. Native American or Alaskan Native
◯ 4. Mexican-American or Hispanic
◯ 5. Oriental, Asian-American, or Pacific Islander
◯ 6. Puerto Rican
◯ 7. Other (Please specify): ______________

Family Background:

2. In what country were you born? ◯ U.S. ◯ Other (Please specify): ______________

3. In what country was your father born? ◯ U.S. ◯ Other (Please specify): ______________

4. In what country was your mother born? ◯ U.S. ◯ Other (Please specify): ______________

5. How old is your: father? ________ mother? ________

6. Religion: father's? ______________________ mother's? ______________________

7. What is the highest educational level reached by each of your parents? Please indicate by placing a "✔" in the corresponding boxes below:

Father	Mother		Name of college or university, city, state
◯	◯	1. Less than high school	
◯	◯	2. High school diploma	
◯	◯	3. Some college	______________________
◯	◯	4. Technical or vocational diploma or certificate	______________________
◯	◯	5. Two year degree; e.g., A.A.	______________________
◯	◯	6. Bachelor's degree	______________________
◯	◯	7. Some graduate work	______________________
◯	◯	8. Master's degree or equivalent	______________________
◯	◯	9. Graduate study after Master's, but not a doctorate	______________________
◯	◯	10. Doctorate degree or equivalent	______________________

8. What is your father's occupation? ____________________

9. What is your mother's occupation? ____________________

10. Are your parents divorced? ◯ Yes ◯ No

11. With whom are you living? Please indicate by placing a "✔" in the appropriate box below:

- ◯ Mother and father
- ◯ Mother only
- ◯ Father only
- ◯ Sometimes with my mother, sometimes with my father
- ◯ Mother and stepfather
- ◯ Father and stepmother
- ◯ Grandparents, aunt, uncle, or cousins
- ◯ Foster parents (not relatives)
- ◯ Someone not listed above (Please specify): ____________________

12. How many older and younger brothers and sisters do you have?

	Younger	**Older**
Brothers		
Sisters		

13. Do you, any of your biological siblings, or parents have a learning disability (broadly defined, including problems such as autism)? ◯ Yes ◯ No ◯ Don't know

If "yes", what is the nature of this learning disability and who has it? ____________________

____

____

14. Have any of your siblings been identified as gifted? ◯ Yes ◯ No

If "yes", please explain who and in what area: ____________________

____

____

15. Has your family lived outside the United States for any length of time? ◯ Yes ◯ No

If "yes", in what country and for how long?

Country	**How long (months)?**

16. Have you attended a school outside the United States for any length of time? ◯ Yes ◯ No

If "yes", in what country, what grade, and for how long?

Country	Grade	How long (months)?

17. What other language(s) besides English can you speak fluently? ____________________

18. How many books are in your home? Please "✔" your response.

◯ None, or very few (0 - 10)
◯ A few (11 - 25)
◯ One bookcase full (26 - 100)
◯ Two bookcases full (101 - 250)
◯ Three or four bookcases full (251 - 500)
◯ Roomful; library (501+)

19. How much support and encouragement in regard to your education have you received from any of the following persons? Please indicate by placing a "✔" in the appropriate boxes below:

	None = 1	2	3	4	5 = A great deal
Mother	◯	◯	◯	◯	◯
Father	◯	◯	◯	◯	◯
Teachers	◯	◯	◯	◯	◯
Friends	◯	◯	◯	◯	◯
Others (Please specify):					
____________	◯	◯	◯	◯	◯
____________	◯	◯	◯	◯	◯

20. Have your parents encouraged you to develop any of your special talents? ◯ Yes ◯ No

If "yes", please describe: ____________________

____

____

21. Have your parents or other adults provided you with special learning programs or aids or tutoring?

◯ Yes ◯ No

If "yes", please describe: ____________________

____

____

22. Is there a special person who has had a significant influence on your education or career goals?

◯ Yes ◯ No

If "yes", please explain: ______________________________

____

____

Schooling:

23. What is the name of your school? ______________________________

24. In what school district is your school located? ______________________________

25. What type of school do you currently attend?

◯ Public ◯ Independent or private (non-church) ◯ Parochial

26. How many students attend your school? Please indicate by placing a "✔" in the appropriate box below:

◯ 1. Less than 100	◯ 6. 500 to 599	◯ 11. 1,000 to 1,499
◯ 2. 100 to 199	◯ 7. 600 to 699	◯ 12. 1,500 to 1,999
◯ 3. 200 to 299	◯ 8. 700 to 799	◯ 13. 2,000 to 2,999
◯ 4. 300 to 399	◯ 9. 800 to 899	◯ 14. 3,000 or more
◯ 5. 400 to 499	◯ 10. 900 to 999	

27. In your school, how many students are in your grade? ______________

28. At what age did you begin first grade? ______________

29. Have you skipped any grades in elementary through high school? (Please circle all that apply.)

None K 1 2 3 4 5 6 7 8 9 10 11 12

30. Have you ever done work in a subject that was at a higher level than the other students in your grade?

◯ Yes ◯ No

If "yes", please explain: ______________________________

____

____

31. What is the highest grade level you will have completed by July? (Please "✔" one)

◯ sixth ◯ seventh ◯ eighth ◯ ninth ◯ tenth

32. Which of the following **math** courses have you taken this year? Place a "✔" for all that apply.

- ☐ 7th grade general math
- ☐ 8th grade general math
- ☐ Pre-Algebra
- ☐ Algebra I
- ☐ Algebra II
- ☐ Geometry
- ☐ Analytic geometry
- ☐ Trigonometry
- ☐ Others (Please specify): ____________

33. Which of the following **science** courses have you taken this year? Place a "✔" for all that apply.

- ☐ 7th grade general science
- ☐ 8th grade general science
- ☐ Earth science
- ☐ Biology
- ☐ Chemistry
- ☐ Physics
- ☐ Others (Please specify): ____________

34. Besides homework and class assignments, to what extent do you learn on your own or conduct your own projects outside of school? Please indicate by placing a "✔" in the appropriate box below:

Never = 1 < ———2———3———4——— > 5 = Very often

☐ ☐ ☐ ☐ ☐

Please describe your project(s): ____________

35. Does your school offer programs for talented and gifted students your age? ☐ Yes ☐ No ☐ Don't know

If "yes", have you been asked to participate? ☐ Yes ☐ No

If "yes", are you currently participating? ☐ Yes ☐ No

36. Are you currently participating in a program for the gifted, besides programs at OPPTAG (i.e., CY-TAG, EXPLORATIONS!), which is not part of your school program? ☐ Yes ☐ No

If "yes", please describe: ____________

37. Besides programs at OPPTAG (i.e., CY-TAG, EXPLORATIONS!), have you ever attended a special summer camp or summer program specifically for gifted students? ◯ Yes ◯ No

If "yes", please explain: ______________________________

____

____

38. What do you like most about your school experience? ______________________________

____

____

39. What do you like least about your school experience? ______________________________

____

____

40. What school experience has affected your educational/career plans the most? ______________________________

____

____

41. List in order of preference your three favorite courses in school:

1. ____________ 2. ____________ 3. ____________

42. Please list the three **extracurricular** activities you have been involved in most since fourth grade:

Most: ______________________________

Second most: ______________________________

Third most: ______________________________

43. Please describe your most creative accomplishment: ______________________________

____

____

44. How did you prepare for taking the SAT or ACT? ______________________________

____

____

45. How many books/magazines have you read in each of the following groups (not including those required for school) in the past 12 months?

	Number of books/magazines
Western stories, adventure stories, or mystery stories (not comic books)	
Science fiction books or magazines (not comic books)	
Science - non fiction	
Plays, poetry, essays, literary criticism, or classics	
Politics, world affairs, biography, autobiography, historical novels	
Religious books or magazines	
Comic books	
Love stories	

46. How often do you read the newspaper?

Never = 1 < ——2——3——4—— > 5 = Every day

○ ○ ○ ○ ○

47. How many hours a week do you spend on computer programming or similar activities? ____________

48. How many hours of each of the following kinds of television programs do you watch each week?

Program	**Number of hours/week**
Cartoons	
Documentaries and educational programs	
Movies	
News	
Sitcom (comedies)	
Video games	
Other (please specify)	
Other (please specify)	

49. When you think about your future occupation, how important do you think skills in each of the following areas will be? Please mark your response by placing a "✔" in the appropriate boxes:

	Not important 1	**Slightly important 2**	**Somewhat important 3**	**Important 4**	**Extremely important 5**
Math	◯	◯	◯	◯	◯
Biology	◯	◯	◯	◯	◯
Chemistry	◯	◯	◯	◯	◯
Physics	◯	◯	◯	◯	◯
Reading & literature	◯	◯	◯	◯	◯
Writing/composition	◯	◯	◯	◯	◯
Social studies	◯	◯	◯	◯	◯
Foreign languages	◯	◯	◯	◯	◯
Computer science	◯	◯	◯	◯	◯

50. List any colleges to which you have considered applying:

1st choice: ____________________

2nd choice: ____________________

3rd choice: ____________________

◯ I do not plan to attend college.

◯ I plan to go to college but have not thought about possible schools.

51. What **ultimate** educational degree do you intend to obtain (e.g., B.A., Masters, Ph.D.)? ____________

52. List the occupations that you are most interested in as possible careers:

1st choice: ____________________

2nd choice: ____________________

3rd choice: ____________________

◯ I haven't considered any occupations yet.

53. How do you feel about each of the following statements?

	Strongly disagree 1	Disagree 2	Neither agree nor disagree 3	Agree 4	Strongly agree 5
I take a positive attitude toward myself.	○	○	○	○	○
Good luck is more important than hard work for success.	○	○	○	○	○
I feel I am a person of worth, on an equal plane with others.	○	○	○	○	○
I am able to do things as well as most other people.	○	○	○	○	○
Every time I try to get ahead, something or somebody stops me.	○	○	○	○	○
Planning only makes a person unhappy, since plans hardly ever work out.	○	○	○	○	○
At times I think I am no good at all.	○	○	○	○	○
People who accept their condition in life are happier than those who try to change things.	○	○	○	○	○
On the whole, I'm satisfied with myself.	○	○	○	○	○
What happens to me is my own doing.	○	○	○	○	○
When I make plans, I am almost certain I can make them work.	○	○	○	○	○
I feel I do not have much of which to be proud.	○	○	○	○	○

54. How important is each of the following to you in your life?

	Not important 1	Slightly important 2	Somewhat important 3	Important 4	Extremely important 5
Being successful in my line of work	◯	◯	◯	◯	◯
Receiving a good education	◯	◯	◯	◯	◯
Finding the right person to marry	◯	◯	◯	◯	◯
Having lots of money	◯	◯	◯	◯	◯
Having strong friendships	◯	◯	◯	◯	◯
Being a leader in my community	◯	◯	◯	◯	◯
Being able to give my children better opportunities than I've had	◯	◯	◯	◯	◯
Living close to parents and relatives	◯	◯	◯	◯	◯
Having leisure time to enjoy avocational interests	◯	◯	◯	◯	◯
Having children	◯	◯	◯	◯	◯
Having a part-time career always	◯	◯	◯	◯	◯
Having a part-time career for some time-period	◯	◯	◯	◯	◯
Having a full-time career	◯	◯	◯	◯	◯

55. At what age did you learn to read? ___________

56. How did you learn to read primarily? ◯ I learned on my own ◯ I was taught

57. To what extent were/are you involved in "tinkering" with equipment, mechanical gadgets, or construction games? Please use the following scale and mark your response by placing a "✔" in the appropriate boxes:

Not involved = 1 < --------2----------- 3 -----------4--------- > 5 = Very involved

	1	2	3	4	5
..as a young child? →	◯	◯	◯	◯	◯
..now? →	◯	◯	◯	◯	◯

58. Do you consider yourself to be gifted? ◯ Yes ◯ No

59. How do you feel about being identified as gifted?

Uncomfortable	Somewhat uncomfortable	Neither comfortable nor uncomfortable	Somewhat comfortable	Comfortable
◯	◯	◯	◯	◯

Appendix B

After high school follow-up survey

I. GENERAL INFORMATION

For each question please fill in the blanks and/or mark "✔" in the appropriate box(es).

1. Name: ____
Last First Middle Maiden

Gender: ( ) Male ( ) Female

Date of Birth: ______ - ______ - ______
Month Day Year

Address:

____
No. Street City State/Country Zip

Telephone number(s): Home: (_____)__________ Office: (_____)__________

E-mail address: ______________________

Are your parents alive? Father: ◯ Yes ◯ No Mother: ◯ Yes ◯ No

Mother's or father's name, telephone number, and address *(if deceased, close relative)*:

______________________________________ (_____)__________
Name Phone

____
No. Street City State/Country Zip

____
E-mail

IMPORTANT

Please write the name and address of a relatively young adult, not living in your family home, who is likely to have the same mailing address for many years and who also is likely to know your address when you move. We need this information to keep in touch with you in the coming years.

Name: ______________________ E-mail: ______________________

Relationship: ______________________ Telephone number: (_____)__________

Address: ____
No. Street City State/Country Zip

2. Of the following degrees and licenses, please indicate which ones you have earned already and which ones you plan to obtain. ***List all degrees (e.g., two BAs) and specify the type (e.g., MD, MBA, MBS, MS).***

Degrees or Licenses	Date Obtained or Anticipate to obtain	Major	School, City, State
High school diploma, G.E.D.			
License or certificate, not requiring college degree			
A.A., two-year college degree			
Bachelor's degree or equivalent			
License/certificate requiring college degree, but not equivalent to graduate degree			
Master's degree or equivalent			
Certificate of Advanced Study			
Law degree			
Ph.D. degree or equivalent			
Medical, dental, or veterinary degree			
Other, Please specify:			

II. FAMILY

For each question please fill in the blanks and/or mark "✔" in the appropriate box(es).

3. What is your current marital status?

- ◯ Single, never married
- ◯ In a permanent relationship
- ◯ Married
- ◯ Engaged
- ◯ Divorced or separated
- ◯ Widowed

4. How many children do you have? _________

5. By whom were you raised?

- ◯ Biological parents
- ◯ Biological mother alone
- ◯ Biological father alone
- ◯ Biological mother and stepfather
- ◯ Biological father and stepmother
- ◯ Adoptive parents
- ◯ Adoptive mother alone
- ◯ Adoptive father alone
- ◯ Others (Please specify): ____________________
- ◯ Comments: ____________________

____

6. What is/was the occupation of your: father? ______________________________

mother? ______________________________

7. What is the **highest** educational level reached by each of your parents? Please indicate by placing a "✔" in the corresponding boxes below:

Father	Mother		Name of institution
◯	◯	1. Less than high school	
◯	◯	2. High school diploma	
◯	◯	3. Some college	____________
◯	◯	4. Technical or vocational diploma or certificate	____________
◯	◯	5. Two year degree; e.g., A.A.	____________
◯	◯	6. Bachelor's degree	____________
◯	◯	7. Some graduate work	____________
◯	◯	8. Master's degree or equivalent	____________
◯	◯	9. Graduate study after Master's, but not a doctorate ...	____________
◯	◯	10. J.D.	____________
◯	◯	11. M.D.	____________
◯	◯	12. Ph.D.	____________

8. How many older and younger brothers and sisters do you have?

	Younger	Older
Full brothers		
Full sisters		
Half brothers		
Half sisters		

III. ACADEMIC INFORMATION PRIOR TO COLLEGE

For each question please fill in the blanks and/or mark "✔" in the appropriate box(es).

Miscellaneous

9. At what age did you start becoming interested in your current career goal? ____________________

Questions 10 to 14 refer to the time when you were growing up, as a child and as an adolescent. Please use the following scale to answer each question, by entering 1, 2, 3, 4, or 5 in the boxes provided.

1 = Never
2 = Hardly Ever
3 = Some
4 = Fair Amount
5 = A Great Deal

	As a Child	As an Adolescent
10. To what extent were you involved in math games or puzzles, playing with numbers, or working math problems for fun?	▢	▢
11. To what extent were you involved with computers?	▢	▢
12. To what extent were you involved in scientific experiments for fun (e.g., using a chemistry set)?	▢	▢
13. To what extent were you involved in playing word games (cross word puzzles), reading, or writing for fun?	▢	▢
14. To what extent were you involved in "tinkering" with equipment, mechanical gadgets, or construction games?	▢	▢

To what extent did you actively seek out the above activities, *in questions 10-14*, on your own versus being encouraged by your family, friends, teachers, or others? Please use the following scale to answer each question, by entering 1, 2, 3, 4, or 5 in the boxes provided.

0 = Not involved
1 = Almost always encouraged by others
2 = Usually encouraged by others
3 = 50% encouraged by others and 50% pursued on my own
4 = Usually pursued on my own
5 = Almost always pursued on my own

	As a Child	As an Adolescent
15. Math games, puzzles, playing with numbers, or working math problems for fun?	◯	◯
16. Computers?	◯	◯
17. Scientific experiments for fun (e.g., using a chemistry set)?	◯	◯
18. Playing word games (cross word puzzles), reading, or writing for fun?	◯	◯
19. "Tinkering" with equipment, mechanical gadgets, or construction games?	◯	◯

Special Programs or Classes

20. Besides programs offered by OPPTAG (e.g., CY-TAG, Math Clinics), did you take any special or advanced math/science classes when you were in junior high school or younger? ◯ Yes ◯ No

If "yes", please specify what the classes were and how old you were when you took them:

____

____

____

To what extent did those classes influence your career and/or educational plans?

◯ **Strongly negatively** ◯ **Somewhat negatively** ◯ **No effect** ◯ **Somewhat positively** ◯ **Strongly positively**

21. Have you participated in any mathematics or science contests, such as MathCounts, math or science olympiads, the American High School Mathematics Examination (AHSME), and the Westinghouse Science Talent Search competition, or been awarded entry into a special honorary program (such as NSF workshops/programs or the Research Science Institute)?

◯ Yes ◯ No

If "yes", please describe: ________________________________

____

____

To what extent did they seem to influence your career and/or educational plans?

( ) Strongly negatively ( ) Somewhat negatively ( ) No effect ( ) Somewhat positively ( ) Strongly positively

22. Did your school offer any programs for the gifted?

Elementary school: ( ) Yes ( ) No ( ) Don't Know

If "yes", did you participate? ( ) Yes ( ) No

If "yes", for how many years did you participate? ____________

Junior high school: ( ) Yes ( ) No ( ) Don't Know

If "yes", did you participate? ( ) Yes ( ) No

If "yes", for how many years did you participate? ____________

Senior high school: ( ) Yes ( ) No ( ) Don't Know

If "yes", did you participate? ( ) Yes ( ) No

If "yes", for how many years did you participate? ____________

23. Have you ever participated in a summer or out-of-school program for gifted and talented students, other than CY-TAG? ( ) Yes ( ) No

If "yes", please fill in the following table: if "no", go to question 25.

Program's Name and Location	The area in which you did your work at the program	Types of Activities

24. To what extent did the above special programs (in question 23) seem to influence your career and/or educational plans?

( ) Strongly negatively ( ) Somewhat negatively ( ) No effect ( ) Somewhat positively ( ) Strongly positively

25. To what extent did CY-TAG seem to influence your career and/or educational plans?

( ) Strongly negatively ( ) Somewhat negatively ( ) No effect ( ) Somewhat positively ( ) Strongly positively

26. Before college, did you experience any mentoring relationships (i.e., a relationship with someone who is advanced in a particular area and helped you learn about that area)? ◯ Yes ◯ No

If "yes", to what extent did this experience seem to influence your career and/or educational plans?

◯ **Strongly negatively** ◯ **Somewhat negatively** ◯ **No effect** ◯ **Somewhat positively** ◯ **Strongly positively**

Please describe the nature of the relationship(s) and its/their influence: ______________________________

____

____

Acceleration

27. Did you skip any grades in elementary through high school? (Please mark "✔" for all that apply.)

(None) [K] [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12]

28. If you were ever accelerated educationally, which of the following forms of acceleration did you use? (Mark "✔" for all that apply.)

◯ Early entrance to kindergarten
◯ Advanced subject matter placement
◯ Early graduation from high school without grade skipping
◯ AP or other exams for college credit
◯ College courses while in high school
◯ Special classes
◯ Other(s); please specify: ______________________________

◯ Grade skipping
◯ Tutors or mentors
◯ Early entrance to college
◯ More than one major in college
◯ BA/MA concurrently
◯ NONE

29. If ever you were accelerated, to what extent did this experience influence your career and/or educational plans?

◯ **Strongly negatively** ◯ **Somewhat negatively** ◯ **No effect** ◯ **Somewhat positively** ◯ **Strongly positively**

Please describe: ____

____

30. If ever you were accelerated, to what degree has your total acceleration (kindergarten to present) affected you in each of the following areas? Please indicate your response by placing a "✔" in the appropriate boxes:

	Strongly unfavorable effect	Moderately unfavorable effect	No effect	Moderately favorable effect	Strongly favorable effect
General academic progress	◯	◯	◯	◯	◯
Grades, marks	◯	◯	◯	◯	◯
Interest in school, formal education	◯	◯	◯	◯	◯
Interest in learning	◯	◯	◯	◯	◯
Interest in mathematics	◯	◯	◯	◯	◯
Interest in science	◯	◯	◯	◯	◯
Interest in humanities	◯	◯	◯	◯	◯
Acceptance of abilities	◯	◯	◯	◯	◯
Ability to get along with age mates	◯	◯	◯	◯	◯
Ability to get along with intellectual peers	◯	◯	◯	◯	◯
Ability to get along with adults	◯	◯	◯	◯	◯
Social life	◯	◯	◯	◯	◯
General emotional well-being	◯	◯	◯	◯	◯
Acceptance of self	◯	◯	◯	◯	◯
Personal growth	◯	◯	◯	◯	◯

High School Experience

31. Please list the name and location of the high school from which you graduated:

____

Name of school City State

32. The type of high school you graduated from: ◯ Public ◯ Private, religious ◯ Private, non-religious

33. How many students were in your high school graduating class? ____________

34. Were you selected for the National Honor Society in high school? ◯ Yes ◯ No

If "no", did your school offer this opportunity? ◯ Yes ◯ No

35. Were you in the top 10 percent of your graduating class? ◯ Yes ◯ No

36. Were you valedictorian? ◯ Yes ◯ No

37. What was your overall grade point average in high school? ________ A = ________

38. Starting with grade 8, please indicate how many **semesters** of each of the following you have taken. If you prefer, enclose a copy of your high school transcript. *We strongly prefer the latter.*

_______ Art
_______ Biological sciences
_______ Business, economics (not secretarial or business machine)
_______ Computer science
_______ English
_______ Foreign languages; please specify _______________________
_______ Home Economics
_______ Mathematics
_______ Performing arts (e.g., music, dance, drama)
_______ Physical sciences
_______ Social sciences (including History and Government)
_______ Vocational, technical (industrial arts)

39. What was the **highest** level mathematics course you took in high school? ___________________

Course grade: _______

40. Did you take any of the following math/science subjects in high school? (Please mark "✔" for all that apply.)

◯ calculus ◯ biology ◯ chemistry ◯ physics

41. Did you ever take any college course while still in high school? ◯ Yes ◯ No
If "yes", what were they:

___________________________ ___________________________

___________________________ ___________________________

42. Were Advanced Placement (AP) program courses available in your high school?
◯ Yes ◯ No ◯ Don't know

If "yes", did you take any AP courses or examinations? ◯ Yes ◯ No ◯ Don't know

If "yes", please indicate how many: Courses: _______ Examinations: _______

Please list course title, level (e.g., Calculus AB or BC), course grade, score on the exam (if taken), and the grade you were in when taken.

Course title	Level	Course grade	Exam score	School grade when taken

43. Did you ever work on an independent research project when in high school? ☐ Yes ☐ No

If "yes", please describe it, its effect on you, and if it was a class requirement: ______________________

____

____

44. List in order of preference your three favorite courses in high school:

1. ______________________ 2. ______________________ 3. ______________________

45. What were your two **least** favorite courses in high school:

1. least favorite: ______________________ 2. second least favorite ______________________

46. Overall, how intellectually stimulating was your high school experience?

☐ **Very boring** ☐ **Somewhat boring** ☐ **Neither stimulating nor boring** ☐ **Somewhat stimulating** ☐ **Very stimulating**

47. What did you like **most** about your high school experience? ______________________

____

____

48. What did you like **least** about your high school experience? ______________________

____

____

49. a) Were you named a Presidential Scholar? ☐ Yes ☐ No
b) Did you place in the Westinghouse Talent Search? ☐ Yes ☐ No

Student Test Scores

50. We would like specific scores from any number of standardized tests given in high school, for example, the Preliminary Scholastic Aptitude Test (PSAT), American College Test (ACT), or College Board SAT or Achievement Tests. If you took any of these tests, please give us your scores for the tests and subtests (i.e., math, verbal, etc.). ***We are especially interested in your high school SAT scores and the date when taken. A copy of your score report would be greatly appreciated. (Of course, we treat test scores most confidentially.)***

____

____

____

51. **If you took the PSAT**, please answer the following questions:

Did you receive a National Merit Letter of Commendation?	◯ Yes	◯ No
Were you a National Merit Semi-finalist?	◯ Yes	◯ No
Were you a National Merit Finalist?	◯ Yes	◯ No
Did you win a National Merit Scholarship?	◯ Yes	◯ No

IV. Undergraduate information

◯ Neither attended, nor attending college *(go to question 55)*

52. What is your present educational status?

◯ Full-time undergraduate student
◯ Part-time undergraduate student
◯ Full-time graduate student
◯ Part-time graduate student
◯ Graduated from a two-year college, no additional education at this time
◯ Graduated from a four-year college, no additional education at this time
◯ Withdrawn from college, not currently enrolled

Name and location of the undergraduate school or program

________________ Name ________________ City ________________ State/Country

53. What is your undergraduate major? ______________________________

54. What aspect of college do you find

most enjoyable? ______________________________

least enjoyable? ______________________________

55. If you were given the opportunity to work in your **ideal** job, how many hours per week would you be **willing** to work?

◯ less than 40 ◯ 40 ◯ 50 ◯ 60 ◯ 70 ◯ more than 70

VI. CY-TAG/OPPTAG EVALUATION

For each question please fill in the blanks and/or mark "✔" in the appropriate box(es).

56. To what degree did your association with CY-TAG (or OPPTAG) influence you educationally?

◯ **Strongly negatively** ◯ **Somewhat negatively** ◯ **No effect** ◯ **Somewhat positively** ◯ **Strongly positively**

57. To what degree did your association with CY-TAG (or OPPTAG) influence you socially and/or emotionally?

◯ **Strongly negatively** ◯ **Somewhat negatively** ◯ **No effect** ◯ **Somewhat positively** ◯ **Strongly positively**

58. How well did CY-TAG (or OPPTAG) make you aware of educational opportunities, such as AP exams and early entrance to college?

◯ **Not at all** ◯ **Some** ◯ **Moderately** ◯ **A lot** ◯ **A great deal**

59. How has CY-TAG (or OPPTAG) participation changed your attitudes toward the following?

	Strongly negatively	Somewhat negatively	No effect	Somewhat positively	Strongly positively
Learning	◯	◯	◯	◯	◯
Mathematics	◯	◯	◯	◯	◯
Science	◯	◯	◯	◯	◯
Humanities	◯	◯	◯	◯	◯
Working toward advanced educational degrees	◯	◯	◯	◯	◯

60. Indicate the degree to which CY-TAG (or OPPTAG) has helped you to accept your giftedness.

◯ It was of great help.
◯ It was of some help.
◯ It neither helped nor hindered.
◯ It was of some hindrance.
◯ It was of great hindrance.
◯ Not applicable. I do not consider myself gifted.

VII. ATTITUDES AND INTERESTS

For each question please fill in the blanks and/or mark "✔" in the appropriate box(es).

61. How do you feel about each of the following statements?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I take a positive attitude toward myself.	▢	▢	▢	▢	▢
Good luck is more important than hard work for success.	▢	▢	▢	▢	▢
I feel I am a person of worth, on an equal plane with others.	▢	▢	▢	▢	▢
I am able to do things as well as most other people.	▢	▢	▢	▢	▢
Every time I try to get ahead, something or somebody stops me.	▢	▢	▢	▢	▢
Planning only makes a person unhappy, since plans hardly ever work out.	▢	▢	▢	▢	▢
At times I think I am no good at all.	▢	▢	▢	▢	▢
People who accept their condition in life are happier than those who try to change things.	▢	▢	▢	▢	▢
On the whole, I'm satisfied with myself.	▢	▢	▢	▢	▢
What happens to me is my own doing.	▢	▢	▢	▢	▢
When I make plans, I am almost certain I can make them work.	▢	▢	▢	▢	▢
I feel I do not have much of which to be proud.	▢	▢	▢	▢	▢

62. How important is each of the following to you in your life?

	Not important	Slightly important	Somewhat important	Important	Extremely important
Being successful in my line of work	◯	◯	◯	◯	◯
A good education	◯	◯	◯	◯	◯
Finding the right person to marry	◯	◯	◯	◯	◯
Having lots of money	◯	◯	◯	◯	◯
Having strong friendships	◯	◯	◯	◯	◯
Being a leader in my community	◯	◯	◯	◯	◯
Being able to give my children better opportunities than I've had	◯	◯	◯	◯	◯
Living close to parents and relatives	◯	◯	◯	◯	◯
Having leisure time to enjoy avocational interests	◯	◯	◯	◯	◯
Having children	◯	◯	◯	◯	◯
Having a part-time career always	◯	◯	◯	◯	◯
Having a part-time career for a limited time-period	◯	◯	◯	◯	◯
Having a full-time career	◯	◯	◯	◯	◯

63. Please list in order of preference your **3 favorite** leisure activities:

Favorite ______________________________

Second most ______________________________

Third most ______________________________

64. Have there been any educational decisions or events you would change if you could? ◯ Yes ◯ No

If "yes", please explain: ______________________________

____

____

65. Is there any special accomplishment that you feel indicates your creativity or originality or of which you are especially proud?

◯ Yes ◯ No

If "yes", please describe: ______________________________

____

____

____

66. At this time, what are your vocational long-range goals? That is, (1) what **field** do you intend to enter, (2) what type of **position** do you intend to obtain, and (3) what ultimate **level** do you intend to reach?

1. ______________________________
2. ______________________________
3. ______________________________

67. How important is it to you to have a career that is primarily dominated by your gender or at least has equal representation of males and females?

◯ **Not at all** ◯ **Some** ◯ **Moderately** ◯ **A lot** ◯ **A great deal**

Please explain your rationale: ______________________________

____

____

68. How many hours per week do you currently devote to:

studying? _____ leisure? _____ research? _____

working for pay? _____ other activities? _____

Although it is sometimes difficult to know how you will feel in the future, try to project to the time when you will have finished your educational training. Which of the following career options would be the most consistent with your future plans. Please note, "permanent relationship" is intended to cover marriage or stable cohabitation.

69. After I have completed my educational training, I plan to:

- ◯ Have a full-time job, enter into a permanent relationship, and have children.
- ◯ Have a full-time job, enter into a permanent relationship, but have no children.
- ◯ Have a full-time career and remain single.
- ◯ Have a part-time career while my children are small and a full-time career before they are born and after they are grown.
- ◯ Have a part-time career always.
- ◯ Have a full-time career only until I enter into a permanent relationship.
- ◯ Have a full-time career only until my children are born, then stop working outside the home.
- ◯ Have a full-time career only until my children are born, then work part time.
- ◯ Never work outside the home.

Comments:

THANK YOU for taking the time to fill out this questionnaire!

Appendix C

Ability scores for talent search participants, by sex and grade

	M				F			
	7th	8th	9th	10th	7th	8th	9th	10th
APM	22.2	24.2	25.2	25.2	22.1	23.3	24.8	25.8
	5.3	4.7	5.2	5.7	3.9	4.4	4.4	4.5
	208	226	136	47	120	162	121	40
MRT	26.7	29.8	31.4	32.1	21.1	22.2	25.4	25.6
	8.5	8.1	7.1	7.0	8.4	9.4	8.9	10.1
	208	226	136	47	120	162	121	40
MCT	47.4	49.6	51.5	53.1	40.7	43.5	46.1	45.8
	6.8	7.3	6.6	6.7	5.6	5.2	6.3	6.1
	208	226	136	47	120	162	121	40
SAT-M	484.6	491.9	502.1	511.1	473.1	474.4	488.3	457.9
	103.4	97.2	108.1	120.4	94.3	102.0	91.5	89.0
	80	108	50	9	42	71	40	14
SAT-V	420.0	432.4	435.5	435.7	442.8	439.7	452.6	407.1
	97.6	99.2	95.8	73.2	86.7	100.2	88.2	55.4
	77	104	47	7	40	71	39	14
ACT-E	21.2	22.9	23.4	23.3	22.9	24.6	25.0	25.4
	4.3	4.0	5.4	4.5	3.7	4.5	4.0	3.1
	82	88	59	23	56	77	55	20
ACT-M	18.8	21.0	21.9	22.8	18.5	20.6	20.2	20.3
	3.6	3.5	4.1	4.5	3.4	4.2	4.6	4.1
	83	89	59	23	55	78	55	20
ACT-R	22.0	23.4	24.9	23.5	22.8	25.6	26.3	27.3
	4.9	4.7	6.3	5.5	6.0	5.7	5.2	4.1
	82	88	59	23	54	78	55	19
ACT-S	23.1	24.1	25.2	24.7	22.0	24.2	24.1	24.5
	9.4	3.9	5.0	3.7	4.6	4.0	4.4	3.6
	84	91	59	23	56	79	56	20
ACT-C	21.2	23.0	23.7	23.7	21.7	23.9	24.1	24.3
	3.7	3.3	5.0	3.9	3.6	3.9	4.0	2.9
	84	90	63	23	55	78	56	21

Note. Each cell in table reports mean score, standard deviation, and sample size on a test for participants, by sex and grade. APM = Raven's Advanced Progressive Matrices; MRT = Mental Rotation Test; MCT = Mechanical Comprehension Test; SAT-M = SAT-Mathematics; SAT-V = SAT-Verbal; ACT-E = ACT-English; ACT-M = ACT-Mathematics; ACT-R = ACT-Reading; ACT-S = ACT-Science Reasoning; and ACT-C = ACT-Composite score.

Appendix D

Means and standard deviations of participants for the Study of Values and Strong Interest Inventory (RIASEC and BIS), by sex

	Graduate Students					
	Males			Females		
	N	Mean	SD	N	Mean	SD
Study of Values						
Theoretical	362	48.54	6.93	343	46.12	6.70
Economic	362	40.10	8.35	343	37.56	7.67
Aesthetic	362	41.33	8.45	343	43.57	7.28
Social	362	38.41	7.24	343	41.99	7.26
Political	362	39.93	6.48	343	36.55	6.32
Religious	362	31.68	10.85	343	34.20	10.77
Strong Interest Inventory						
General Occupational Themes						
Realistic	362	52.29	8.93	340	48.74	8.59
Investigative	362	58.94	5.82	340	58.33	6.25
Artistic	362	49.89	9.99	340	53.06	9.06
Social	362	45.91	10.22	340	48.96	9.78
Enterprising	362	39.87	8.02	340	40.21	7.40
Conventional	362	44.59	8.64	340	44.44	8.58
Strong Interest Inventory						
Basic Interest Scales						
Agriculture	362	48.60	9.42	340	47.41	8.80
Nature	362	48.42	9.17	340	52.07	9.14
Adventure	362	55.51	8.63	340	50.57	9.45
Military activities	362	46.21	7.75	340	44.02	5.95
Mechanical activities	362	55.78	8.25	340	52.10	8.78
Science	362	61.36	5.47	340	60.14	6.02
Mathematics	362	59.38	5.51	340	57.24	6.77
Medical science	362	50.73	8.97	340	51.25	8.39
Medical service	362	47.73	7.17	340	48.76	7.99
Music/dramatics	362	50.12	9.59	340	54.19	9.17
Art	362	47.77	9.71	340	53.97	9.14
Writing	362	49.63	9.49	340	51.46	9.42
Teaching	362	54.78	8.22	340	55.00	8.44
Social service	362	44.35	10.24	340	48.54	9.38
Athletics	362	49.62	9.39	340	45.91	8.21
Domestic arts	362	46.11	8.31	340	51.93	7.85
Religious activities	362	44.28	10.27	340	46.74	10.24
Public speaking	362	45.58	8.88	340	43.70	8.79
Law/politics	362	47.29	9.11	340	45.24	8.87
Merchandising	362	37.86	8.15	340	40.53	8.69
Sales	362	41.44	5.89	340	40.82	5.83
Business management	362	39.49	8.93	340	39.48	9.19
Office practices	362	42.75	6.51	340	44.80	7.37

Appendix D, continued

	All Talent Search Participants					
	Males			Females		
	N	Mean	SD	N	Mean	SD
Study of Values						
Theoretical	587	47.20	6.94	429	40.86	7.90
Economic	587	42.23	7.58	429	36.56	6.56
Aesthetic	587	37.94	7.50	429	44.86	8.08
Social	587	35.57	6.77	429	41.82	7.26
Political	587	43.27	6.60	429	39.13	6.74
Religious	587	33.80	10.70	429	36.76	9.97
Strong Interest Inventory General Occupational Themes						
Realistic	517	49.70	9.22	364	43.53	8.01
Investigative	517	53.85	8.30	364	52.64	8.96
Artistic	517	43.96	10.03	364	54.27	9.45
Social	517	39.96	9.65	364	49.63	10.24
Enterprising	517	44.25	9.41	364	46.36	9.78
Conventional	517	47.61	9.62	364	47.83	10.05
Strong Interest Inventory Basic Interest Scales						
Agriculture	517	43.78	8.43	364	44.26	8.36
Nature	517	42.23	9.59	364	48.97	9.52
Adventure	333	56.05	9.59	233	51.71	9.93
Military activities	517	51.95	11.01	364	47.51	9.26
Mechanical activities	517	53.95	8.73	364	45.41	8.17
Science	517	58.14	7.44	364	54.05	8.77
Mathematics	517	56.77	7.91	364	52.96	9.43
Medical science	517	48.44	9.95	364	50.41	9.53
Medical service	517	47.87	8.73	364	51.86	10.32
Music/dramatics	517	44.55	9.27	364	55.59	9.36
Art	517	44.17	9.84	364	53.87	9.71
Applied arts	184	48.24	9.50	131	53.20	8.83
Writing	517	44.24	10.06	364	53.67	9.70
Culinary arts	184	41.90	9.02	131	51.34	9.31
Teaching	517	42.78	10.02	364	50.95	10.14
Social service	517	40.58	8.53	364	51.38	10.03
Athletics	517	49.34	10.26	364	45.82	9.03
Domestic arts	333	40.70	8.22	233	51.20	9.77
Religious activities	517	44.27	9.54	364	48.34	10.14
Public speaking	517	45.53	10.26	364	48.49	9.92
Law/politics	517	47.64	10.16	364	49.08	10.00
Merchandising	517	41.90	9.06	364	46.26	9.45
Sales	517	47.37	8.79	364	46.88	8.70
Business management	517	41.76	9.48	364	43.52	9.11
Data management	184	48.58	9.72	131	46.88	8.62
Computer activities	184	57.92	8.26	131	51.61	9.73
Office practices	517	46.59	7.64	364	49.61	9.38

Appendix D, continued

	High Space Talent Search Participants					
	Males			Females		
	N	Mean	SD	N	Mean	SD
Study of Values						
Theoretical	147	48.90	7.14	105	42.20	7.89
Economic	147	43.39	7.55	105	35.05	6.41
Aesthetic	147	37.79	6.45	105	46.24	7.82
Social	147	35.21	6.91	105	42.42	7.20
Political	147	42.11	6.04	105	37.00	6.14
Religious	147	32.59	10.89	105	37.09	9.96
Strong Interest Inventory General Occupational Themes						
Realistic	129	50.98	9.20	91	44.91	7.81
Investigative	129	53.41	8.64	91	54.09	8.52
Artistic	129	42.45	9.99	91	55.01	9.16
Social	129	37.54	9.42	91	48.27	9.49
Enterprising	129	41.95	8.83	91	44.45	9.11
Conventional	129	46.57	9.89	91	46.78	8.89
Strong Interest Inventory Basic Interest Scales						
Agriculture	129	42.64	7.46	91	45.59	8.77
Nature	129	41.12	9.42	91	50.07	9.14
Adventure	84	55.76	9.38	56	53.71	9.04
Military activities	129	51.41	10.97	91	47.10	10.39
Mechanical activities	129	55.87	8.79	91	47.20	8.19
Science	129	58.62	7.87	91	55.76	8.32
Mathematics	129	57.29	8.54	91	54.27	8.51
Medical science	129	46.88	9.79	91	49.54	8.26
Medical service	129	47.19	8.49	91	50.69	9.01
Music/dramatics	129	43.69	9.11	91	55.36	8.93
Art	129	43.10	9.81	91	55.24	9.13
Applied arts	45	47.49	9.49	35	55.09	8.10
Writing	129	41.88	9.83	91	53.27	9.71
Culinary arts	45	39.36	9.15	35	49.69	10.02
Teaching	129	41.42	9.90	91	50.24	9.52
Social service	129	38.85	7.87	91	50.93	9.37
Athletics	129	46.24	9.85	91	45.37	8.46
Domestic arts	84	40.26	8.53	56	50.21	10.14
Religious activities	129	42.88	9.27	91	47.76	9.95
Public speaking	129	42.14	9.95	91	46.77	9.35
Law/politics	129	44.68	9.29	91	48.52	9.78
Merchandising	129	39.63	8.13	91	44.44	9.07
Sales	129	45.60	8.20	91	44.99	7.23
Business management	129	39.86	8.71	91	41.96	8.75
Data management	45	47.78	9.66	35	46.20	8.60
Computer activities	45	58.49	6.99	35	51.46	9.02
Office practices	129	45.83	7.01	91	47.70	7.70

Appendix D, continued

	Mid Space Talent Search Participants					
	Males			Females		
	N	Mean	SD	N	Mean	SD
Study of Values						
Theoretical	295	47.28	6.64	215	41.36	7.74
Economic	295	42.48	7.80	215	36.71	6.78
Aesthetic	295	38.16	7.58	215	44.87	8.14
Social	295	35.00	6.72	215	41.42	7.51
Political	295	43.45	6.75	215	39.39	6.76
Religious	295	33.64	10.88	215	36.26	10.15
Strong Interest Inventory General Occupational Themes						
Realistic	266	49.78	9.32	177	44.10	8.63
Investigative	266	54.23	8.12	177	52.80	8.68
Artistic	266	44.01	9.74	177	54.22	9.65
Social	266	39.83	9.25	177	49.66	10.69
Enterprising	266	44.86	9.13	177	46.82	9.92
Conventional	266	48.07	9.25	177	48.12	10.56
Strong Interest Inventory Basic Interest Scales						
Agriculture	266	43.63	8.46	177	44.38	8.49
Nature	266	42.56	9.60	177	49.34	9.50
Adventure	170	56.49	9.04	112	52.03	10.00
Military activities	266	52.50	11.19	177	47.92	9.31
Mechanical activities	266	54.18	8.69	177	45.83	8.56
Science	266	58.53	7.24	177	54.42	8.64
Mathematics	266	57.16	7.31	177	53.20	9.78
Medical science	266	48.47	10.27	177	51.31	9.45
Medical service	266	47.88	8.67	177	52.36	10.57
Music/dramatics	266	44.28	9.02	177	55.21	9.80
Art	266	44.50	9.68	177	54.10	9.92
Applied arts	96	49.20	9.40	65	53.65	8.66
Writing	266	44.09	9.69	177	53.42	9.77
Culinary arts	96	42.74	8.84	65	51.46	9.08
Teaching	266	42.43	9.67	177	51.25	10.39
Social service	266	40.45	8.53	177	51.02	10.45
Athletics	266	49.58	10.08	177	45.50	9.27
Domestic arts	170	40.66	7.82	112	52.04	9.90
Religious activities	266	44.27	9.61	177	48.10	10.25
Public speaking	266	45.79	9.93	177	48.37	9.57
Law/politics	266	48.24	10.30	177	48.58	9.70
Merchandising	266	42.50	8.91	177	46.62	9.45
Sales	266	47.72	8.65	177	46.87	8.74
Business management	266	42.04	9.53	177	43.47	9.30
Data management	96	49.52	9.35	65	46.74	8.78
Computer activities	96	58.32	7.97	65	52.71	9.68
Office practices	266	46.67	7.64	177	49.97	9.60

Appendix D, continued

	Low Space Talent Search Participants					
	Males			Females		
	N	Mean	SD	N	Mean	SD
Study of Values						
Theoretical	145	45.31	6.90	109	38.60	7.81
Economic	145	40.53	6.89	109	37.72	6.02
Aesthetic	145	37.64	8.31	109	43.50	8.05
Social	145	37.09	6.54	109	42.05	6.80
Political	145	44.09	6.73	109	40.67	6.82
Religious	145	35.34	9.99	109	37.46	9.64
Strong Interest Inventory General Occupational Themes						
Realistic	122	48.17	8.88	96	41.17	6.46
Investigative	122	53.48	8.36	96	50.98	9.68
Artistic	122	45.45	10.54	96	53.68	9.40
Social	122	42.78	10.08	96	50.88	10.02
Enterprising	122	45.36	10.25	96	47.30	10.00
Conventional	122	47.71	10.10	96	48.29	10.16
Strong Interest Inventory Basic Interest Scales						
Agriculture	122	45.32	9.14	96	42.78	7.52
Nature	122	42.69	9.72	96	47.25	9.77
Adventure	79	55.39	10.95	65	49.45	10.24
Military activities	122	51.30	10.66	96	47.13	8.00
Mechanical activities	122	51.42	8.18	96	42.93	6.80
Science	122	56.79	7.31	96	51.76	9.06
Mathematics	122	55.36	8.38	96	51.27	9.46
Medical science	122	50.01	9.18	96	49.58	10.68
Medical service	122	48.56	9.10	96	52.04	11.03
Music/dramatics	122	46.04	9.86	96	56.50	8.94
Art	122	44.60	10.18	96	52.17	9.70
Applied arts	43	46.88	9.72	31	50.13	9.44
Writing	122	47.05	10.47	96	54.51	9.59
Culinary arts	43	42.70	8.98	31	52.94	8.94
Teaching	122	45.00	10.61	96	51.08	10.32
Social service	122	42.70	8.81	96	52.46	9.87
Athletics	122	52.08	10.30	96	46.81	9.11
Domestic arts	79	41.25	8.81	65	50.62	9.21
Religious activities	122	45.74	9.52	96	49.34	10.13
Public speaking	122	48.54	10.33	96	50.34	10.82
Law/politics	122	49.47	10.14	96	50.54	10.69
Merchandising	122	42.99	9.94	96	47.30	9.67
Sales	122	48.46	9.46	96	48.68	9.58
Business management	122	43.14	9.94	96	45.10	8.92
Data management	43	47.33	10.58	31	47.94	8.46
Computer activities	43	56.42	9.98	31	49.48	10.52
Office practices	122	47.24	8.24	96	50.74	10.21

Appendix E

Hit rates in discriminant function analyses using preferences and spatial ability to classify

Another way to evaluate the utility of the predictors in forecasting group membership is to examine the hit rates of the discriminant functions. Hit rates represent the accuracy of the prediction model, that is, the proportion of observations correctly classified. These may be compared to base rate expectations to ascertain the efficacy of the model in predicting group membership. For each of the five criterion variables, the hit rates for predicting membership in each of the three groups (science-math, humanities, and other) and the overall hit rates for each model are presented.

The tables in this appendix report a summary of base rates and hit rates for each of the complete (preferences + spatial ability) models in the prediction of group membership. Base rates for group membership in humanities, other, and math-science categories appear under the marginal totals in the right-hand column of each summary. Along the diagonal of each summary, the number of correctly classified observations (and corresponding hit rates) for humanities, other, and math-science classifications appear in bold text. The prediction models utilizing spatial ability, in combination with either the SOV or RIASEC, exhibited high hit rates for those criterion groups that were more uniformly distributed across the three classes. For example, in 14 of the 15 cases in which at least one-third of all participants were members in a given group, the model improved the prediction of that group membership over base rates. However, as would be expected, these models were less effective at predicting rare events. For example, hit rates were less than base rates in seven of the nine cases in which less than one-fourth of all participants were members in a given group.

Finally, the bottom, right-hand cell reports the total number of individuals in each analysis and, in bold, the overall accuracy of the model. The overall hit rates ranged from 50-68%. In most cases, the model exhibited a meaningful improvement over base rate expectations: an additional 8 percentage points on average and as much as 17 percentage points. Coursework preferences exhibited the greatest improvements: The accuracy of the prediction of favorite course based on spatial ability and preferences (SOV or RIASEC) was increased by 12 and 17 percentage points, respectively (SOV: $z = 4.06$, $p < .001$; RIASEC: $z = 5.00$, $p < .001$). Least favorite coursework increased similarly, by 9 and 11 percentage points (SOV: $z = 2.91$, $p = .002$; RIASEC: $z = 3.66$, $p < .001$). The prediction of preferred leisure activities was not improved significantly (SOV: $z = 0.12$, *ns*; RIASEC: $z = 1.00$, *ns*). The prediction of undergraduate major and occupational field were intermediate (increases of 5-8 percentage points): undergraduate major (SOV: $z = 1.58$, $p = .06$; RIASEC: $z = 2.51$, $p = .006$); occupational field (SOV: $z = 1.78$, $p = .04$; RIASEC: $z = 1.45$, $p = .07$). Here also, models based on criterion variables with more uniformly distributed criterion groups exhibited greater improvement in predicting group membership (hit rates greater than base rates) than did models based on criterion variables with one or more sparsely populated classes.

Favorite course: SOV and spatial ability

Observed group membership	Predicted group membership: Humanities	Other	Science-Math	Total (priors)
Humanities	**167 (69%)**	0 (0%)	76 (31%)	243 (45%)
Other	25 (40%)	**0 (0%)**	37 (60%)	62 (12%)
Science-Math	91 (39%)	0 (0%)	**142 (61%)**	233 (43%)
Total	283 (53%)	0 (0%)	255 (47%)	538 **(57%)**

Favorite course: RIASEC and spatial ability

Observed group membership	Predicted group membership: Humanities	Other	Science-Math	Total (priors)
Humanities	**136 (66%)**	0 (0%)	70 (34%)	206 (44%)
Other	18 (35%)	**2 (4%)**	31 (61%)	51 (11%)
Science-Math	62 (30%)	1 (0%)	**143 (69%)**	206 (44%)
Total	216 (47%)	3 (1%)	244 (53%)	463 **(61%)**

Appendix E, continued

Least favorite course: SOV and spatial ability

Observed group membership	*Predicted group membership* Humanities	Other	Science-Math	Total (priors)
Humanities	**132 (61%)**	0 (0%)	86 (39%)	218 (41%)
Other	56 (56%)	**0 (0%)**	44 (44%)	100 (19%)
Science-Math	81 (38%)	0 (0%)	**133 (62%)**	214 (40%)
Total	269 (51%)	0 (0%)	263 (49%)	532 **(50%)**

Least favorite course: RIASEC and spatial ability

Observed group membership	*Predicted group membership* Humanities	Other	Science-Math	Total (priors)
Humanities	**134 (70%)**	1 (1%)	56 (29%)	191 (42%)
Other	56 (64%)	**1 (1%)**	31 (35%)	88 (19%)
Science-Math	69 (38%)	1 (1%)	**111 (61%)**	181 (39%)
Total	259 (56%)	3 (1%)	198 (43%)	460 **(53%)**

Leisure activities: SOV and spatial ability

Observed group membership	*Predicted group membership* Humanities	Other	Science-Math	Total (priors)
Humanities	**14 (8%)**	159 (91%)	1 (1%)	174 (33%)
Other	11 (4%)	**292 (95%)**	4 (1%)	307 (58%)
Science-Math	0 (0%)	47 (94%)	**3 (6%)**	50 (9%)
Total	25 (5%)	498 (94%)	8 (2%)	531 **(58%)**

Leisure activities: RIASEC and spatial ability

Observed group membership	*Predicted group membership* Humanities	Other	Science-Math	Total (priors)
Humanities	**27 (17%)**	126 (81%)	3 (2%)	156 (34%)
Other	18 (7%)	**242 (93%)**	1 (0%)	261 (56%)
Science-Math	6 (13%)	32 (71%)	**7 (16%)**	45 (10%)
Total	51 (11%)	400 (87%)	11 (2%)	462 **(60%)**

Undergraduate major: SOV and spatial ability

Observed group membership	*Predicted group membership* Humanities	Other	Science-Math	Total (priors)
Humanities	**20 (20%)**	24 (24%)	54 (55%)	98 (19%)
Other	14 (10%)	**44 (32%)**	79 (58%)	137 (29%)
Science-Math	7 (3%)	32 (12%)	**236 (86%)**	275 (54%)
Total	41 (8%)	100 (20%)	369 (72%)	510 **(59%)**

Undergraduate major: RIASEC and spatial ability

Observed group membership	*Predicted group membership* Humanities	Other	Science-Math	Total (priors)
Humanities	**25 (32%)**	13 (17%)	39 (51%)	77 (18%)
Other	14 (13%)	**38 (34%)**	59 (53%)	111 (25%)
Science-Math	4 (2%)	23 (9%)	**222 (89%)**	249 (57%)
Total	43 (10%)	74 (17%)	320 (73%)	437 **(65%)**

Appendix E, continued

Anticipated occupational field: SOV and spatial ability

Observed group membership	*Predicted group membership* Humanities	Other	Science-Math	Total (priors)
Humanities	**0 (0%)**	25 (96%)	1 (4%)	26 (6%)
Other	0 (0%)	**239 (87%)**	35 (13%)	274 (63%)
Science-Math	0 (0%)	78 (57%)	**60 (43%)**	138 (32%)
Total	0 (0%)	342 (78%)	96 (22%)	438 **(68%)**

Anticipated occupational field: RIASEC and spatial ability

Observed group membership	*Predicted group membership* Humanities	Other	Science-Math	Total (priors)
Humanities	**0 (0%)**	18 (86%)	3 (14%)	21 (6%)
Other	0 (0%)	**197 (85%)**	34 (15%)	231 (61%)
Science-Math	0 (0%)	71 (57%)	**53 (43%)**	124 (33%)
Total	0 (0%)	286 (76%)	90 (24%)	376 **(66%)**

Appendix F

Table F1

Incremental validity of spatial ability beyond preferences, verbal ability and mathematical ability in discriminant function analyses

	Pillai's Trace	Δ	*p*		Pillai's Trace	Δ	*p*
Favorite course							
SOV	.11			RIASEC	.16		
SOV + M + V	.17	.06	.01	RIASEC + M + V	.31	.14	.0001
SOV + M + V + S	.18	.01	*ns*	RIASEC + M + V + S	.31	.00	*ns*
Least favorite course							
SOV	.06			RIASEC	.11		
SOV + M + V	.11	.05	.05	RIASEC + M + V	.19	.08	.001
SOV + M + V + S	.15	.04	.05	RIASEC + M + V + S	.22	.03	*ns*
Preferred leisure activity							
SOV	.08			RIASEC	.13		
SOV + M + V	.15	.07	.01	RIASEC + M + V	.18	.05	.01
SOV + M + V + S	.17	.02	*ns*	RIASEC + M + V + S	.19	.01	*ns*
Undergraduate major							
SOV	.20			RIASEC	.26		
SOV + M + V	.31	.11	.0001	RIASEC + M + V	.39	.13	.0001
SOV + M + V + S	.34	.03	.05	RIASEC + M + V + S	.41	.02	*ns*
Anticipated occupational field							
SOV	.15			RIASEC	.15		
SOV + M + V	.19	.04	.05	RIASEC + M + V	.16	.01	*ns*
SOV + M + V + S	.23	.04	.05	RIASEC + M + V + S	.20	.04	.05

Note. The first row of each set of three rows reports the Pillai's trace statistic (explained variance) for the DFA based on preferences alone; the second reports Pillai's trace for DFA based on preferences and mathematical and verbal abilities, the incremental validity of the second model (Δ), and the *p*-value of the significance test for additional variance explained; the third reports Pillai's trace for DFA based on preferences and mathematical, verbal, and spatial abilities, the incremental validity of the third model over the second (Δ), and the *p*-value of the significance test for additional variance explained. Values of Δ may not equal the differences between reported Pillai's trace statistics due to rounding. SOV = Study of Values, RIASEC = general occupational themes of Strong Interest Inventory, M = mathematical ability, V = verbal ability, and S = spatial ability.

Appendix F, continued

Table F2

Two sets of discriminant functions (Values + Abilities and Interests + Abilities) for five criterion variables across three criterion groups (science-math, humanities, other)

Values + Abilities

	F_1					F_2				
	Fav.	Least	Leis.	Major	Occ.	Fav.	Least	Leis.	Major	Occ.
Theoretical	.57	.45	.55	.63	.66	.29	.40	.38	.23	.19
Economic	.52	.33	.59	.49	.42	.00	.49	-.26	-.29	.64
Aesthetic	-.39	-.21	-.51	-.48	-.51	.81	-.44	-.02	.62	-.13
Social	-.36	-.22	-.54	-.30	-.37	-.16	-.32	-.32	.05	-.61
Religious	-.32	-.13	-.30	-.04	-.07	-.52	-.28	.39	-.18	-.30
Math ability	.46	.59	.17	.39	.32	.13	-.18	.42	.07	-.37
Verbal ability	-.35	.01	-.40	.00	-.19	.25	.49	.62	.64	.19
Spatial ability	.58	.84	.70	.64	.74	.30	.27	.41	.30	.24
Pillai's Trace	**.16**	**.13**	**.14**	**.24**	**.21**	**.03**	**.03**	**.03**	**.10**	**.02**

Interests + Abilities

	F_1					F_2				
	Fav.	Least	Leis.	Major	Occ.	Fav.	Least	Leis.	Major	Occ.
Realistic	.06	.22	-.13	.20	.22	-.27	.10	-.58	-.50	-.05
Investigative	.00	.01	-.40	.30	.05	.11	.37	-.57	-.35	-.34
Artistic	-.61	-.50	-.81	-.65	-.58	.48	.32	.07	-.43	-.27
Social	-.51	-.42	-.76	-.29	-.58	-.20	.56	-.26	.10	.31
Enterprising	-.52	-.39	-.55	-.34	-.32	-.54	.46	-.26	.13	.00
Conventional	.02	.23	-.35	.14	.06	-.32	.50	-.24	.00	-.28
Math ability	.30	.40	.22	.31	.29	.09	.40	.07	-.32	.17
Verbal ability	-.44	.03	-.33	-.17	-.28	.25	-.45	.54	-.61	-.37
Spatial ability	.47	.68	.66	.55	.82	-.03	-.03	-.08	-.41	-.02
Pillai's Trace	**.22**	**.18**	**.16**	**.28**	**.19**	**.09**	**.04**	**.04**	**.13**	**.01**

Note. Arguments in table are the weights for each preference dimension and three ability measures in each of five discriminant functions based on a preference measure (either SOV or RIASEC) and three ability measures with favorite course, least favorite course, preferred leisure activity, undergraduate major, and expected occupation as the criterion variables. The proportion of variance in group membership (science-math, humanities, or other) that is explained by each function (Pillai's trace) is reported in bold for each function. F_1 = first discriminant function, F_2 = second discriminant function, Fav. = favorite course, Least = least favorite course, Leis. = preferred leisure activity, Major = undergraduate major, and Occ. = anticipated occupation.

Appendix F, continued

Table F3

Correlations between discriminant function scores across five criterion variables

DFAs based on Values + Abilities

		F_1					F_2				
		Fav.	Least	Leis.	Major	Occ.	Fav.	Least	Leis.	Major	Occ.
F_1	Fav.		**.78**	**.89**	**.79**	**.84**	-.05	-.01	-.01	-.35	-.13
	Least	**.81**		**.69**	**.87**	**.87**	.21	.11	.41	.16	.02
	Leis.	**.89**	**.69**		**.74**	**.84**	-.17	.27	-.02	-.33	.16
	Major	**.78**	**.86**	**.69**		**.96**	.01	.26	.41	.05	.06
	Occ.	**.85**	**.89**	**.81**	**.95**		-.07	.18	.36	-.05	-.02
F_2	Fav.	.00	.21	-.10	.05	.00		**-.08**	**.26**	**.76**	**.27**
	Least	-.05	.00	.23	.24	.13	**-.09**		**.22**	**.29**	**.76**
	Leis.	-.02	.35	-.03	.39	.35	**.21**	**.22**		**.64**	**.11**
	Major	-.35	.09	-.35	.03	-.07	**.77**	**.24**	**.59**		**.38**
	Occ.	-.07	-.06	.24	.09	.01	**.19**	**.79**	**.07**	**.24**	

DFAs based on Interests + Abilities

		F_1					F_2				
		Fav.	Least	Leis.	Major	Occ.	Fav.	Least	Leis.	Major	Occ.
F_1	Fav.		**.74**	**.80**	**.79**	**.85**	.08	.16	-.36	.06	.05
	Least	**.80**		**.66**	**.76**	**.86**	.06	-.08	-.06	-.40	-.15
	Leis.	**.81**	**.67**		**.68**	**.83**	-.07	-.12	-.12	.08	.16
	Major	**.83**	**.80**	**.67**		**.83**	-.27	.03	-.51	.02	.15
	Occ.	**.88**	**.85**	**.81**	**.85**		-.06	.05	-.33	-.17	-.03
F_2	Fav.	-.02	-.02	-.17	-.24	-.09		**-.23**	**.59**	**-.46**	**-.52**
	Least	.20	.00	-.11	.11	.14	**-.21**		**-.47**	**.33**	**.48**
	Leis.	-.31	-.03	-.02	-.44	-.31	**.47**	**-.51**		**-.34**	**-.45**
	Major	.07	-.31	.15	-.02	-.16	**-.53**	**.27**	**-.21**		**.41**
	Occ.	.10	-.09	.22	.13	.01	**-.52**	**.44**	**-.35**	**.46**	

Note. Arguments in table reflect correlations between discriminant function scores across five criterion variables. Correlations below the diagonal are based on subsets of the 547 talent search participants for whom 5-year follow-up surveys were secured: 223 cases were used in the analyses based on the SOV and three ability measures, and 211 cases were used in the analyses based on RIASEC and abilities. Correlations above the diagonal are based on subsets of the 513 talent search participants for whom 5-year follow-up surveys were *not* secured: 166 cases were used in the analyses based on the SOV and abilities, and 157 cases were used in the analyses based on RIASEC and abilities.

Appendix F, continued

Table F4

Correlations between first discriminant function scores for analyses based on the SOV and three ability measures versus RIASEC and three ability measures across five criterion variables

F_1 scores of participants with longitudinal data

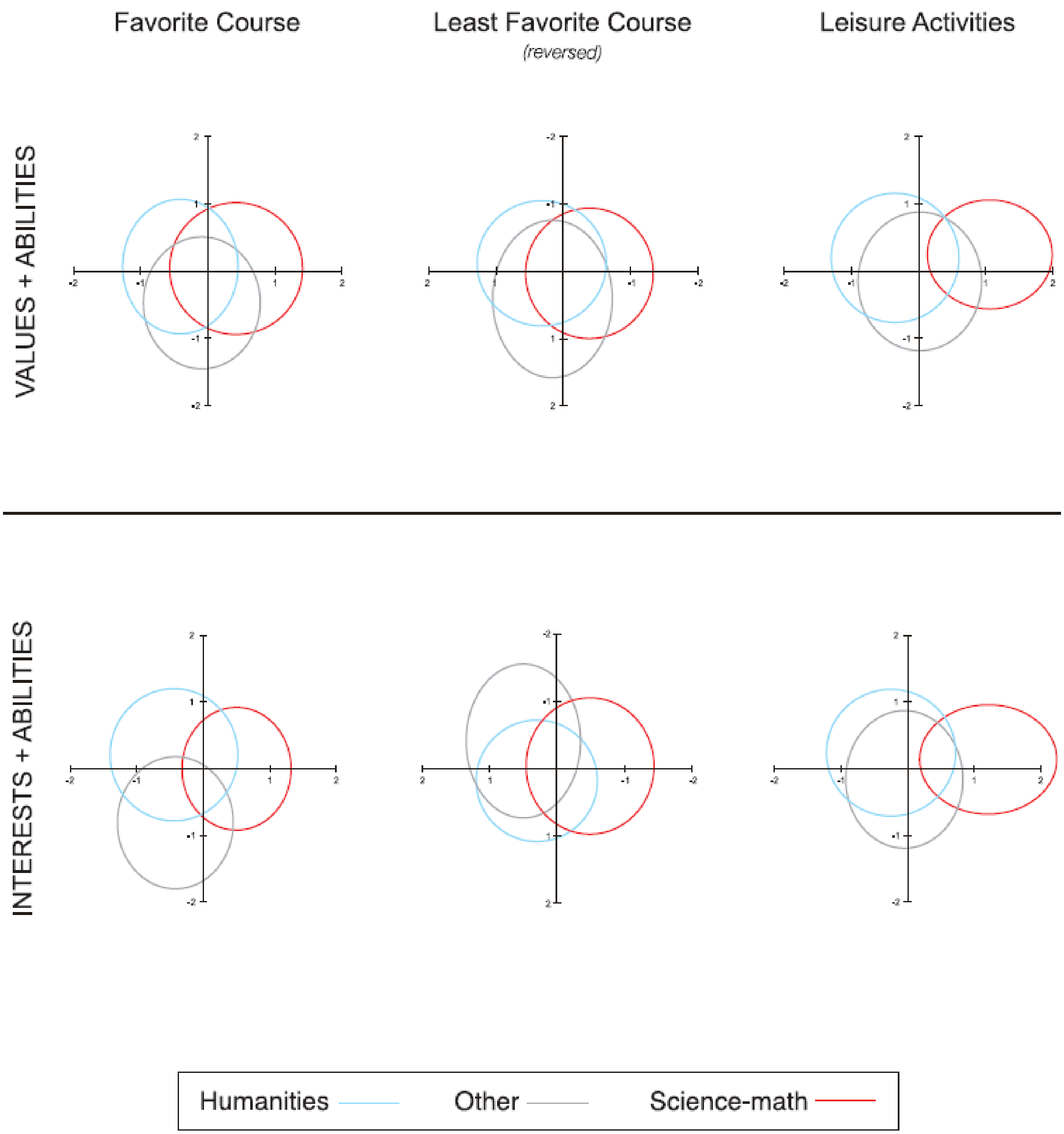
		F_1 (RIASEC + M + V + S)				
		Fav.	Least	Leis.	Major	Occ.
F_1 (SOV + M + V + S)	Fav.	.80	.62	.73	.70	.84
	Least	.63	.72	.65	.66	.84
	Leis.	.75	.63	.78	.69	.86
	Major	.60	.66	.60	.70	.74
	Occ.	.70	.70	.69	.75	.85

F_1 scores of participants without longitudinal data

		F_1 (RIASEC + M + V + S)				
		Fav.	Least	Leis.	Major	Occ.
F_1 (SOV + M + V + S)	Fav.	.78	.56	.71	.67	.79
	Least	.58	.73	.70	.64	.83
	Leis.	.74	.62	.75	.71	.86
	Major	.59	.64	.64	.70	.75
	Occ.	.68	.66	.71	.74	.83

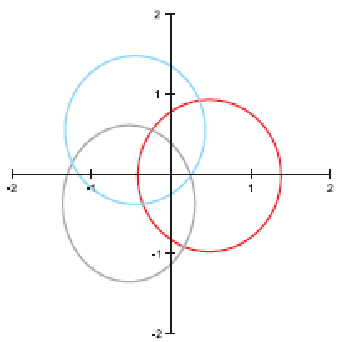
Note. Arguments in table reflect correlations among participants' scores on the first functions derived from the DFAs based on the SOV and three ability measures (along left) were correlated to participants' scores on the first functions derived from the DFAs based on the RIASEC and three ability measures (along top).
SOV = Study of Values, RIASEC = general occupational themes of Strong Interest Inventory, M = mathematical ability, V = verbal ability, and S = spatial ability. F_1 = first discriminant function, Fav. = favorite course, Least = least favorite course, Leis. = preferred leisure activity, Major = undergraduate major, and Occ. = anticipated occupation.

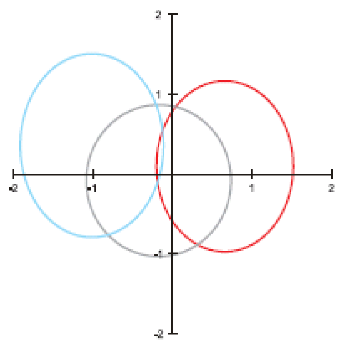
Figure 10. Scores on discriminant functions for each criterion group. Individuals were categorized according to their group membership (science-math, humanities, or other) on each relevant criterion variable and graphed according to their scores on each of the discriminant functions. The top row represents functions based on values and abilities; the bottom row represents functions based on interests and abilities. In each coordinate system, scores on the first functions are represented along the x-axis, and scores on the second functions are represented along the y-axis. Each ellipse represents science-math (in red), humanities (in blue), or other (in gray). Each ellipse originates at the mean scores on F_1 and F_2 (as x,y coordinates) for each of the three criterion groups. The shape of the ellipse is defined by the standard deviations of the function scores for that group; that is, the ellipse is extended from its origin horizontally 1 SD of the F_1 scores of the group to the left and 1 SD to the right. The ellipse is extended from its origin vertically 1 SD of the F_2 scores of that group up and 1 SD down.

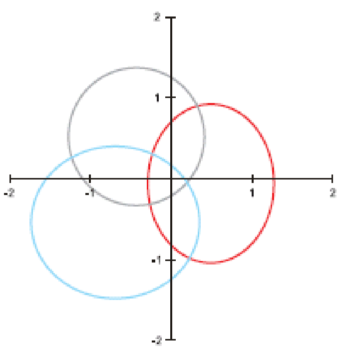

Favorite Course
Least Favorite Course
(reversed)
Leisure Activities
VALUES + ABILITIES
INTERESTS + ABILITIES
Humanities
Other
Science-math

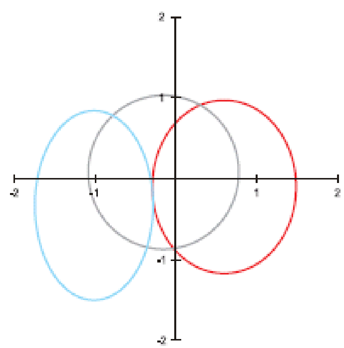
Undergraduate Major

Anticipated Occupation









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