The educational and vocational preferences of a cohort spatially gifted females and males from the Study of Mathematically Precocious Youth

By

Melissa Bernadine Lange

A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Psychology

Major Professor: Douglas L. Epperson

Iowa State University

Ames, Iowa

1999

Graduate College
Iowa State University

This is to certify that the Master's thesis of

Melissa Bernadine Lange

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy

TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION

Spatial-visualization ability, as defined most commonly as the ability to generate, retain, retrieve, and transform visual images (Lohman, 1994), has had a long and extensive history in the psychological literature. Many factor analytic studies have been conducted to investigate the existence of a major group factor involving spatial ability and the possible breakdown of this major group factor into subdivisions (minor group factors), that correspond to a variety of spatial abilities (Kelley, 1928; El Koussy, 1935; Thurstone, 1931, 1938, 1950). Another focus of the literature has been on the relationship to and the influence of spatial ability on other abilities, in particular mathematical ability (Casey, Nuttall, Pezaris, & Benbow, 1995). Gender differences in spatial ability have also been a major focus of research. While spatial-visualization has been prominent in the research literature, a great deal of confusion remains regarding a clear definition of what is meant by "spatial ability(s)."

In addition, very little is known about individuals who excel on measures of spatial abilities. Do spatially gifted individuals differ from non-spatially gifted individuals in their abilities, preferences, interests, and values? The present study will attempt to identify and examine the unique profile of interests, values, abilities, and preferences of individuals who are spatially gifted. In particular, vocational and educational preferences will be explored in the hopes of gaining a better understanding of the unique needs of students in this overlooked population. By identifying the educational and vocational preferences and needs of the spatially gifted, educators can be better equipped to design interventions and educational experiences that develop the unique talents of these individuals.

The Study of Mathematically Precocious Youth (SMPY) and its extensive data bank provides a unique opportunity to examine the differential degrees of spatial-visualization ability in a sample of intellectually gifted students. While studies have been conducted using the data from the Cohorts 1, 2, and 3 of the SMPY longitudinal study, little has been done to profile the educational and vocational preferences and interests of participants in Cohort 4. Participants in this particular cohort have all been administered three independent measures of spatial visualization (the Cubes, the Bennett Mechanical Comprehension test, and the Vandenberg Mental Rotation test). A composite score based on these three measures of spatial-visualization will be used to identify students falling in the top and bottom quartiles (by gender) on spatial-visualization ability. The present study will explore differences between spatially gifted adolescents and intellectually gifted students who are not identified as being spatially gifted. In addition, gender differences within the two spatial ability groups will be explored.

Rationale

The rationale for the present study is consistent with the long-term goals of the Study of Mathematically Precocious Youth outlined in Benbow & Arjmand (1990). The primary goal of the SMPY has been to "identify the factors that lead to creative work and/or high achievement in the sciences" (Benbow, et al.). Benbow and Arjmand outlined the primary components involved in SMPY research: intellectual ability, educational experiences, and personal attitudes, interests, and values. Consistent with this research, the primary goal of the present study has been to profile the individuals in SMPY's fourth cohort, paying particular attention to the unique abilities, interests, values, preferences, and experiences of individuals who are identified as being spatially gifted, in addition to intellectually gifted.

An additional impetus in profiling these spatially gifted adolescents has been the drastic under-representation of females in academic study and careers in mathematics, physical sciences, and engineering fields, in comparison to females representation in careers in law, business, and medicine. A variety of statistics proliferate the literature on the lack of females in science and engineering, and while theses statistics may vary, they do call attention to the drastic need to identify and nurture the talents of women who may be successful in math, science, and engineering. Based on statistics from the 1989 American College Testing (ACT) Program, only 1% of females taking the ACT exam in 1989 indicated that they planned to pursue a major in the physical sciences and only 2 % indicated plans to major in engineering or biological sciences. None reported an interest in or plans to major in mathematics. Gifted females are no different, with only 20% of gifted females versus 40% of gifted males planning to pursue a career in math or the sciences (Benbow & Minor, 1986; Benbow, 1988). This under-representation or lack of interest in the math and the sciences is not limited to precollegiate females. Meade (1991) reports that just over 15% of engineering undergraduates are women and 14% of engineering master's degrees and 9% of engineering doctorates were issued to women in 1989-90. Faculty representation in colleges of engineering is also low, with only 3% of engineering faculty being women (Meade, 1991).

Farmer, Wardrop, Anderson, and Risinger (1995) point out that parity of women in science, engineering, and technical engineering has become a priority for government agencies, such as the National Science Foundation and the Department of Education. The lack of women in science and engineering represents a huge loss of talent for the United States (Meade, 1991; McLure & Piel, 1978). This under-representation of women in engineering and the sciences also represents a huge loss to women in the form of expanded educational, occupation, and economic opportunities. Occupations in engineering were identified as one of the top 5 most lucrative potential occupations for women by the United States Department of Labor (1990). While math abilities are important to success in careers in science and engineering, Schaefers, Epperson, and Nauta (1997) point out that gender differences in the representation and persistence of women in math-related technical fields is not fully explained by mathematical abilities alone. It has been hypothesized that mechanical comprehension and spatial abilities are critical for high-level performance in careers in the physical sciences and engineering, as well as creative arts (Achter, Lubinski, and Benbow, 1996). Achter et al. argue that an untapped talent pool for engineering and physical sciences exists, and that the use of mechanical comprehension and spatial ability measures may be used to uncover these unused resources.

The present study is unique in comparison to most of the literature on the under-representation of females in engineering and the sciences. While previous research into under-representation has focused on potential barriers to women's involvement in these fields, researchers studying the under-representation of females have frequently failed to assess talent and the important role it plays in women's pursuit and success in these fields. While some investigators have looked at mathematical ability, the role of spatial ability has been completely ignored in explaining the under-representation of females. High spatial ability and strong (high) Realistic vocational interests are critical to success in engineering and the sciences. The low proportion of women who are both spatially gifted and who possess strong realistic interests helps to explain the under-representation of women in these careers. The present study attempts to gain a better understanding of the unique abilities, occupational interests and values, and educational/ occupational preferences of the spatially gifted, with the future goal being better identification of the spatially gifted. By identifying these untapped individuals, we can design educational opportunities and intervention to increase their participation in careers in math, engineering, and the sciences.

Research Questions and Hypotheses

The present study sought to answer four questions regarding the abilities, vocational interests and values, educational and vocational preferences, and extracurricular and leisure-time preferences of individuals identified as possessing gifts and talents in the area of spatial-visualization. In all four areas of inquiry, the purpose was not only to identify these abilities, preferences, values, and interests, but to also investigate differences between varying levels of spatial ability (high versus low) and genders. In looking at differences based on gender, comparisons were made between males and females in the overall sample and within males and females in the high spatial ability group.

Because of the extensive body of literature and research focusing on the relationship between spatial and mathematical abilities, the first research question involved examining the mathematical abilities of individuals in the study. More precisely, the following question directed the subsequent research: What differences exist between the four experimental groups (High-Spatial Males, High-Spatial Females, Low-Spatial Males, and Low-Spatial Females) in their mathematical ability patterns as measured by participants' scores on the Scholastic Aptitude Test (SAT)?

Based on the research reviewed (Humphreys, Lubinski, and Yao (1993); Lubinski, Benbow, & Sanders, 1993; Casey, Nuttall, Pezaris, & Benbow, 1995), it was hypothesized that spatially gifted (High-Spatial) females would have higher SAT-M scores than females in the low spatial-visualization group. In addition, High-Spatial females should have SAT-M scores that are a little lower than High-Spatial males and roughly equivalent to the SAT-M scores of the Low-Spatial Males. High-Spatial males were hypothesized to have higher SAT-M scores than the remaining three groups.

The second area of inquiry focused on the vocational interest and values of the sample of SMPY Cohort 4 participants. Vocational interests were measured using the Strong Interest Inventory, while vocational values of the sample were measured by the Study of Values (Allport, Vernon, and Lindzey, 1970). Both the Strong Interest Inventory and the Study of Values are described in more depth in Chapter 3. Two research question were asked: Do spatially gifted adolescents differ in their vocational interests and values from gifted adolescents who are not spatially gifted? Are there gender differences among the spatially gifted population in vocational interests and values?

For vocational interests, it was hypothesized that males would have more narrowly defined vocational interests (in particular, Realistic and Investigative), while females would have more competing vocational interests (Lubinski & Benbow, 1992), regardless of there level of spatial-visualization ability. Social and Artistic vocational interests were hypothesized to be more prevalent in the females versus male groups. Realistic and Investigative vocational interests should also be more prevalent in both spatially gifted groups in comparison to the non-spatially gifted groups (Lubinski & Benbow, 1992; Lubinski, Benbow, & Sanders, 1993; Benbow & Lubinski, 1993; Lippa, 1995).

Based on research looking at the positive correlation between the Strong Investigative theme and the Theoretical themes on the Study of values, it was hypothesized that theoretical values would be more prominent for individuals identified as being spatially gifted (Schmidt, Lubinski, & Benbow, in press). Overall, it was expected that males versus females would rank Theoretical value as their most preferred or top-ranked value. Similarly, the Aesthetic theme and Social theme of the Study of Values have been shown to positively correlate with the Artistic and Social General Occupational Themes of the Strong, respectively. Based on these correlations, it was hypothesized that females regardless of their level of spatial ability would be more like to have the Aesthetic and Social themes as their top-ranked values, compared to males in the sample.

Third, the present study sought to answer the following questions: How do spatially gifted adolescents differ from gifted adolescents who are not spatially gifted in their educational and vocational preferences as measured by their responses on a background (life data) questionnaire? Are there gender differences in educational and vocational preferences among the spatially gifted population? To assess educational and vocational preferences, participants responded to questions about their enrollment in math and science course, their favorite courses in school, the least and most liked aspects of their educational experiences, the educational experience that has most affected them, and their choice of a future occupation.

It was hypothesized that spatially gifted males would report completing the most and highest levels of science and math courses among the four groups. Females, regardless of their spatial visualization ability, were hypothesized to report enrolling in fewer math and science courses (Lubinski & Benbow, 1992). Preferences for courses in math and science should be more prevalent in the spatially gifted groups. In addition, spatially gifted adolescents were expected to be more likely to prefer and be enrolled in vocational courses than non-spatially gifted adolescents. Spatially gifted adolescents, in particular males, were expected to report math and science courses as being important for future careers. This would be coupled with a higher prevalence of future science and math occupations for individuals scoring higher on the spatial-visualization composite. The preferred occupations of this population (High-Spatial) should involve working with and manipulating "things" or objects (Benbow & Lubinski, 1993; Lubinski, Benbow, & Sanders, 1993; Lippa, 1995). In regards to gender differences, females (particularly those in the Low-Spatial group) were hypothesized to report preferring occupations and courses involving social interactions, creativity, and the humanities or social sciences (Schmidt, Lubinski, & Benbow, in press).

Finally, the present study sought to answer questions regarding the extracurricular and leisure-time activities of individuals identified as spatially gifted. The research questions to be answered were: Do individuals identified as being spatially gifted differ from non-spatially gifted adolescents in their preferences for extracurricular activities? Do gender differences in self-reported preferences for extracurricular activities exist among the spatially gifted population? Extracurricular activities investigated included participation and involvement in a variety of clubs, competitions, artistic endeavors, and athletic activities. In addition, participants responded to questions about their reading habits and the amount of time they spent per week watching television, playing video games, and computer programming. Lastly, participants were asked about their involvement in "tinkering" activities, which were defined as activities involving mechanical gadgets and construction sets.

It was hypothesized that Spatially gifted adolescents, regardless of gender, should report preferences for and participation in extracurricular activities that involve "tinkering" or working with objects (e.g., gardening, building, sewing, etc.) (Schmidt, Lubinski, & Benbow, 1996). Based on their hypothesized interests (Realistic & Investigative) and values (theoretical) profiles, spatially gifted students were expected to report being involved in a greater number of extracurricular activities and hobbies (Humphreys, Lubinski, & Yao, 1993). Spatially gifted adolescents would be expected to show less involvement or interest in creative projects or extracurricular activities involve writing. In regards to gender differences, it was hypothesized that spatially gifted males would be more likely to report participation in projects or activities involving science or math (e.g., science fair projects, math contests). Females were expected to report involvement in more diverse extracurricular hobbies and activities than males.

CHAPTER 2. REVIEW OF THE LITERATURE

Defining Spatial Ability

To gain a better understanding of what is meant by the term "spatial ability", one must survey its long history in the research literature, paying particular attention to the many factor analytic studies that have been conducted. The research on spatial ability is far from being debate free. After almost a century of research aimed at gaining a better understanding of spatial ability, we still lack a solid and clear definition. Difficulty in defining spatial ability may arise from differences in the way researchers describe or view this ability. Elliot and Smith (1983) contend that these differences in perspective are related to whether or not the researcher adopts a broad or narrow description/definition of what is meant by the term "spatial ability." When defined broadly, spatial ability refers to individual differences in the processing of non-linguistic information. In contrast, spatial ability has been defined more narrowly as referring to individual differences in performance on spatial tests. Lohman (1994) commented on the difficulty in defining "spatial ability", stating that "much of the confusion [in defining spatial ability] lies in whether abilities are defined by performance on a certain class of tasks or by skill in executing certain types of mental processes (p.1005)." Embedded in this is the additional issue of whether spatial ability is a single unitary ability or a cluster/group of abilities that involve "different aspects of the process of image generation, storage, retrieval, and transformation" (Lohman, 1994). For the purpose of this study, Lohman's (1994) definition of spatial (-visualization) ability as the ability to mentally generate, retain, retrieve, and transform well-structured visual images was adopted.

Factor Analytic History of Spatial Abilities

Elliot and Smith (1983) organize the history of spatial ability research into three phases, each of which addresses the important issues and questions that have been raised in regards to spatial ability. Studies conducted in their first phase (1904-1938) focus on the fundamental question regarding the existence of spatial ability. As more evidence for the existence of a spatial factor surfaced, there was a shift in the direction or focus of empirical research on spatial abilities, marking the beginning of Elliot and Smith's (1983) second phase. Studies conducted between 1938 and 1961 can be classified into two categories: (1) studies aimed at investigating differences in possible subdivisions of the spatial factor; and (2) research aimed at the generation of new, psychometrically-sound tests of spatial ability. The focus of research on spatial abilities from the 1960's to the present (the third phase) has been on establishing "the status of spatial abilities in terms of the interrelation of many different abilities" and on determining the "different sources of variance in performance on spatial tests" (Elliot and Smith, 1983).

Interest in spatial ability or a spatial factor and individual differences related to these specific abilities emerge with and grew out of early theories and measures of general intelligence (Elliot and Smith, 1983; Humphreys and Lubinski, 1996). Early tests of general intelligence, such as the Binet-Simon *Scales of Intelligence* (1905), contained spatially-oriented test items. Spearman's (1904) two-factor theory of intelligence also represents an important starting point for the study of spatial ability. According to Spearman, intelligence can be analyzed or divided into a general ability factor (g), or "general energy," and one or more specific/group factors (s). Spearman's general factor accounted for what was common among all tests of intelligence, while the specific factors represented the specific abilities that were peculiar or unique to each test (Spearman, 1904; Elliot and Smith, 1983). Spearman's two-factor theory helped in paving the way for research focusing on the existence of group factors that "enter into *some* distinct abilities,...and which correspond fairly closely to the important aptitudes (i.e. verbal, spatial, and numerical)" (Smith, 1964). Lastly, Stephenson's (1931,1935) work in identifying a group factor for verbal ability distinct from the general ability factor (g) can be seen as an additional impetus for the increased interest in spatial ability and the development of non-verbal tests at the early part of this century (Smith, 1964; McGee, 1979; Elliot & Smith, 1983), as researchers began to search for other group factors that were distinct from g.

During the 1920's and 1930's (Elliot & Smith's first phase), early factor analytic studies by Kelley (1928), El Koussy (1935), Thurstone (1931, 1935), and other researchers investigated the existence of spatial factor as a subtype of intellectual ability (Guttman, Epsteing, Amir, & Guttman, 1990). In her investigations of "practical" ability, McFarlane (1925) found evidence for the presence of a group factor in addition to g for boys. Individuals possessing abilities that related to this group factor excelled at analysis and judgements involving concrete spatial situations. Using a comprehensive battery of 28 spatial tests, El Koussy (1935) found evidence for a group factor (*k*) in 8 of the tests used. El Koussy defined *k* as the "ability to obtain and the facility to utilize visual spatial imagery." Along with El Koussy, Thurstone can be credited with helping to establish the existence of a separate spatial factor (Elliot & Smith, 1983). Thurstone (1931, 1938) viewed human intelligence as consisting of many independent or primary factors versus one general ability factor g. Thurstone's (1931, 1938) early work provided evidence for a "space" factor that involves possessing a "facility in holding a mental image [spatial/visual imagery] and mentally twisting, turning, or rotating it to…reach a solution."

Moving into Phase II, later research by Thurstone (1950, 1951) would divide this "space" factor into a number of subdivisions. Included in Thurstone's subdivisions of the spatial factor would be three spatial-visual orientation factors (S1, S2, S3) and memory, kinesthetic, and closure factors. Thurstone's S1 factor relates to the ability to visualize an object or rigid configuration when it is moved or seen from different angles. While the S1 factor relates to the movement of an entire object or configuration, S2 refers to the ability to visualize a configuration in which parts or components of configuration are moved or displaced. Finally, Thurstone's S3 refers to the ability to think about spatial relations in which the orientation of the observer's body represents an essential part of the problem (Smith, 1964). Thurstone (1950, 1951) was not the first to identify possible subdivisions of a spatial factor (Smith, 1964; Elliot & Smith, 1983). Kelley (1928) was one of the first to divide the spatial factor into two parts, one related to the sensing and retention of geometric forms and a second related to a facility in the mental manipulation of spatial relations and spatial-visual images.

When discussing the division of the spatial factor into subdivisions related to more specific abilities and situations, it is helpful to refer to Vernon's (1950) hierarchical theory of intelligence. Vernon conceptualized the structure of human abilities using a hierarchical model in which a general ability factor (g) is extracted first through the use of factor analysis. Immediately below the general factor in the hierarchical model are the two major group factors proposed by Vernon: verbal-numerical-educational (*v:ed)* and mechanical-spatial-practical (*k:m*) (Vernon, 1950). Further analysis leads to the division of the major group factors into minor group factors. The *v:ed* factor is comprised of the verbal, numerical, and fluency (minor) group factors, while *k:m* consists of the spatial, mechanical information, and psychomotor (minor) group factors (Sattler, 1992). Combined measures of the general factor (g) and the *v:ed* factor are most commonly used in college admissions testing (i.e. SAT, ACT, and GRE) (Humphreys & Lubinski, 1996). Tests of the *k:m* factor were used extensively during World War II in the selection of pilots, and they are useful predictors for success in occupations that involve mechanical and technical tasks, as we will discuss later.

The distinction between verbal and spatial abilities in Vernon's hierarchical model is a distinction that reoccurs in the literature. Lohman (1988) points to the existence of a similar verbal-spatial distinction in Guilford's (1967) semantic versus figural content and in the work of Gazzaniga (1983) on hemispheric specialization as it relates to verbal-sequential versus spatial-analog processing. A similar parallel can also be drawn between the verbal-spatial distinction and Snow's (1964) "two cultures" (Humphreys & Lubinski, 1996).

Returning to the division of the major spatial group factor into minor group factors and specific factors, strong evidence came from studies involving the United States Army Air Force (Guilford & Lacey, 1947). From this research, two spatial factors were identified: a spatial relations factor and a visualization factor (*Vz*). The spatial relations factor was defined as "the ability to determine the relationships between different spatially arranged stimuli and responses, and the comprehension of the arrangement of elements within a visual stimulus pattern." Visualization was defined as "the ability to imagine the rotation of depicted objects, the folding and unfolding of flat patterns, and the relative changes of position of objects in space" (Guilford Lacey).

Additional factor analytic studies during the 1950's resulted in a variety of different models involving two or more spatial factors (Burt, 1949; French, 1951; Michael, Guilford, Fruchter, and Zimmerman, 1957). The enormous factor analytic literature and the numerous spatial factors identified only added to the confusion in defining spatial ability. It was clear that spatial ability did not consist of a unitary factor, but rather a group of different spatial abilities. Myers (1958) concluded that the term "spatial abilities" represented a complex family of abilities whose relationships with one another remained unknown. Ekstrom, French, and Harman (1979) argued that the basic problem with factor analytic studies of spatial abilities was they had not been successful in "building an integrated theory of the organization of spatial abilities based on a priori definition of specific tests and their roles in the model." Guttman et al. (1990) supported this view arguing that factor analytic research on spatial abilities has resulted in nothing more than a plethora of factor names that are vague and overlap in content.

While a hierarchical model of cognitive abilities has been useful to this point in conceptualizing the relationship of a spatial ability factor(s) to a general factor (g) and other aptitudes and their corresponding group factors, researchers (Guttman, 1954; Marshalel, Lohman, & Snow, 1983; Ackerman, Sternberg, & Glaser, 1989; Guttman, et al., 1990; Lubinski & Dawis, 1992) have used the concept of a radex to arrange cognitive abilities based on their content and complexity. The Radex model places general intelligence at the center, with different major content abilities (verbal, figural, and numerical) as slices of the ability circle. Complexity of processing is reflected in the distance from the centroid of the radex, with the most complex abilities and measures located closest to g.

Zimmerman (1954) was one of the first to consider the degree of difficulty of a spatial task as a possible determinant in its factor loadings with other spatial measures. He hypothesized that the spatial relation and visualization factors were differentiated by their relative amounts of complexity or difficulty (Smith, 1964). Zimmerman (1954) conducted a study using three different forms of a single test (Visualization of Manouvres), which differed only in the level of difficulty or complexity. He found that the simplest form of the test loaded highest with the Perceptual Speed factor, while the moderately difficult form of the test loaded highest with the Space factor. The most difficult version of the test seemed to provide the best measure of the Visualization (*Vz*) factor. Zimmerman concluded that different factors entered the same kind of test material at different levels of complexity. The degree of complexity involved in the spatial test dictated the need to utilize different response procedures. The *Vz* factor involves a higher level of intellectual processing in comparison to the Perceptual Speed factor, which is more closely related to the automatic processing involved in timed spatial ability tests.

Further studies by Guilford (1967, 1971), Wattanawaha (1977), and Guttman et al. (1990) point to the influence of different stimulus characteristics and task demands on the factor loadings of spatial ability tests. Guilford's Structure of Intellect model (1967) proposes that intellectual activities can be best understood in terms of the mental operations performed, the content involved, and the products that result (Elliot & Smith, 1983). Wattanawaha (1977) identified four independent characteristics of spatial tasks that may influence factor loadings: (1) the dimensionality of the stimulus (2-D vs. 3-D); (2) the amount of internalization required (static vs. kinetic imagery); (3) the manner in which the answer must be presented (i.e. multiple choice, drawing, etc.); and (4) the type of thinking required for the solution. Guttman, Epstein, Amir, and Guttman (1990) added to the Radex model by incorporating a method of facet theory (mapping sentence) designed by Guttman (1980). The resulting model was that of a cylindrex. The facets use in the study were: (1) the rule task (inference vs. application); (2) the presence or absence of mental rotation; (3) the dimensionality of the stimulus presented; and (4) the presence or absence of reflection in the test stimuli. Guttman et al. (1990) concluded that the combination of facet theory with regional analysis can be useful in the facilitating "the classification and design of spatial ability tests and in the conceptualization of spatial and other abilities," which is consistent with the Lohman's (1988) suggestions for the coordination of facet models with hierarchical models.

The factor analytic literature on spatial abilities has progressed from answering the basic question about the existence of one or more spatial group factors. In addition, factor analytic research has attempted to explain the relationship of spatial abilities to other human abilities and the interrelationships of minor spatial group factors. Current research has focused on the nature of different types of spatial factors (i.e. spatial relations, spatial orientation, visualization, etc.) and gender differences that have been found on measures of spatial ability.

The Importance of Spatial Abilities

While spatial ability has been prominent in hierarchical models of human abilities and in other areas of psychological research, such as investigations into the distinction between spatial abilities and verbal abilities and research on individual differences, this prominence has not carried over into practice. With the exception of their use in empirical research and as "performance" or "non-verbal" reasoning tests, spatial ability tests are not widely used

(Lohman, 1988). Educational testing, especially testing for college admissions, has focused on the use of tests that measure general ability and the verbal-numerical-educational (*v:ed*) factor. Because of their history of use in military personnel selection for mechanical and technical assignments, spatial ability tests' utilization has been limited to personnel selection and vocational counseling for occupations that fall below the professional level (Humphreys & Lubinski, 1996). Lohman (1988) presented possible reasons for the limited utilization of spatial ability tests in practical settings.

While verbal and general ability measures have been shown to be useful in predicting success in school and work, spatial ability tests have not been shown to play an important role in predicting success in traditional educational settings or courses. McGee (1979) provides a review of early predictive validity studies using spatial ability measures for the prediction of success in vocational-technical training programs and of success in a variety of occupations. The predictive validity of spatial ability has been shown to be higher for grades in engineering and trade schools, for pilot selection for air crews (Guilford & Lacey, 1947), and for machine workers and bench workers (Ghiselli, 1973). A 1957 study conducted by the United States Employment Service categorized jobs on the basis of worker trait characteristics (e.g. interests, aptitudes) and found that jobs requiring a high level of spatial ability fell into four categories: engineers, scientists, draftsmen, and designers. More recent studies have supported the importance of high spatial ability in careers in engineering and physical sciences (Humphreys, Davey, & Kashima, 1986; Lubinski & Benbow, 1992; Benbow & Lubinski, 1993; Humphreys, Lubinski, & Yao, 1993; Achter, Lubinski, & Benbow, 1996).

Research by Humphreys and his colleagues (Humphreys, Davey, & Kashima, 1986; Humphreys, Lubinski, & Yao, 1993; and Humphreys & Yao, unpublished) has sought to examine the usefulness of spatial visualization measures in educational and occupational selection and attainment, while investigating the unique characteristics of spatially-talented individuals. In a study investigating experimental measures of cognitive privilege/ deprivation, Humphreys, Davey, and Kashima (1986) used three composite scores based on Vernon's Structure of Intellect model: a general intelligence composite, a verbal-numerical-educational (*v:ed*) composite, and a mechanical-spatial-practical (*k:m*) composite. They found that the general intelligence and *v:ed* keys were almost parallel measures of the same thing, while the mechanical-spatial key appeared to provide some degree of differential prediction. More importantly, Humphreys et al. (1986) found support for the idea that students self-select engineering and physical science educational paths on the basis of their spatial-visualization abilities.

Humphreys, Lubinski, and Yao (1993) further investigated the role of spatial visualization in becoming an engineer, physical scientist, or artist. They hypothesized that while mathematical ability was important in securing educational credentials in engineering and the physical sciences, spatial ability also played a critical role in individuals' educational and occupational successes in these fields. In other words, spatial visualization ability would add incremental validity in the prediction of group membership for physical science and engineering students. Beyond finding support for their hypothesis, their study provides excellent insight into the unique characteristics of individuals who are spatially-gifted. Members of the "High-Space" group had math grades similar to those of the "High Intelligence" group and their science grades were slightly lower. "High Space" students had much lower grades in foreign languages, English, and social studies, with both males and females in the "high space" groups avoiding majors in the social sciences and humanities. They did have the highest grades of the three groups in vocational courses. While they scored above average on verbal and mathematical achievement measures, spatially-gifted individuals were less likely to be enrolled in college preparatory courses, and they had a higher drop-out rate. "High Space" individuals were more likely to be found in occupations in which a high school education was considered to be sufficient (i.e. skilled trades and labor occupations) and were less likely to have educational credentials beyond a high school diploma. To their advantage, "high space" individuals were motivated to achieve and reported interests and participation in a wider variety of hobbies. Hobbies and interests involved a preference for working with objects, such as gardening, building, sewing, and tinkering.

Humphreys et al.'s (1993) results regarding the educational and occupational aspirations and attainments of spatially-gifted students provides more evidence for the under-appreciation of spatial abilities and the limited use of spatial visualization measures in educational and occupational settings. Lohman (1988) argued that the limited use of spatial ability tests and the under-appreciation of spatial ability in practice and everyday life may result from a bias in our education system, and culture in general, towards verbal ability. The curriculum taught in our education system and the tests used to assess school achievement are heavily based on verbal content and aptitudes. The criterion measures used in educational and work settings, and in life in general, show an over-reliance on verbal abilities. Humphreys and Lubinski (1996) argue that spatially gifted students are going overlooked because of a bias in our culture toward verbal and quantitative abilities.

Humphreys et al. (1993) hypothesize that spatially-gifted students are "turned off" from formal education by the highly verbal nature of the pre-college curriculum and the tests used to assess academic achievement in the schools. Support for their hypothesis can be found in the lower levels of academic and occupational attainment, the lower levels of occupational aspirations, and higher drop-out rates for students identified as having high spatial abilities.

While numerous studies have supported the notion that spatial abilities play a critical role in predicting educational and occupational success in engineering and the physical sciences (Humphreys & Yao, unpublished manuscript; Humphreys, Davey, & Kashima, 1986; Humphreys et al., 1993; Benbow & Lubinski, 1993) , not much is know about the unique characteristics of the spatially gifted. Myers (1958) was one of the first to advocate for the wider significance of spatial abilities and the need to identify and profile spatially gifted individuals:

> We believe that the person with this [spatial] ability, or these abilities, will characteristically reason in a different manner from people who have little of these abilities. Their interests are likely to differ. They are likely to be more successful in solving certain problems. We believe that these abilities can be developed, that they are partially dependent upon innate characteristics, but that they often remain undeveloped because they are not appreciated. We believe that these abilities are much broader in scope than the limited criteria for which they have thus far been shown to be valid. They may even influence the ways in which one studies philosophy or appreciates literature....
>
> "In our judgment, spatial ability is an important and pervasive trait, affecting our perception of our environment and our style of thinking about it. When better tests are built and a better theory provided for their use, we believe it possible that we will find spatial ability to be similar in importance to such traits as verbal or social intelligence. (p. 100)

Teaming ability measures with measures of personal preferences, interests, and values can provide a more comprehensive picture of the unique characteristics of gifted (spatially-, mathematically-, intellectually-gifted) students, while also providing insight into how personality characteristics and features influence the educational/ occupational decision-making process (Lubinski, Benbow, and Sanders, 1993).

Smith (1964) provides an overview of the early research done on the relationship between spatial ability and interests, attitudes, and "temperament." Smith reported that evidence has been found to support an association between spatial ability and practical, mechanical, and scientific interests. In contrast, "academic" interests were found to be moderately associated with verbal ability. An additional spatial-verbal distinction was found in gender-related attitudes and interests. Smith (1954) concluded that spatial abilities are associated with masculine attitudes and interests, while feminine attitudes and interests are more closely associated with verbal ability. Smith viewed these associations as being consistent with the gender differences in spatial abilities that are prevalent in the research literature. Lastly, Smith (1964) summarized findings regarding the relationship between spatial abilities and "temperament." He concluded that individuals who scored high on spatial ability tests relative to verbal tests tended to be more self-confident and self-sufficient. These individuals demonstrated greater vigor/drive and more freedom from nervousness and emotionality. In addition, individuals scoring high on spatial or mechanical comprehension measures tended to be more introverted and possessed more asocial traits. On the other hand, individuals scoring higher on verbal ability measures were characterized as being more emotional and extroverted.

More recent studies conducted with participants in the Study of Mathematically Precocious Youth (SMPY) at Iowa State University have further explored the unique interest, value, and preference profiles of mathematically gifted adolescents. A major emphasis of the SMPY study has been focused on the achievement of intellectually talent youth in the mathematics and science disciplines (Benbow, 1988; Benbow & Lubinski, 1993; Lubinski & Benbow, 1992; Lubinski, Benbow, & Sanders, 1993). While most studies have relied on subject samples of mathematically precocious adolescents, results from these studies have been helpful in shedding some light on the unique characteristics of individuals who may also be spatially gifted. In addition, these studies have provided valuable information about the gender-differences in spatial ability found in gifted populations.

Using the Holland's (1985) hexagon and Allport, Vernon, and Lindzey's (1970) Study of Values (SOV), Benbow, Lubinski, and their colleagues (Humphreys et al., 1993; Lubinski & Benbow, 1992; Benbow & Lubinski, 1993, Lubinski, Benbow, & Sanders, 1993) have found consistent differences in the interest, value, and preference profiles of gifted adolescents based on their unique abilities and gender. The SOV is comprised of six value dimensions (viz. Theoretical, Aesthetic, Social, Economic, Religious, and Political). Holland's model of vocational interests consists of six interest categories: Investigative, Artistic, Social, Enterprising, Conventional , and Realistic. To supplement the Holland's hexagon, Prediger (1982) believed that two fundamental dimensions underlie the relations among the six vocational interests: a People-Things dimension and a Ideas-Data dimension. The People-Things dimension relates to the degree to which different vocations involve impersonal tasks (e.g. "things"—machines, tools, etc.) versus interpersonal tasks (caring for and relating to other "people"). Prediger's People-Things dimension has been shown to be highly related to gender, with males favoring work involving "things" and females gravitating towards "people" (Lubinski & Benbow, 1992; Lippa, 1998).

In a 1992 article, Lubinski and Benbow review SMPY research and discuss the gender differences that have been found among the gifted. Beyond the well-documented gender differences for mathematically ability favoring males, they found gender differences favoring males in mechanical reasoning, spatial ability measures, and number of math and science courses. More relevant to our discussion of the unique characteristics of spatially-gifted individuals were gender differences in vocational interests and values. Lubinski and Benbow (1992) reported that theoretical values were more characteristic of males and social values were more characteristic of females. More importantly, theoretical values are more characteristic for individuals employed in engineering or physical science fields. Social values were found to be negatively correlated with interests in physical science and engineering. A later study by Schmidt, Lubinski, and Benbow (in press) provided further support for these findings. Schmidt et al. found that the Theoretical value of the SOV correlated positively with mechanical and spatial ability, Investigative vocational interests (as measured by the Strong Interest Inventory), number of science books read, future occupational importance of math and physics, science course preferences, and tinkering with things. In addition, it correlated negatively with a variety of measures that include: ACL (Adjective Checklist) Nurturance and Affiliation, MPQ Social Closeness, and preference for course work in the humanities. The Social value correlated negatively with mechanical and spatial ability, future occupational importance of math, and tinkering.

Lubinski et al. (1993) examined differences between mathematically gifted males and females on vocational interests. Mathematically talented males tended to have intense and narrow interests in the Investigative and Realistic sectors of Holland's hexagon, while mathematically gifted females tended to have interests that were more balanced or evenly divided among Holland's Investigative, Social, and Artistic vocational interests. Realistic interests correlate positively with mechanical and spatial ability, a like of tinkering, and future occupational importance of math, physics, and computer science, while correlating negatively with preferences for course work in the humanities (Schmidt et al., in press). Similarly, Investigative interests correlate positively with SOV Theoretical values and preferences for course work in the sciences. As for the vocational interests that were more characteristic of mathematically gifted females, Social and Artistic, both correlated negatively with mechanical and spatial ability. The research by Schmidt et al. on the vocational preferences and interest of intellectual gifted adolescents is consistent with the previous research reviewed in Lubinski and Benbow (1992).

With similar patterns of gender differences in math and spatial abilities, it is safe to assume that the research on the vocational and educational preferences, interests, and values of mathematically gifted adolescents will predict a similar profile of preferences, interests, and values for individuals who are identified as being spatially gifted. Benbow and Lubinski (1993) list the following abilities and interests as being important for success in engineering or the physical science: high mathematical reasoning ability, high spatial-mechanical reasoning ability, intense Investigative vocational interests and Theoretical values, and a preference for activities and hobbies involving contact with objects (i.e. tinkering, building) versus people. Based on a review of the literature, it is probable that spatially gifted individuals, in particular males, would have this same ability and preference profile, making them well suited for success in the engineering and physical science fields.

There can be serious educational and occupational implications for the spatially gifted if we think back to the role that spatial abilities and tests of spatial ability play in practice today. If we continue to relegate measures of spatial ability to their limited utilization in personnel selection and vocational counseling, we will continue to overlook a population of individuals who are uniquely suited for occupations in the physical science and engineering fields. In addition, we are overlooking the unique educational needs of the spatially gifted. By not using adequate assessment tools, we cannot identify spatially gifted students and design interventions and educational opportunities and experiences that further develop their unique talents and abilities.

CHAPTER 3. METHODS

Participants

The participants in the present study were drawn from Cohort 4 of the SMPY's planned fifty-year longitudinal study of intellectual talent (Lubinski & Benbow, 1994), currently in its third decade. Participants were identified through the 1992 to 1996 SMPY talent searches at Iowa State University, conducted by the Office of Precollegiate Programs for Talented and Gifted (OPPTAG). Students who scored in the top 3%, according to national norms, on standardized achievement tests administered in their schools (e.g., Iowa Test of Basic Skills) were invited to take the Scholastic Aptitude Test (SAT) as part of the talent search. Cohort 4 (N>1000) consists of students (87.5% Caucasian and 10.2% Asian) who scored 430 or higher on the SAT-V or 500 or higher on the SAT-M by age 13. The students in this cohort represent the top 0.5% ability level. These participants are primarily from the Midwest, with a large concentration coming from the state of Iowa. All participants in the study were enrolled in summer programs for intellectually talented youth offered through OPPTAG.

Independent Measures

The independent variable, a spatial ability composite score, was created using a principal component based on the intercorrelations of the Vandenberg Mental Rotation Test, the Bennett Mechanical Comprehension Test, and the Cubes test. Each participant's spatial ability composite was calculated using the participant's scores from three different measures of spatial-mechanical ability: the Bennett Mechanical Comprehension Test, the Vandenberg Mental Rotation Test, and the Cubes test. Scores on each of these tests were converted to z-scores. The spatial composite was calculated using the following equation:

$$C_{spatial} = (.50)\ MRT_Z + (.30)\ Cubes_Z + (.20)\ BMC_Z$$

Where $C_{spatial}$ equals the spatial composite score, MRT_Z is the subject's z-score on the Vandenberg Mental Rotation Test, $Cubes_Z$ equals the subject's z-score on the Cubes test, and BMC_Z equals the subject's z-score on the Bennett Mechanical Comprehension test.

Bennett Mechanical Comprehension Test.

The Bennett Mechanical Comprehension Test (Form S; Bennett, 1969; Psychological Corporation, 1980) was designed to assess comprehension of physical and mechanical principles in practical situations. It is a 30-minute timed test, containing 58(?) multiple-choice items. The manual reports reliability coefficients (split-half) ranging from .81 to .93. The mechanical skills assessed by the BMCT are especially relevant to educational-vocational tracks involving a degree of "realistic interests" (according to Holland, 1985) or "things" (referring to Prediger's 1976 data-people-things-ideas map of the world of work). Validity data for these tracks are cited in the BMCT Manual (Psychological Corporation, 1980).

Vandenberg Mental Rotation Test (MRT)

The Mental Rotation Test (Vandenberg & Kuse, 1978) is a paper and pencil test that measures three-dimensional spatial-visualization and uses figures similar to those originally designed by Shepard and Metzler (1971). Standard procedures were used in administering and scoring the MRT (maximum score = 40). Participants are required to match a standard figure to two identical, but rotated figures. There are four options from which participants must choose. The two "correct" or identical figures are randomly sequenced with two distractors (mirror images of the standard or images with slight feature differences from the standard). Skills assessed by this instrument are particularly relevant to highly technical domains such as engineering. The internal consistency of this instrument, based on a sample of 2978 males and females, was .88 (Vandenber & Kuse, 1978), and the test-retest coefficients, based on samples of 336 and 456 people over a one-year time span, were .83 and .70, respectively (Kuse, 1977).

Cubes

Cubes (Johnson & Meade, 1987, adapted from a test by Thurstones, 1938) is a paper-and-pencil test, which purports to measure three-dimensional spatial-visualization. The test consists of pictures of 32 pairs of cubes requiring the participant to judge whether the two cubes are rotated versions of the same cube or of different cubes. A different pattern is printed on the side of each cube. The reliability for the Cubes test is .82 for twelfth-grad students and .70 for eleventh-grade students (Johnson & Meade, 1987).

Dependent Measures

The Strong Interest Inventory

Participants in Cohort 4 were administered the research version of the Strong Interest Inventory (available through Consulting Psychologists Press, Palo Alto, California, and simply referred to as the Strong henceforth). This instrument is an augmented version of the Strong-Campbell Interests Inventory (SCII; Hansen & Campbell, 1985) and includes some additional biographical items and experimental objectively scored questions about data, people, and things (Harmon, Hansen, Borgen, & Hammer, 1994). Both the SCII and the Strong contain identical measures yielding 23 Basic Interest scales and 6 General Occupational Themes, based on Holland's (1985) RIASEC dimensions: **R**ealistic (interest in working with things and gadgets, working outdoors, and need for structure), **I**nvestigative (interest in sciences, particularly mathematics and the physical science; prefer independent work), Artistic (interest in creative expression in writing and the arts and preference for little structure), Social (people interests and attraction to the helping professions), Enterprising (preference for leadership roles aimed at achieving economic objectives), and Conventional (preference for well-structured environments and chains of command, and tendency to follow rather than lead). Holland (1985) proposed a hexagonal structure to represent the interrelationships of these six vocational types, such that more similar types were arranged physically closer than types that were less similar (Fig. 4). Recent research has offered substantial support for the hexagonal organization of the RIASEC over other hypothesized configurations in adult samples (Rounds & Tracey, 1992. Rounds, Tracey, & Hubert, 1992; Tracey & Rounds, 1993), as well as in intellectually gifted adolescent samples (Lubinski et al., 1995)

Study of Values (SOV)

The Study of Values (Allport et al., 1970) is a measure of personality-related values, conceptualized as basic motive or interests. Like the Strong Interest Inventory, the SOV yields scores along six dimensions (brief descriptions are given in parentheses): *Theoretical* (concern for the discovery of truth and tendency to think in empirical, critical, and rational terms), *Economic* (appreciation for what is practical or useful; tend to judge matters in terms of tangible, financial implications), *Aesthetic* (dominant value is in form and harmony; sensitive to grace, beauty, and symmetry), *Social* (altruistic and genuine philanthropic love of people; tend to be kind, sympathetic, and unselfish), *Political* (interested primarily in power, influence, renown, and leadership), and *Religious* (value unity; tend to by mystical and seek to relate themselves to a higher reality).

The SOV is an ipsative instrument, requiring respondents to make rank judgments between various value statements. Because of its ipsative nature, the SOV measures the relative strength of all six values intraindividually. Reliability information reported by the Manual (Allport et al., 1970) included split-half reliability coefficients ranging from .73 (Theoretical) to .90 (Religious), and test-retest (over one-month) reliability coefficients ranging from .77 (Social) to .92 (Economic). Configural and test-retest stability of these themes for intellectually gifted participants 13 to 33 years of age can be found in Lubinski, Benbow, and Ryan (1995); SOV validity data can be found in Allport et al., (1970) and Dawis (1991).

Scholastic Aptitude Test

The SAT was designed as a college-entrance exam, to be taken by college-bound high school junior and senior to predict college performance. It consists of mathematical (SAT-M) and verbal (SAT-V) subtests. Scores for each subtest are standardized on a scale ranging from 200 to 800.

Background Questionnaire

This questionnaire was designed by SMPY and consists of 157 variables pertaining to attitudes, demographics, family background, and future plans, with particular emphasis placed on educational and vocational intentions. For the current study, 13 variables were included from the background questionnaire. They are: Mathematics and Science courses taken in the last year, ratings of academic subjects and school experience ("What do you like most/least about your school experience?" "List your three favorite courses in school", "What school experience has affected you educational/career plans the most?"), reading preferences ("How many books/ magazines have you read in the last 12 months, not including those required for school, in the following categories?": Science – fiction & non fiction, Plays/Poetry/Essays, Love Stories, Biographies, etc.), number of hours a week spent computer programming or watching television (broken down into specific types of television programs), possible future occupations, and questions about preferred extracurricular activities and hobbies (in particular, tinkering with gadgets).

Procedure

Subjects in the proposed study were drawn from data collected on intellectually gifted participants from SMPY's Cohort 4. All of the participants came to summer programs at ISU, sponsored by OPPTAG, in order to take high school or college courses at an accelerated pace. As part of their OPPTAG experience, participant completed tests and questionnaires for use in SMPY's ongoing longitudinal study. Prior to attending the summer programs, participants took the SAT at testing sites located in their local communities. The background questionnaires were mailed to participants' homes, completed there, and mailed back to ISU for scoring a few weeks before students arrived at ISU. The ability tests were administered at ISU under standardized mass-testing conditions (Lubinski & Benbow, 1994) – all within a 2 – 2.5-hour time frame.

The scores from three independent spatial ability measures (Cubes, BMCT, and MRT) were combined to form a spatial-visualization ability composite score for each of the study participants. Four experimental groups were used in the present study: Low spatial ability males, High spatial ability males, Low spatial ability females, and High spatial ability females. Subjects were identified and assigned to one of the four groups based on whether they scored in the top or bottom quartile by gender on their spatial-visualization ability composite scores. It is important to point out that the top and bottom quartiles were constructed separately for males and females due preliminary analysis revealing a low representation of females in the high spatial ability group when a gender-mixed sample was used. This is discussed further in the following chapter of this paper.

The high and low spatial ability male groups each consist of 165 males subjects. The High spatial ability male group consists of the males who scored in the top 25% of the males in original sample on their spatial composite score. Males in this group ranged in age from eleven to eighteen, with a mean age of 14.3 years old. The low spatial ability male group consists of the males who scored in the bottom 25% of the males in the original sample on their spatial composite score. The males in the low spatial ability group ranged in age from eleven to sixteen years old, with a mean age of 13.5. The low and high spatial ability female groups each consist of 114 subjects each. Females in the high spatial ability group (spatially gifted) represent the females scoring in the top quartile on their spatial ability composite. Spatially gifted females ranged in age from eleven to sixteen years old, with a mean age of 14.2 years. Finally, the low spatial ability female group consisted of the females scoring in the bottom quartile on the spatial ability composite score. These females ranged in age from eleven to sixteen years old, with a mean age of 13.7 years old. No information was collected about the ethnicity of the subjects.

The four experimental groups were compared on each of the dependent variables previously listed: mathematical ability, vocational interests and values, educational and vocational preferences, and involvement in a variety of extracurricular activities. In addition to comparing the four experimental groups, comparisons were made based on gender and level of spatial ability. One-way analysis of variance procedures were used to make group comparisons for non-categorical data. Chi-squared analysis and logistic regression procedures were used in the analysis of categorical data.

CHAPTER 4. RESULTS

Spatial Ability

As discussed in the previous chapter, the four experimental groups (high spatial ability males, high spatial ability females, low spatial ability males, and low spatial ability females) were created by using the top and bottom quartiles on the spatial ability composite score within gender groups versus the top and bottom quartiles of the entire sample. The decision to use groups based on the quartiles within genders was made because of the low representation of females in the high spatial ability group when a gender-mixed sample was used. Out of the 280 individuals identified as spatially gifted based on their spatial composite scores, only 56 (20%) were females. This low number of females did not provide an adequate sample of high spatial ability females to conduct comparison of the abilities, interests, values, and preferences of the four experimental groups.

Table 1 provides the mean spatial composite score and range for the High Spatial ability male, High Spatial ability female, Low Spatial ability male, and Low spatial ability female groups constructed using a gender-mixed sample and by using separate quartile cut-off scores for males and females. Consistent with the research by Feingold (1995) on the importance of differences in central tendency and variability in comparisons between groups, males were over-represented in the high spatial ability group (selected from a mixed-gender population) and had a higher mean score and a larger range of scores of the spatial ability composite as compared to females in the high spatial ability group.

Table 1. Mean spatial composite scores for the groups using a gender-mixed sample and for experimental groups.

	Mean Spatial Composite	Range of Scores
Groups from Gender-Mixed Sample		
Low Spatial Males (n= 108)	-1.01	(-2.34, -0.58)
High Spatial Males (n= 224)	1.01	(0.59, 1.94)
Low Spatial Females (n= 172)	-1.13	(-2.24, -0.59)
High Spatial Females (n= 56)	0.89	(0.60, 1.51)
Experimental Group (quartiles by gender)		
Low Spatial Males (n= 165)	-0.81	(-2.34, -0.31)
High Spatial Males (n= 165)	1.13	(0.78, 1.94)
Low Spatial Females (n= 114)	-1.33	(-2.24, -0.88)
High Spatial Females (n= 114)	0.66	(0.29, 1.51)

Mathematical Ability

Analysis of variance procedures were used to investigate possible differences in mathematical ability between males and females and high versus low spatial ability individuals. The dependent variable, mathematical ability, was measured by participants' SAT-I Mathematics subtest scores. Mean SAT-M scores and standard deviations for each of the groups can be found in Table 2. Table 3 provides a summary of the analysis of variance results. A significant main effect for gender was found favoring males ($F = 3.93$, $df = 1$, $p = 0.05$). The mean SAT-M score for males was 536.34 versus 499.86 for females.

Table 2. Mean SAT-Mathematical scores for the four experimental groups

	Mean SAT-M	Standard Deviation
Experimental Group		
Low Spatial Males (n= 48)	486.88	103.08
High Spatial Males (n= 76)	567.58	112.47
Low Spatial Females (n= 34)	447.65	105.89
High Spatial Females (n= 40)	544.25	96.87
Gender		
Males (n = 124)	536.94	115.46
Females (n = 74)	499.86	111.50
Spatial Group		
High Spatial Ability (n = 116)	559.53	107.50
Low Spatial Ability (n = 82)	470.61	105.41

A significant main effect was also found for spatial ability, favoring spatially gifted individuals ($F = 31.59$, $df = 1$, $p < 0.01$). On average, high spatial ability individuals scored approximately 90 points higher on the SAT-M subtest than peers in the low spatial ability group. The mean SAT-M score for the high spatial ability individuals was 559.53 compared to a mean SAT-M score of 470.61 for individuals in the low spatial ability group.

While the gender by spatial ability interaction was not significant, differences in mathematical ability were found between the spatial ability groups within gender. These differences followed the predicted pattern, with spatial ability being an important predictor of mathematical ability (spatial ability and mathematical ability were correlated at $r = .39$). SAT-M scores for high spatial ability males (males in the top quartile of spatial composite

Table 3. Summary of the analysis of variance for SAT-M group comparisons and post hoc tests for hypothesized relationships.

Analysis of Variance

	Sum of Squares	df	Mean Square	F	Significance
Corrected Model	424773.97	3	141591.32	12.58	.00
Intercept	47368899.10	1	47368899.10	4207.54	.00
Spatial Ability	355618.42	1	355618.42	31.59	.00
Gender	44267.33	1	44267.33	3.93	.05
Spatial X Gender	2859.38	1	2859.38	0.25	.62
Error	2184071.04	194	11258.10		
Total	56706936.00	198			
Corrected Total	2608845.01	197			

scores) were significantly higher than the SAT-M scores for the males in the low spatial ability group ($t = 4.13$, $p = .00$). With 95% confidence, we would expect the population mean for males in the high spatial ability group on the SAT-M to be between 30.45 and 130.96 points higher than the population mean for males in the low spatial ability. A similar pattern was found between high spatial ability females and low spatial ability females. With 95% confidence, females in the high spatial ability group would be expected to score between 33.02 to 160.19 points higher on the SAT-M than females in the low spatial ability group. As predicted, there was a tendency for high spatial ability males to score higher than high spatial ability females on the SAT-M, but this difference in scores was not statistically significant. Similarly, females in the high spatial ability group tended to score higher than males in the low spatial ability group, but this difference was not significant.

Vocational Interests and Values

Occupational Interests

The Strong Interest Inventory (Research Version of SCII, 1985) and the Study of Values (Allport, Vernon, & Lindzey, 1970) were used to measure the vocational interests and values of participants in the present study. It was hypothesized that there would be differences in both vocational interests and values based on level of spatial ability and gender. Table 4 provides a summary of the mean score of the experimental groups on the General Occupational Themes scales of the Strong Interest Inventory. In addition, the mean scores on the General Occupational Themes are also provided by gender and by spatial ability group (high versus low). An analysis of variance was done to compare the mean values by gender and level of spatial ability. Statistically significant differences in the mean scores of the experimental groups were found on all of the General Occupational Themes with the exception of the Conventional Scale.

Table 5 summarized the analysis of variance and post hoc test results. For the Realistic scale, a significant main effect was found for spatial ability ($F = 14.39$, $df = 1$, $p < .01$). Individuals identified as having high spatial ability scored higher than individuals in the low spatial ability, regardless of gender (for males: $t = 2.81$, $p = .03$; for females: $t = 2.61$, $p = .05$). With 95% confidence, we would expect high spatial ability males to score 0.24 to 5.49 points higher than low spatial ability males on the Realistic scale and high spatial ability females to score up to 6.38 points higher than low spatial ability females on the Realistic scale. A significant main effect was also found for gender ($F = 35.39$, $df = 1$, $p < .01$), favoring males.

Table 4. Mean General Occupational Theme Scores[a] and standard deviations of the four experimental groups.

	R	I	A	S	E	C
Experimental Group						
Low Spatial Males (n=134)	47.25 (9.16)	53.54 (8.53)	44.57 (10.39)	42.41 (10.05)	44. (9.52)	47.41 (9.57)
High Spatial Males (n=143)	50.12 (9.21)	53.48 (7.98)	43.80 (9.56)	38.67 (9.30)	42.66 (8.97)	48.17 (10.01)
Low Spatial Females (n=98)	42.32 (7.18)	50.91 (9.36)	54.50 (8.95)	50.87 (9.57)	47.80 (10.06)	48.14 (10.16)
High Spatial Females (n=93)	45.53 (7.67)	55.17 (7.45)	55.35 (8.80)	49.04 (9.97)	44.72 (8.78)	46.60 (7.76)
Gender						
Males (n=277)	48.73 (9.28)	53.51 (8.24)	44.17 (9.96)	40.38 (9.81)	43.74 (9.29)	47.81 (9.79)
Females (n=191)	43.88 (7.58)	52.98 (8.73)	54.92 (8.86)	49.98 (9.78)	46.30 (9.56)	47.39 (9.08)
Spatial Group						
High Spatial Ability (n=236)	48.31 (8.91)	54.14 (7.80)	48.35 (10.84)	42.76 (10.81)	43.47 (8.93)	47.56 (9.20)
Low Spatial Ability (n=232)	45.17 (8.72)	52.43 (8.97)	48.76 (10.95)	45.87 (10.72)	46.13 (9.84)	47.72 (9.81)

[a] There are Six General Occupational Themes on the Strong: Realistic (R), Investigative (I), Artistic (A), Social (S), Enterprising (E), and Conventional (C)

Table 5. Analysis of Variance of Strong Interest Inventory group comparisons and post hoc tests for hypothesized relationships.

	Sum of Squares	df	Mean Square	F	Significance
Realistic Scale					
Spatial Ability	1042.41	1	1042.41	14.39	.000
Gender	2564.34	1	2564.34	35.39	.000
Spatial X Gender	3.37	1	3.37	.05	.829
Error	33620.73	464	72.46		
Corrected Total	37343.25	467			
Investigative Scale					
Spatial Ability	498.63	1	1042.41	7.16	.008
Gender	24.56	1	24.56	0.35	.008
Spatial X Gender	528.39	1	528.39	7.59	.553
Error	32318.40	464	69.65		
Corrected Total	33216.90	467			
Artistic Scale					
Spatial Ability	0.20	1	0.20	0.00	.962
Gender	13041.75	1	13041.75	143.34	.000
Spatial X Gender	74.55	1	74.55	0.82	.366
Error	42217.81	464	90.99		
Corrected Total	55349.56	467			

Table 5. (continued)

	Sum of Squares	df	Mean Square	F	Significance
Social Scale					
Spatial Ability	811.88	1	811.88	8.62	.003
Gender	10226.45	1	10226.45	108.54	.000
Spatial X Gender	82.89	1	82.89	0.88	.349
Error	43718.81	464	94.22		
Corrected Total	55154.12	467			
Enterprising Scale					
Spatial Ability	799.56	1	799.56	9.19	.003
Gender	693.60	1	693.60	7.97	.005
Spatial X Gender	19.45	1	19.45	0.22	.637
Error	40386.60	464	87.04		
Corrected Total	41924.63	467			
Conventional Scale					
Spatial Ability	17.02	1	17.02	0.19	.665
Gender	19.94	1	19.94	0.22	.639
Spatial X Gender	150.04	1	150.04	1.66	.198
Error	41957.33	464	90.43		
Corrected Total	42130.25	467			

Table 5. (continued)

Post Hoc Tests

	Mean difference	Std. Error	Sig.	95% Confidence Interval (lower bound, upper bound)
<u>Realistic</u>				
Low versus High Males	-2.87	1.02	.026	(-5.49, -0.24)
Low versus High Females	-3.21	1.23	.045	(-6.38, -4.48 E-02)
High Males vs. Low Females	7.80	1.12	.000	(4.93, 10.67)
High Males vs. High Females	4.59	1.13	.000	(1.68, 7.51)
Low Males vs. Low Females	4.94	1.13	.000	(2.03, 7.84)
<u>Investigative</u>				
Low versus High Females	-4.26	1.21	.002	(-7.37, -1.16)
<u>Artistic</u>				
Low Males vs. Low Females	-9.93	1.27	.000	(-13.19, -6.68)
Low Males vs. High Females	10.79	1.29	.000	(-14.10, -7.48)
Low Females vs. High Males	10.70	1.25	.000	(7.49, 13.92)
High Females vs. High Males	11.56	1.27	.000	(8.29, 14.82)
<u>Social</u>				
Low versus High Males	3.54	1.17	.013	(0.54, 6.54)
Low Males vs. Low Females	-8.66	1.29	.000	(-11.97, -5.34)
Low Males vs. High Females	-6.83	1.31	.000	(-10.20, -3.47)
Low Females vs. High Males	12.20	1.27	.000	(8.934, 15.47)
High Females vs High Males	10.37	1.29	.000	(7.05, 13.69)
<u>Enterprising</u>				
Low Females vs. High Males	5.14	1.22	.000	(2.00, 8.28)

For the Investigative scales, a significant main effect for spatial ability ($F = 7.16$, $df = 1$, $p = .01$) and a significant gender by spatial ability interaction were found ($F = 7.59$, $df = 1$, $p = .01$). The mean Investigative scale score for individuals in the high spatial ability group was 54.32 compared to a mean Investigative scale score of 52.22 for individuals in the low spatial ability group. While the mean Investigative scale score was the same for males in the high and low spatial ability groups, females in the low spatial ability group scored significantly lower than females identified as being spatial gifted ($t = 3.52$, $p < .0001$).

On the Artistic scale, a significant main effect was found for gender ($F = 143.34$, $df = 1$, $p < .01$), with females having a higher mean on the Artistic scale of the Strong Interest inventory (54.92 versus 44.17) than males. No significant main effect was found for spatial ability. There were no statistically significant differences between the scores of females in the high versus low spatial ability group. Similar to the Artistic scales, a significant main effect for gender was found for the Social interest scale of the Strong ($F = 108.54$, $df = 1$, $p < .01$), with females scoring significantly higher than males on the social scale (see table 5). A significant main effect for spatial ability was found on the Social scale ($F = 8.62$, $df = 1$, $p = .01$), with low spatial ability individuals having higher Social scale scores versus high spatial ability peers. Lastly, significant main effects for gender ($F = 7.97$, $df = 1$, $p =.01$) and spatial ability ($F = 9.19$, $df = 1$, $p = .01$) were found for the Enterprising scale of the Strong Interest Inventory. Low spatial ability individuals had a higher mean Enterprising scale score than high spatial ability individuals (46.13 versus 43.47). Females also scored higher (46.30) on the Enterprising scale of the Strong compared to males (43.74).

It was hypothesized that males would have more narrowly defined vocational interests, while females would have more competing interests (Lubinski & Benbow, 1992).

This hypothesis was investigated using two methods. First, the standard deviation or amount of variation across the Strong Interest Inventory General Occupational Themes (GOT) for each subject was computed using the SPSS standard deviation function. Table 6 provides a list of the median standard deviations for the four experimental groups. The difference in the median standard deviations of the Strong General Occupational Themes subscales for the four experimental groups was not statistically significant, as determined by the Kruskal-Wallis one-way ANOVA test.

Table 6. Median standard deviations on the General Occupational Themes and the Kruskal-Wallis results.

		Median Standard Deviation	**Number**
Entire Population		8.262	955
Experimental Group			
Low Spatial Males		7.941	134
High Spatial Males		8.359	143
Low Spatial Females		7.867	98
High Spatial Females		8.432	93
Kruskal-Wallis Results			
Chi^2 = 2.9558	df = 3	Significance = .3985	

The second method for investigating the differences in vocational interests and differentiation of the profile was examined by calculating the total difference between each of the six General Occupation Theme scores and the individual's mean GOT score. A mean GOT score was calculated for each subject by summing each of his/her GOT scores and dividing by six. This mean score was then subtracted from each of the individual's GOT scores, resulting in six difference scores. The absolute values of the difference scores were added to provide a measure of the amount of intraindividual variation/differentiation in the profile. An analysis of variation revealed no significant differences in the amount of differentiation in the profiles of high and low spatial ability individuals and males and females, as found in the analysis using the standard deviation function. No support was found for the hypothesis that males would have more narrowly defined vocational interests compared to females. A possible explanation may have to do with the age of the participants in the study. Adolescents in the study are at an age where they should still be exploring different occupational interests and opportunities. They have not begun to circumscribe their interests and career choices.

Occupational Values

The Study of Values (Allport, Vernon, & Lindzey, 1970) is designed to measure the relative prominence of 6 basic values or motives in personality: Theoretical, Economic, Aesthetic, Social, Political, and Religious. The test consists of statement made up of two contrasting/alternative value statements. Students are asked to indicate the strength of their preference for the alternative answers by weighting each alternative. Because of the ipsative nature of this measure, statistical analysis involved comparing the most prominent or top-ranked values.

Chi-squared procedures were used to compare the percentage of subjects by gender, spatial ability, and gender by spatial ability who endorsed each value as their most prominent value. Statistically significant gender differences were found on the Theoretical, Economic, Aesthetic, and Social Values ($X^2 = 70.80$, df = 5, p = .00). A greater proportion of males (39.6%, n = 97) had Theoretical as their top value, compared to 17.7% (n = 33) females. In contrast, a greater proportion of females (32.3%, n = 60) endorsed the Aesthetic value as their top value, compare to 9.0% (n = 22) of males. As seen in Table 7, females were more equally distributed in their endorsement of Theoretical (17.7%), Social (15.6%), Political (16.1%), and Religious (14.0%) values versus males who were more variable ranging from 4.9% for social to 39.6% for Theoretical.

Table7 provides a summary of the proportions of individuals by gender, level of spatial ability, and experimental group for top-ranked values. There was significant differences in the proportion of high spatial ability versus low spatial ability subjects for endorsement of each of the SOV values as their top-ranked value ($X^2 = 20.07$, df = 5, $p < .0001$). Similar to the results for males, individuals in the high spatial ability group tended to endorse Theoretical as their top-ranked value (32.9%), compared to the other values and compared to individuals in the low spatial ability group (27.0%). For low spatial ability subjects, an equal proportion (27%, n = 54) of individuals had Theoretical or Political as their most prominent value. In comparison to high spatial ability individuals, a greater proportion of low spatial ability individuals had Political as their top-ranked value (27.0% versus 11.3%), while a greater proportion of individuals in the high spatial ability group (12.6%) versus individuals in the low spatial ability group (6.5%), endorsed Economic as their most prominent value.

Table 7. Percentage of subjects who had one of the Study of Value Themes as their top-ranked value by gender and spatial ability groups.

	Aesthestic	Economic	Political	Religious	Social	Theoretical
Gender						
Males	9.0 (n=22)	13.9 (n=34)	20.4 (n=50)	12.2 (n=30)	4.9 (n=12)	39.6 (n=97)
Females	32.3 (n=60)	4.3 (n=8)	16.1 (n=30)	14.4 (n=26)	15.6 (n=29)	17.7 (n=33)
Spatial Group						
High	19.9 (n=46)	12.6 (n=29)	11.3 (n=26)	13.9 (n=32)	9.5 (n=22)	32.9 (n=76)
Low	18.0 (n=36)	6.5 (n=13)	27.0 (n=54)	12.0 (n=24)	9.5 (n=19)	27.0 (n=54)
Experimental Group						
Low Males	9.7 (n=11)	8.0 (n=9)	28.3 (n=32)	11.5 (n=13)	7.1 (n=8)	35.4 (n=40)
High Males	8.3 (n=11)	18.9 (n=25)	13.6 (n=18)	12.9 (n=17)	3.0 (n=4)	43.2 (n=57)
Low Females	28.7 (n=25)	4.6 (n=4)	25.3 (n=22)	12.6 (n=11)	12.6 (n=11)	16.1 (n=14)
High Females	35.4 (n=35)	4.0 (n=4)	8.1 (n=8)	15.2 (n=15)	18.2 (n=18)	19.2 (n=19)

Educational and Vocational Preferences

Educational Preferences

The educational preferences of the four groups were assessed using open-ended questions about their educational experiences and preferences: (1) What do you like most about your school experience?, (2) What do you like least about your school experience?, and (3) What school experience has affected your educational/career plans the most? Responses to the most liked and least liked school experiences were coded into seven general themes: available courses, intellectual level of courses, size or student-teacher ratio of educational setting, teachers, athletics, social, and other. Lastly, students were asked to list in order of preference their three favorite courses in school.

No significant differences were found between the four groups in students' reports of their most liked school experience. The social aspects of school and available courses were the most highly endorsed by all four experimental groups. Chi-squared analysis of the responses of the four experimental groups to the question regarding what students liked least about their school experience revealed marginally significant ($X^2 = 31.294$, df = 21, p = .07) differences in responses. Table 8 provides a summary of the responses of the four experimental groups for both least liked school experience and the school experience that has most affected their educational/career plans. There was a tendency for females to endorse social aspects of school as their least liked part of their school experience compared to males. Available course, the intellectual level of the courses, and teachers were among the most common responses.

Table 8. Percentage (and number) of student responses to questions regarding school experiences.

What do you like least about school?

	Low Males	High Males	Low Females	High Females
Available Courses	12.8 (n = 19)	20.1 (n = 30)	18.6 (n = 18)	15.6(n = 17)
Intellectual Level	32.2 (48)	18.8 (28)	22.7 (22)	20.2 (22)
Class Size/Ratio	2.7 (4)	1.3 (2)	2.1 (2)	0
Teachers	11.4 (17)	16.8 (25)	13.4 (13)	18.3 (20)
Athletics	0	1.3 (2)	0	0.9 (1)
Social Life	9.4 (14)	8.7 (13)	17.5 (17)	18.3 (20)
Principal	2.0 (3)	0.7 (1)	0	0
Other	29.5 (44)	32.2 (48)	25.8 (25)	26.6 (29)

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

	Low Males	High Males	Low Females	High Females
Available Courses	59.8 (n = 70)	56.6 (n = 73)	45.1 (45)	52.1 (n = 50)
Intellectual Level	0.9 (1)	5.4 (7)	2.2 (2)	0
Class Size/Ratio	0	0	0	0
Teachers	9.4 (11)	5.4 (7)	14.3 (13)	9.4 (9)
Athletics	0	1.6 (2)	0	0
Social Life	0.9 (1)	0	2.2 (2)	2.1 (2)
Principal	0.9 (18)	0	0	0
Other	28.2 (33)	31.0 (40)	36.3 (33)	36.5 (35)

Responses to the question about what school experience has affected the educational and career plans of these students the most were coded into the following seven themes: available course, intellectual level of courses, teachers, athletics, social aspects of school, principal, and other. Chi-squared analysis revealed only marginally significant differences in the responses of the four experimental groups to this question ($X^2 = 27.75$, df = 18, p = .07). Table 8 provides a summary of the responses of the four experimental groups.

Academic Course Preferences

While no significant differences were found in participants' math and science course enrollment, significant gender differences were found between males and females for most preferred course ($X^2 = 73.99$, df = 13, p < .0001). Figure 1 provides a graph of the proportion of individuals by gender who endorsed a given course as their most preferred course. A greater proportion of males (39.9%, n = 127) versus females (24.4%, n = 55) chose mathematics as their favorite course. Courses in the physical sciences were second to courses in mathematics for males, with 26.4% (n = 86) of males versus 14.7% (n = 33) of females choosing physical science courses as their most preferred course. A greater proportion of females versus males selected courses in English (18.2% versus 5.5%) and Art/Music (17.3% versus 6.4%) as their most preferred course. While the number of individuals choosing a computer science course were low, males (particularly those identified as spatially gifted) were more likely to choose a computer science course as their most preferred course.

While not as prominent as the gender differences in preferred courses, there were significant differences between the course preferences of spatially gifted individuals and individuals in the low spatial ability group ($X^2 = 26.77$, df = 13, p = .01). Figure 2 provides a

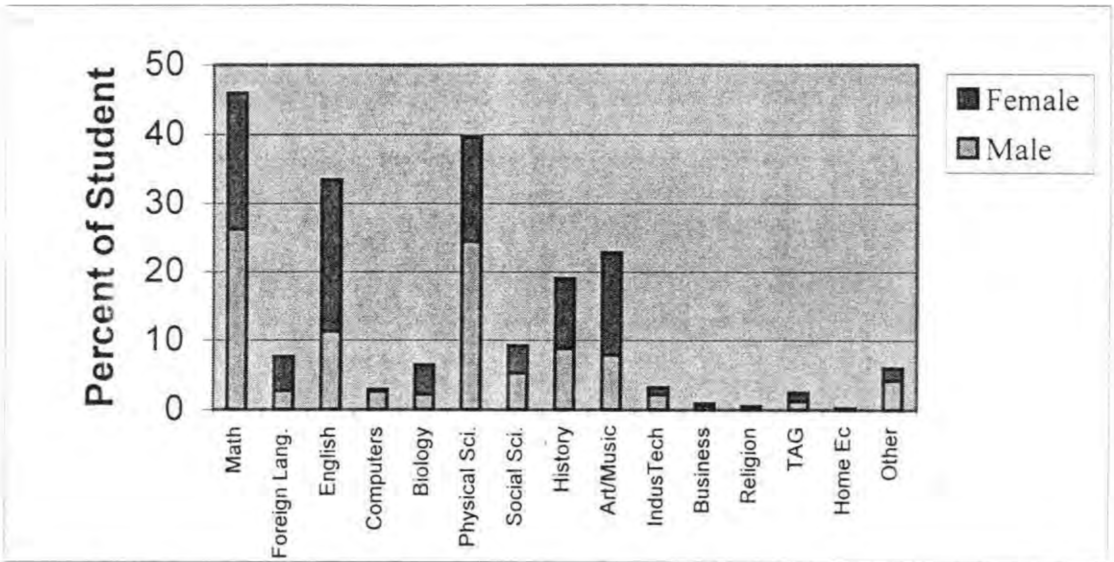

Figure 1. The percent of males versus females selecting a course as their most preferred.

graph of the proportion of individuals by spatial ability group who selected courses as their most liked or preferred. For both groups, courses in mathematics were the most likely to be selected as the most preferred course. A greater proportion of individuals in the low spatial ability group versus high spatial ability individuals selected a course in English (14.5% versus 6.9%, respectively) and History (9.1% versus 4.0%). For the spatially gifted, courses in Art/Music had the second highest proportion of students preferencing them (13.8%, n = 22).

Occupational Preferences

A great deal of studies have reported differences in the career choices of males and females, with females being less likely to preference or pursue educational studies and careers in the physical sciences and math (Callahan & Reis, 1996; Reis, Callahan, & Goldsmith, 1996). With this in mind, subjects in the current study were asked to list the three occupations they were "most interested in as possible careers." Occupational preferences were coded using an occupational classification system developed by Stevens and Hoisington (1987). Occupations were further grouped into 16 occupational groups: Management (e.g. business and administrative careers), Engineering, Math/Computer Science, Science (includes natural, physical, and medical scientists), Doctors (includes veterinarians), Health

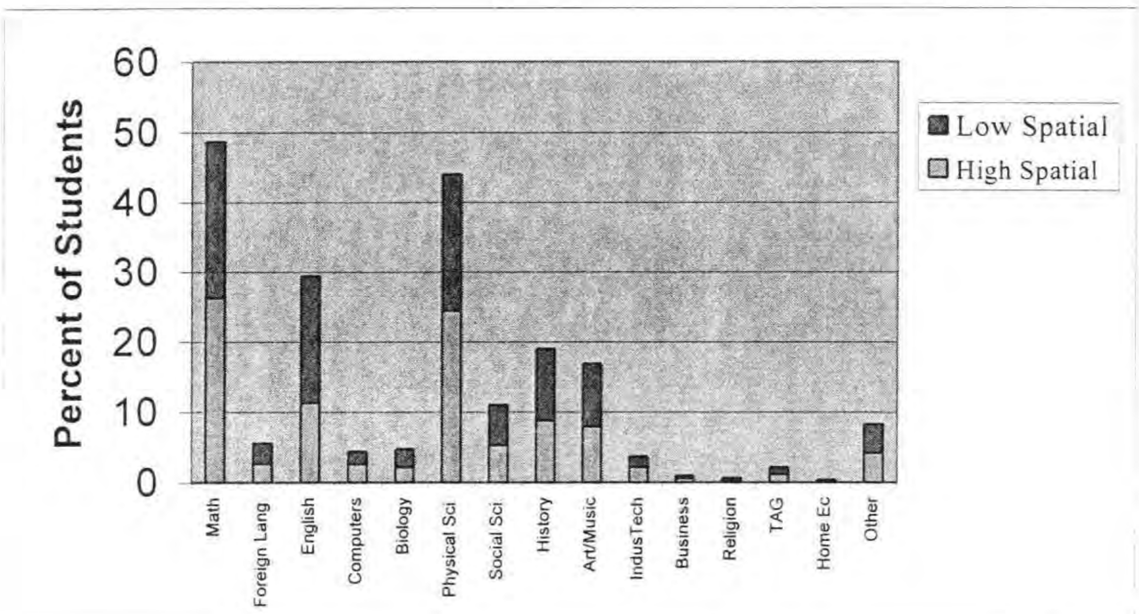

Figure 2. The percent of high versus low spatial ability individuals selecting a course as their most preferred.

(non-doctoral medical workers), Professors (post-secondary educators), Teachers (Pre-kindergarten through twelfth grade), Social Sciences (e.g. counselors, social workers), Law (e.g. lawyers, judges), Entertainment (e.g. writers, artists, athletes, entertainers), Technicians (non-medical jobs), Sales, Office work (e.g. secretaries, administrative support), Homemakers, and Students.

Significant differences in the occupational preferences of males versus females were found ($X^2 = 69.4$, df = 12, $p < .01$). Figure 3 is a graph of the percent of males versus females who preferenced a career in one of the 13 occupational groups. Consistent with the literature, males versus females were more likely to preference careers in math/computer science (17.2% vs. 3.8%) and engineering (26.7% vs. 8.2%). In contrast, females were more likely to endorse careers in medicine, which was the top career choice for females (24.5%), and the entertainment industry (15.8%). Females versus males were also more likely to preference career in education (6.5% vs. 0.4%), law (9.8% vs.3.9%), and the social sciences (6.0% vs, 1.7%).

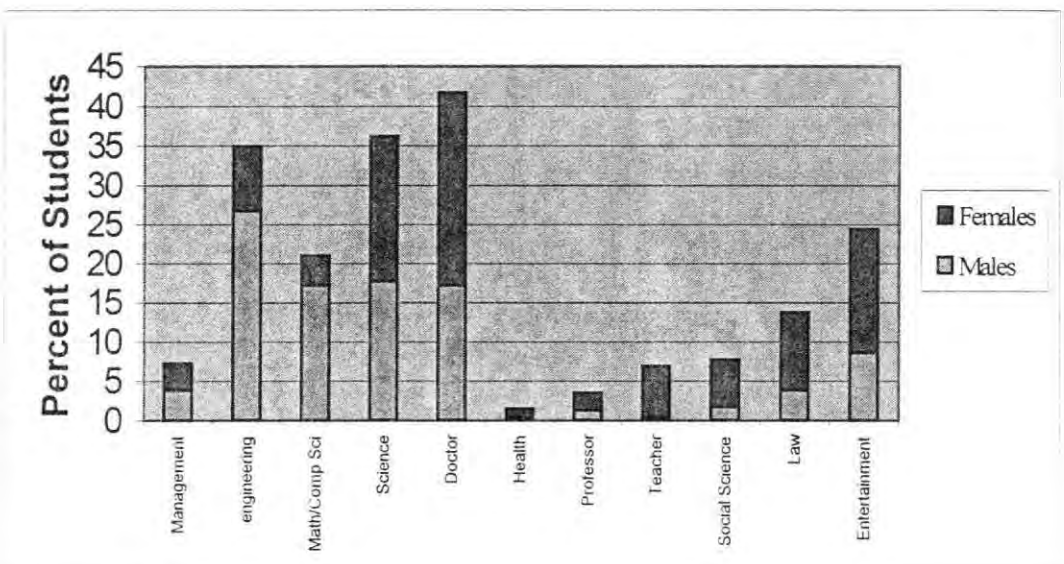

Figure 3. Percent of males versus females for most preferred occupation

Significant differences in occupational preferences were also found between individuals identified as spatially gifted and individuals in the low spatial ability group ($X^2 = 36.87$, df = 12, $p <.01$). Figure 4 provides a graph of the percent of subjects in each of the spatial ability groups who preferenced careers in the 13 occupational groups. Most striking were the differences in engineering, math/computer science, and medical career. 23.9% of high spatial ability subjects, compared to 13.5% of low spatial ability subjects chose a career in engineering as their top choice of a possible occupation. Similarly, more individuals identified as spatially gifted preferenced careers in math and computer science (15.9%) as their first choice versus individuals in the low spatial ability group (7.0%). Significant differences were not found between the high and low spatial ability groups for science careers, with 16.7% of low spatial ability individual versus 19.4% of high spatial ability individual selecting a possible career in the natural, physical, or medical sciences. In contrast, individuals in the low spatial ability group were more likely to choose a career as a doctor as their top career choice versus individuals in the high spatial ability group (27.0% vs. 13.4%, respectively). They were also slightly more likely to choose occupations in the entertainment industry (14.4% vs. 9.0%).

Extracurricular Activities

A number of different variables were used to assess the extracurricular activities of spatially gifted females and males. Students were asked directly about their extracurricular activities, reading preferences, television/computer/videogame use, and participation in activities involving "tinkering." Students were asked to list the three extracurricular activities they had been most involved in since fourth grade. Student responses were coded into the following themes: arts, athletics, clubs/organizations/research, contests/competitions/clinics, gifted programs, religious activities, community services, and other. Statistically significant differences in the extracurricular activities of males and females were revealed using Chi-squared analysis ($X^2 = 48.92$, df = 7, $p < .0001$). Figure 5 provides a summary of the percentage of males and females who reported their involvement

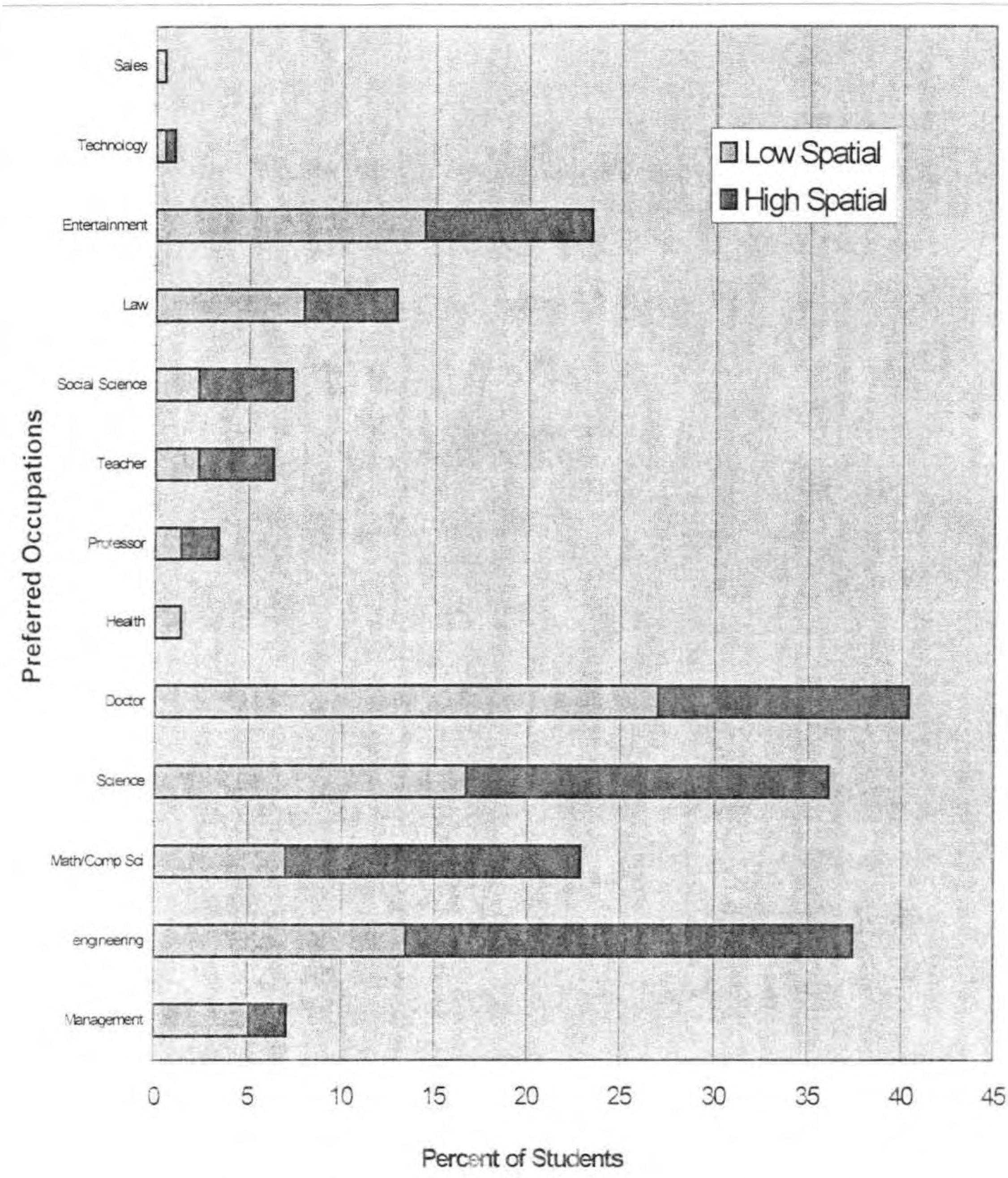

Figure 4. Percent of high versus low spatial ability individuals for most preferred occupation.

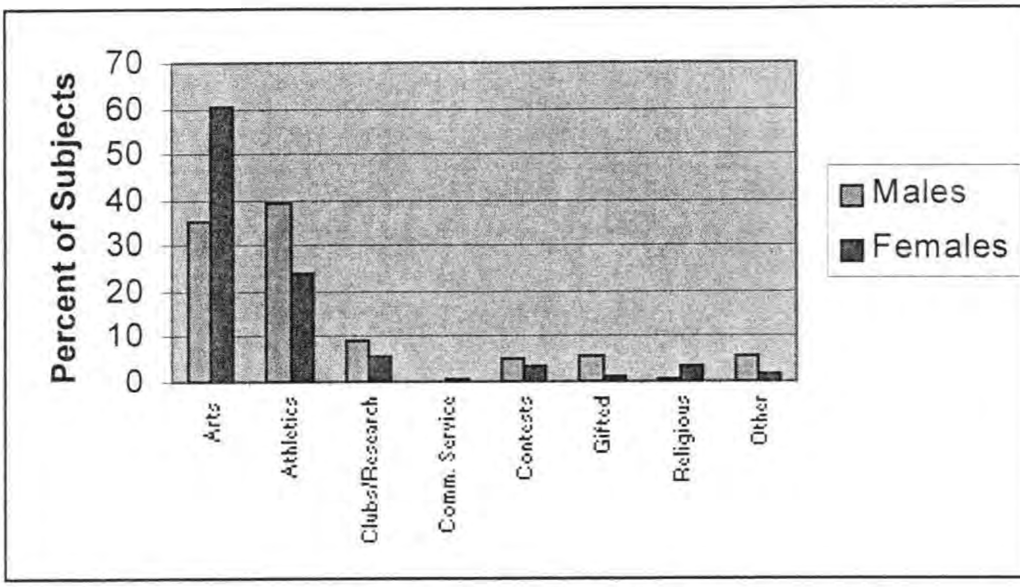

Figure 5. Percent of males versus females reporting involvement in extra-curricular activities.

in a variety of extracurricular activities. For both males and females, extracurricular activities involving arts and athletics were the most highly endorsed. A greater proportion of females (60.5%, n = 133) reported involvement in art-related extracurricular activities versus males (35.1%, n = 107). Athletics were the most highly endorsed extracurricular activity for males, with 39.3% of males versus 24.1 % of females who reported involvement in athletic activities. No statistical differences were found in the extracurricular activities of low versus high spatial ability students.

Table 9 provides a summary of the percentage of individuals in each of the extracurricular activities by experimental groups. There were statistically significant differences in the extracurricular activities of the four experimental groups ($X^2 = 60.41$, df = 21, $p < .0001$). A greater proportion of males and females in the high spatial ability groups reported involvement in art-related activities compared to males and females in the low

Table 9. Percentage (and number) of students involved in extracurricular activities.

Extracurricular Activities

	Low Males	**High Males**	**Low Females**	**High Females**
Arts	34.4 (n = 52)	35.7 (n = 55)	54.5 (n = 60)	66.4 (n = 73)
Athletics	43.7 (66)	35.1 (54)	29.1 (32)	19.1 (22)
Clubs/Research	7.9 (12)	9.7 (15)	4.5 (5)	6.4 (7)
Community Service	0	0	0.9 (1)	0
Contests/Clinics	4.6 (7)	5.8 (9)	3.6 (4)	2.7 (3)
Gifted Programs	5.3 (8)	5.8 (9)	1.8 (2)	0.9 (1)
Religious	0	0.6 (1)	2.7 (3)	3.6 (4)
Other	4.0 (6)	7.1 (11)	2.7 (3)	0.9 (1)

spatial ability groups. Art-related activities were the most highly endorsed extracurricular activities for spatially gifted groups, with 54.5% of high spatial ability males and 66.4% of high spatial ability males reporting involvement. In contrast, athletic activities were more highly endorsed by both the low spatial ability males (43.7%) and low spatial ability females (35.1%).

Reading Preferences

Students were also asked how many books or magazines they had read in each of the following groups/genres in the past 12 months: Western/Adventure/Mystery books, Science Fiction book, Science-non-fiction, Literature/Classics, Historical/Autobiographical books, Religious books, Comic books, and Romance novels. Required readings for school were not included in these counts. An analysis of variance (Table 10) revealed significant differences

Table 10. Analysis of Variance for number of books read per year by males versus females by genre.

	Sum of Squares	df	Mean Square	F	Significance
Western/Adventure/Mystery					
Between Groups	8994.42	1	8994.42	23.41	.000
Within Groups	205558.21	535	384.22		
Total	214552.63	536			
Science Fiction					
Between Groups	941.92	3	941.92	2.87	.091
Within Groups	173045.21	527	328.36		
Total	173987.13	528			
Science - Non Fiction					
Between Groups	679.15	1	679.15	6.68	.010
Within Groups	53316.52	524	101.75		
Total	53995.67	525			
Literature/Classics					
Between Groups	4143.81	1	4143.81	34.21	.000
Within Groups	63594.35	525	121.13		
Total	67738.16	526			

Table 10. (continued)

	Sum of Squares	df	Mean Square	F	Significance
Political/Biographies					
Between Groups	987.95	1	987.95	4.64	.032
Within Groups	110298.45	518	212.93		
Total	111286.30	519			
Religious					
Between Groups	294.64	1	294.64	8.01	.005
Within Groups	19014.87	517	36.78		
Total	19309.51	518			
Comic Books					
Between Groups	8479.06	1	8479.06	26.17	.000
Within Groups	169100.17	522	323.95		
Total	177579.23	523			
Romance Novels					
Between Groups	6278.31	1	6278.31	49.87	.000
Within Groups	63830.67	507	90.43		
Total	70108.98	508			

in the numbers of books read by males versus females in seven of the eight genres. Females, in comparison to males, read significantly more western/adventure/mystery books (16.72 vs 8.40, $p < .0001$), literature/classics (9.20 versus 3.51, $p < .0001$), historical/autobiographical books (8.46 vs. 5.65, $p = .03$), religious books (2.87 vs. 1.34, $p = .01$) and romance novels ((7.75 vs. 0.63, p<. 0001). In contrast, males read more comic books (10.18 vs. 1.98, $p < .0001$) and science/non-fiction books (5.50 vs. 3.19, $p = .01$) per year than females. While not statistically significant, there was a tendency for males to read more science fiction books per year compared to females.

Table 11 provides the analysis of variance results for the number of books read per year by spatial ability group. Significant differences were found in the number of western/adventure/mystery novels and literary books read by individuals in the high versus low spatial ability groups. Individuals in the low spatial ability group read significantly more western/adventure/mystery books (14.41 vs. 9.22) and literary classics (6.99 vs 4.72) compared to individuals identified as being spatially gifted. While not statistically significant, there was a tendency for low spatial ability individuals to read more romance novels than high spatial ability individuals (4.59 versus 2.71, $p = .057$). The high spatial ability group were also more likely to read more science fiction versus their peers in the low spatial ability group (12.57 vs. 9.85), but this difference was not statistically significant.

In examining the number of books read per year by the students in the four experimental groups, an analysis of variance (Table 12) revealed significant differences in the number of books read in the following genres: western/adventure/mystery, classics/literature, religious, comic books, and romance. Post hoc tests (using Tukey HSD) were used for multiple comparisons and are also included in Table 12. For

Table 11. Analysis of Variance for number of books read per year by high versus low spatial ability subjects by genre.

	Sum of Squares	df	Mean Square	F	Significance
Western/Adventure/Mystery					
Between Groups	3617.72	1	3617.72	9.18	.003
Within Groups	210934.91	535	394.27		
Total	214552.63	536			
Science Fiction					
Between Groups	975.09	1	975.09	2.97	.085
Within Groups	173012.03	527	328.30		
Total	173987.13	528			
Science - Non Fiction					
Between Groups	15.02	1	15.02	.15	.703
Within Groups	53980.65	524	103.02		
Total	53995.67	525			
Literature/Classics					
Between Groups	664.71	1	664.71	5.20	.023
Within Groups	67073.45	525	127.76		
Total	67738.16	526			

Table 11. (continued)

	Sum of Squares	df	Mean Square	F	Significance
Political/Biographies					
Between Groups	151.21	1	151.21	0.71	.402
Within Groups	111135.18	518	214.55		
Total	111286.39	519			
Religious					
Between Groups	66.73	1	66.73	1.79	.181
Within Groups	19242.78	517	37.22		
Total	19309.51	518			
Comic Books					
Between Groups	155.24	1	155.24	0.46	.499
Within Groups	177423.99	522	323.95		
Total	177579.23	523			
Romance Novels					
Between Groups	500.58	1	500.58	3.65	.057
Within Groups	69608.40	507	137.30		
Total	70108.98	508			

western/adventure/mystery books, low spatial ability females read the most books on average per year compared to high spatial ability females ($t = 2.65$, $p = .04$), compared to low spatial ability males ($t = 4.07$, $p <.0001$), and compared to high spatial ability males ($t = 71$, $p < .0001$). With 95% confidence, females in the high spatial ability group would be expected to read .60 to 12.99 more western/adventure/mystery books than males in the high spatial ability group.

A similar pattern emerged for the low spatial ability females compare to the other three groups on literature books and romance novels. Low spatial ability females read more books from the literature genre than low spatial ability males ($t = 4.85$, $p <.01$) and high spatial ability males ($t = 5.95$, $p < .01$). While there was a tendency for females in the low spatial ability group to read more literature books than spatially gifted females, this difference was not statistically different. For romance novels, low spatial ability females read significantly more books per year than low spatial ability males ($t = 6.03$, $p < .01$) and high spatial ability males ($t = 6.54$, $p < .01$). There was a tendency for low spatial ability females to read more romance novels per year than females in the high spatial ability group, but this difference was not statistically significant.

Consistent with the findings for differences in number of comic books read by gender and spatial ability considered separately, both high and low spatial ability males read more comic books than both females groups. With 95% confidence, the males in the high spatial ability group would be expected to read 1.41 to 13.25 more comic books per year than high spatial ability females. Similarly, high spatial ability males read more comic books per year than low spatial ability females ($t = 3.99$, $p <.01$) and high spatial ability females ($t = 4.03$, $p <.01$).

Table 12. Analysis of Variance and post hoc test results for number of books read per year by the experimental groups

	Sum of Squares	df	Mean Square	F	Significance
Western/Adventure/Mystery					
Between Groups	12994.43	3	4298.14	11.36	.000
Within Groups	201658.20	533	378.35		
Total	214552.63	536			
Science Fiction					
Between Groups	1951.75	3	650.58	1.99	.115
Within Groups	172035.38	525	327.67		
Total	173987.13	528			
Science - Non Fiction					
Between Groups	743.47	3	247.83	2.43	.065
Within Groups	53252.20	522	102.02		
Total	53995.67	525			
Literature/Classics					
Between Groups	4967.19	3	1655.73	13.80	.000
Within Groups	62770.97	523	120.02		
Total	67738.16	526			

Table 12. (continued)

	Sum of Squares	df	Mean Square	F	Significance
Political/Biographies					
Between Groups	1224.91	3	408.30	1.91	.126
Within Groups	110061.49	516	213.30		
Total	111286.40	519			
Religious					
Between Groups	362.41	3	120.80	3.28	.021
Within Groups	18947.10	515	36.79		
Total	19309.51	518			
Comic Books					
Between Groups	8725.00	3	2908.33	8.96	.000
Within Groups	168854.23	520	324.72		
Total	177579.23	523			
Romance Novels					
Between Groups	6998.17	3	2332.72	18.67	.000
Within Groups	63110.81	505	124.97		
Total	70108.98	508			

Table 12. (continued)

Post Hoc Tests

	Mean difference	Std. Error	Sig.	95% Confidence Interval (lower bound, upper bound)
Western/Adventure/Mystery				
Low Males vs. Low Females	-9.84	2.415	.000	(-16.04, -3.63)
High Males vs. Low Females	-13.77	2.412	.000	(-19.97, -7.57)
Low vs. High Females	6.97	2.623	.039	(0.23, 13.71)
High Females vs. High Males	6.80	2.412	.025	(0.60, 12.99)
Science Fiction				
High Males vs. Low Females	5.32	2.263	.087	(-0.50, 11.13)
Literature/Classics				
Low Females vs. Low Males	6.67	1.375	.000	(3.14, 10.20)
Low Females vs. High Males	8.22	1.381	.000	(4.67, 11.77)
High Females vs. High Males	4.80	1.366	.003	(1.29, 8.31)
Religious				
Low Males vs. High Males	-2.26	.764	.016	(-4.23, -.30)
Comic Books				
Low Males vs. Low Females	7.24	2.271	.008	(1.41, 13.08)
Low Males vs. High Females	7.39	2.284	.007	(1.52, 13.25)
High Males vs. Low Females	9.01	2.260	.000	(3.20, 14.81)
High Males vs. High Females	9.15	2.273	.000	(3.31, 14.99)
Romance Novels				
Low Females vs. Low Males	8.50	1.409	.000	(4.88, 12.12)
Low Females vs. High Males	9.24	1.413	.000	(5.61, 12.87)
High Females vs. Low Males	4.92	1.428	.003	(1.25, 8.59)
High Females vs. High Males	5.66	1.432	.000	(1.98, 9.34)

Computer and Television Use

Students were also asked how many hours they spent per week computer programming, playing video games and watching television. Television watching was further divided into the following types of programs: cartoons, documentaries/educational programs, movies, news, and sitcoms. In general, females reported spending less time per week watching television, playing video games, or computer programming. An analysis of variance (Table 13) revealed significant gender differences in the number of hours per week spent programming, playing video games, and watching cartoons and educational programs on television. Males on average spent significantly more hours per week than females computer programming (5.41 vs. 1.94, $p < .01$) and playing video games (2.37 vs. .37, $p < .01$). Males also reported watching significantly more hours of cartoons (2.03 vs. 1.11, $p < .01$) and educational programs (w.94 vs. 1.24, $p < .01$) on television than females. No significant differences were found between individuals identified as being spatially gifted and individuals in the low spatial ability group from time spent per week programming, playing games, or watching television. There was a tendency for individuals in low spatial ability group to watch more hours of educational programs (1.85 hours/week) versus individuals in the high spatial ability group (1.59 hours/week), but this difference was not statistically significant.

Table 14 provides the results from the analysis of variance for hours spent watching television and computer programming for the four experimental groups, along with the Tukey post hoc comparisons. Similar to the results for gender differences, the four experimental groups differed in the hours per week spent computer programming , playing video games, and watching cartoons and educational programs. With 95% confidence, males

Table 13. Analysis of variance for number of hours per week of television or computer use by males versus females.

	Sum of Squares	df	Mean Square	F	Significance
Computer Programming					
Between Groups	1527.62	1	1527.62	50.58	.000
Within Groups	15765.36	522	30.20		
Total	17292.98	523			
Cartoons					
Between Groups	107.96	1	107.96	14.50	.000
Within Groups	3962.33	532	7.45		
Total	4070.29	533			
Educational/Documentaries					
Between Groups	59.58	1	59.58	11.69	.001
Within Groups	2695.40	529	5.10		
Total	2754.98	530			
Movies					
Between Groups	20.46	1	20.46	1.85	.174
Within Groups	5937.92	537	11.06		
Total	5958.38	538			

Table 13. (continued)

	Sum of Squares	df	Mean Square	F	Significance
News					
Between Groups	9.16	1	9.16	1.49	.223
Within Groups	3335.31	543	6.14		
Total	3344.47	544			
Sitcoms					
Between Groups	0.52	1	0.52	0.03	.864
Within Groups	9551.13	543	17.59		
Total	9551.65	544			
Video Games					
Between Groups	499.46	1	499.46	49.08	.000
Within Groups	5312.18	522	10.18		
Total	5811.64	523			

Table 14. Analysis of variance and post hoc test results for hours per week of television or computer us by experimental groups.

	Sum of Squares	df	Mean Square	F	Significance
Computer Programming					
Between Groups	1631.23	3	543.74	18.05	.000
Within Groups	15661.75	520	30.12		
Total	17292.98	523			
Cartoons					
Between Groups	124.56	3	41.52	5.58	.001
Within Groups	3945.73	530	7.45		
Total	4070.29	533			
Educational/Documentaries					
Between Groups	88.40	3	29.47	5.82	.001
Within Groups	2666.58	527	5.06		
Total	2754.98	530			
Movies					
Between Groups	27.10	3	9.03	0.82	.486
Within Groups	5931.28	535	11.09		
Total	5958.38	538			

Table 14. (continued)

	Sum of Squares	df	Mean Square	F	Significance
News					
Between Groups	16.03	3	5.34	0.87	.457
Within Groups	3328.43	541	6.15		
Total	3344.46	544			
Sitcoms					
Between Groups	31.11	3	10.37	0.59	.622
Within Groups	9520.53	541	17.60		
Total	9551.64	544			
Video Games					
Between Groups	511.68	3	170.56	16.73	.000
Within Groups	5299.95	520	10.19		
Total	5811.63	523			

Table 14. (continued)

Post Hoc Tests	Mean difference	Std. Error	Sig.	95% Confidence Interval (lower bound, upper bound)
Computer Programming				
Low Males vs. Low Females	2.58	0.690	.001	(0.81, 4.36)
Low Males vs. High Females	3.47	0.690	.000	(1.70, 5.24)
High Males vs. Low Females	3.47	0.690	.000	(1.70, 5.25)
High Males vs. High Females	4.36	0.690	.000	(2.59, 6.13)
Cartoons				
Low Males vs. Low Females	1.25	0.342	.001	(0.37, 2.13)
Low Males vs. High Females	0.99	0.338	.019	(0.12, 1.85)
High Males vs. Low Females	5.32	2.263	.087	(2.59, 6.13)
Educational/Documentaries				
Low Males vs. Low Females	0.96	0.283	.004	(0.23, 1.68)
Low Males vs. High Females	1.02	0.280	.002	(0.30, 1.74)
Video Games				
Low Males vs. Low Females	2.24	0.403	.000	(1.21, 3.28)
Low Males vs. High Females	2.13	0.404	.000	(1.10, 3.17)
High Males vs. Low Females	1.86	0.403	.000	(0.82, 2.90)
High Males vs. High Females	1.75	0.404	.000	(0.71, 2.79)

in the low spatial ability group would be expected to spend .81 to 4.36 hours per week more than low spatial ability females and 1.70 to 5.24 hours per week more than high spatial ability females on computer-related activities.

Involvement in "Tinkering" Activities

Finally, "tinkering" with equipment, mechanical gadgets, or construction games has been hypothesized to be an activity in which individuals with strong spatial abilities and interests in engineering excel at and enjoy. In looking at the field of engineering and the employment patterns of female engineers, Robinson and McIlwee (1989) suggested that females tend to choose careers in electrical engineering over those in mechanical engineering because they associate mechanical engineering with "tinkering." Subjects were asked to rate the extent to which they were (as a young child) and are currently involved in "tinkering" activities. Subjects rated involvement with tinkering on a 5-point scale (1 being not involved to 5 being very involved). Comparisons by gender, level of spatial ability, and experimental group were made for subjects' rating of "tinkering" involvement currently and as a young child.. Table 15 provides a summary of the percentage of individuals by gender and spatial ability who rated themselves on each level of tinkering involvement.

Analysis using Chi-squared procedures revealed statistically significant differences in current and childhood tinkering involvement for males versus females and high versus low spatial ability levels. 36.1% of males versus 8.9% of females reported high involvement in tinkering as a child ($X^2 = 64.41$, df = 4, $p < .01$). 28.3% of males versus 5.9% of females reported high involvement in current tinkering activities ($X^2 = 90.19$, df = 4, $p < .01$). Similarly, 30.1% of individuals identified as being spatially gifted versus 20.3% individuals

Table 15. Involvement in tinkering activities as a child and currently by gender and spatial ability groups (percentage and number of people in each group).

Tinkering As A Child Level of Involvement	**Males**	**Females**	**Low Spatial**	**High Spatial**
1 – Not Involved	4.4% (n=14)	12.6% (n=27)	10.2% (n=27)	5.2% (n=14)
2	13.1 (42)	26.6 (57)	19.2 (51)	17.8 (48)
3	19.3 (62)	25.7 (55)	25.6 (68)	18.2 (49)
4	27.1 (87)	26.2 (56)	24.8 (66)	28.6 (77)
5 – Very Involved	36.1 (116)	8.9 (19)	20.3 (54)	30.1 (81)
Current Tinkering Level of Involvement	**Males**	**Females**	**Low Spatial**	**High Spatial**
1 – Not Involved	5.6% (n=18)	15.9% (n=35)	13.4% (n=36)	6.2% (n=17)
2	9.9 (32)	32.7 (72)	19.0 (51)	19.4 (53)
3	23.0 (74)	24.1 (53)	22.7 (61)	24.2 (66)
4	33.2 (107)	21.4 (47)	29.4 (79)	27.5 (75)
5 – Very Involved	28.3 (91)	5.9 (13)	15.6 (42)	22.7 (62)

in the low spatial ability group reported high involvement in tinkering as a young child ($X^2 = 13.53$, df = 4, $p < .01$). 22.7% of individuals in the high spatial ability group versus 15.6% individuals in the low spatial ability group rated themselves as being highly involved in tinkering activities currently ($X2 = 10.97$, df = 4, $p = .03$)

CHAPTER 5. DISCUSSION

In keeping with the primary purpose of this paper, this discussion focuses on the differences that were found between individuals who were identified as being spatially gifted and their academically gifted peers who fell in the bottom quartile on a composite measure of spatial ability. Particular attention is given to profiling the unique abilities, interests, values, and preferences of spatially gifted females in the study because of the extensive literature discussing the lack of females in the math and the sciences (Meade, 1991; Ware, Steckler, & Leserman, 1985; Robinson & Mcilwee, 1989, McLure & Piel, 1978).

Before discussing the results from the comparisons made between the four experimental groups in this study, it is important to discuss preliminary analysis using spatially gifted individuals who were identified as being in the top quartile of the gender-mixed sample on the spatial composite measure. The results from this preliminary analysis point to the important role that talent plays in success in engineering and the sciences, a role that has been ignored in the literature on the under-representation of females in these occupations.

While females have made substantial progress in their representation in careers in law, medicine, and business, the same progress has not been made in the fields of engineering and physical sciences. A great deal of research has focused on trying to identify barriers to women's representation in these career fields. Self-efficacy, mentors/role models, and sex-role stereotyping have all been implicated and studied in great depth. Unfortunately, this literature fails to consider how differences in mathematical and spatial-mechanical reasoning abilities may serve as the main barrier to women in science and engineering. As seen in this study, women are under-represented in the high spatial ability group when selecting from a gender-mixed sample and using the conservative cut-off score of the top-quartile. Only twenty percent of the individuals identified as spatially gifted were females. This number would most likely be significantly lower if a more stringent, but more accurate, cut-off score had been used. The under-representation of females in this group provides strong evidence for the argument that spatial ability or talent may be the best explanation for the under-representation of women in science and engineering.

In addition to mathematical and spatial abilities, high or intense realistic interests have also been identified as an important attribute for success or excellence in engineering and physical science careers. Analysis looking at the number or proportion of females who would be in both the top-quartile for the spatial composite and the Realistic scale (score of 54) of the Strong revealed more conclusive evidence for the role of ability and vocational interests in the under-representation of females. Only 10.7% (n = 6) of females identified as spatially gifted from the gender-mixed sample versus 33.5% (n = 75) of males were in both the top-quartile on the spatial ability composite and the top-quartile for Realistic interest scores. This pattern was mirrored in the analysis using experimental groups selected within gender groups. Only 14.0% of females scored higher than 55 on the Realistic scales versus 22.4% of low spatial ability males and 35% of high spatial ability males. This low proportion of women who possess the relative attributes for success in science and engineering provide clear evidence for an explanation of female under-representation based on abilities and vocational interests, which has been long-ignored in the literature.

Mathematical Ability

In first looking at the mathematical abilities of the subjects in the present study, it is clear that spatial ability contributes to mathematical abilities, as supported by the literature on the relationship between math and spatial ability (Lubinski & Humphreys, 1990; Gallagher, 1987; Casey, Nuttall, Pezaris, & Benbow, 1995; Friedman, 1995). As predicted, individuals who had been identified as being spatially gifted scored significantly higher on the SAT-M, with their mean score being almost 90 points higher than individuals in the low spatial ability group. In comparing the mean SAT-M scores of the four experimental groups and looking at differences related to spatial ability, gender differences seem less prominent. This may come as a surprise, particularly when we consider the amount of research and debate that has gone into the issue of gender differences in mathematical ability as measured by the SAT-M. The argument for the identification of and nurturance of the talents of spatially gifted youth are strengthened. Here is a population of individuals with talents that are not valued by our educational system, but these talents are definitely influential on other abilities that are considered essential. If talents and gifts in spatial abilities are related to math and can potentially enhance or have a positive impact on success in math or science fields, how might these unrecognized talents contribute to other areas of individual success and performance? In recalling the words of Myer (1958), talents and gifts in spatial ability may influence the way individuals problem-solve, create, and interpret their world, including areas far from the concrete world of science.

The difference between low and high spatial ability populations is important because abilities in mathematics and spatial ability are necessary, if not critical for success in engineering and science majors and occupations (Humphrey, Lubinski, & Yao, 1993). In engineering and the sciences, mathematically ability is an important component for success in training, education, and preparation for a career. In essence, mathematical abilities unlock the door to educational and occupational opportunities in math, science, and engineering fields. Once individuals have begun and have successfully completed their education in science and engineering, spatial ability begins to play a more prominent and critical role in the day-to-day activities involved in an engineering or science career (Humphrey et al., 1993). What types of talents are lost when we continue to focus on mathematical abilities? It is conceivable that there are spatially gifted individuals who are turned-off or are directed away from careers in engineering on the basis of lower mathematical abilities (Betz, 1994).

Occupational Interests

Occupational interests have held a prominent role in theories of career choice and vocational psychology (Campbell & Holland, 1972). Holland's hexagonal model of vocational interests has been influential in the development, validation, and application of interest inventories, such as the Strong Interest Inventory used in the present study (Campbell & Borgen, unpublished), and in the applied area of career counseling. As previously discussed in the introductory portion of this paper, the vocational interests of gifted males and females have been examined, along with investigations into the vocational interests that characterize individuals interested in careers in engineering and the sciences.

Based on research by Schmidt, Lubinski, and Benbow (1996) it was hypothesized that differences would be found between the vocational interests of males and females in the current study. Males were hypothesized to score highest on the Investigative and Realistic General Occupational Themes of the Strong. Investigative and Realistic interests were also hypothesized to be more prevalent in both spatially gifted groups in comparison to the non-spatially gifted groups (Lubinski & Benbow, 1992; Lubinski, Benbow, & Sanders, 1993; Benbow & Lubinski, 1993; Lippa, 1995). Social and Artistic vocational interests were expected to be more prevalent in females versus males. For the most part, gender differences in the predicted direction were found. The mean scores for the Realistic scale for males were significantly higher than those of females. When comparisons were done by experimental groups, spatially gifted females and low spatial ability males did not differ significantly on their Realistic scale scores, spatially gifted females scored significantly higher on the Realistic scales compared to low spatial ability females. This suggests that spatially gifted females as a group do possess vocational interests in traditionally male-dominated fields and may benefit from career exploration activities that increase their knowledge and self-efficacy in Realistic occupational fields. Unfortunately, the significant difference in Realistic scores favoring males, particularly those identified as being spatially gifted, provides further support for the argument that under-representation is due to difference in abilities and vocational interests.

The results for Investigative scores on the Strong were even more interesting. Spatially gifted females as a group scored higher than both male groups and significantly higher than females in the low spatial ability group. For both the female groups, mean scores on the Investigative scales were second highest, with scores on the Artistic scale being the highest. While mean scores on the Social scale were third for both high and low spatial ability females, both male groups' mean scores on the Social scale were their lowest out of all six interest scales. This was consistent with the prediction that Social interests would be more prominent for females. The prominence of social interests for females is consistent with the literature that has shown that females prefer and place greater value on person-oriented occupations (Lippa, 1998; Eccles, 1994; Lips, 1992). The prominence of social interests and values for females and their preference for working with people has been implicated in the literature as a possible reason for their under-representation in math, science, and engineering fields (McLure & Piel, 1978; Lips, 1992; Reis, Callahan, & Goldsmith, 1996). Part of this preference for person-oriented interests and occupations is associated with the fact that females have the added difficulty of thinking about how they will combine their choice of a career with having a family.

As a final note on the investigation into the occupational interests of females and males in this study, it was hypothesized that males would have a more narrowly defined range of occupational interests compared to females (Lubinski & Benbow, 1992). McGinn (1976) reported that gifted boys in comparison to gifted girls were found to have a more unidimensional set of interest on the Strong-Campbell Vocational Interest test. This uni-dimensional set of interest was consistent with our hypothesis about the vocational interests of males, with high scores on the Investigative scale and low scores on the other five scales. In contrast, females had a more diverse range of interests, scoring higher than average on several interest scales (McGinn, 1976). This hypothesis was tested using two types of statistical analysis. The first was to compare the four experimental groups' overall standard deviation across the six interest scales to get a measure of the amount of variation within the profile. This analysis yielded no significant differences in the standard deviations, indicating no difference in the amount of differentiation.

A second method of analysis was used to investigate the amount of differentiation in the occupational interest profiles of the four experimental groups. This method of analysis involved calculating a difference score that reflected the amount of variation/differentiation of the each of the GOT scores from a mean GOT score. No significant differences were found in the amount of profile differentiation for males and females or high versus low spatial ability individuals. These results do not support the literature indicating that males have more narrowly defined vocational interests than females. As previously discussed, these results may be explained by the age of the participants, who should be exploring a variety of vocational options, rather than narrowing down their options.

Occupational Values

In contrast to the prominence of vocational interests in career counseling and vocational psychology, values have been more frequently ignored in theory and application. Dawis and Lofquist's (1984) Theory of Work Adjustment (TWA) has offered a useful model for conceptualizing the role that values and preferences play in the interaction between the individual and his/her work environment. The degree to which the values and preferences of the individual match the demands and characteristics of the his/her work environment predict the level of satisfaction and satisfactoriness that will result, which in turn, predicts the overall success of the individual in his/her work environment. The Theory of Work Adjustment has served as a useful theoretical component in the conceptual framework guiding much of the research done in association with the Study of Values (Benbow & Lubinski, 1993).

Based on the research by Schmidt, Lubinski, and Benbow (1996), it was hypothesized that males would be more likely to have Theoretical as their most prominent value, while females would be more likely to endorse the Social or Aesthetic values as their top-ranked value. In addition, it was hypothesized that high Theoretical value scores would be more prominent in males and females identified as spatially gifted. As predicted, a larger proportion of males, regardless of spatial ability level, had Theoretical as their top-ranked value relative to the other five values of the Study of Values, and a larger proportion of females endorsed Aesthetic as their most prominent value. Surprisingly, roughly equal proportions of females endorsed Theoretical (17.7%), Political (16.1%), Social (15.6%), and Religious (14.4%). The higher proportion of females with Theoretical versus Social is most likely a result of the population used in this study, with many of these women expressing an interest in being enrolled in science courses at the time of assessment.

Consistent with the hypotheses of the present study, individuals in the high spatial ability groups were more likely to endorse Theoretical as their most prominent value, followed by Aesthetic, which is most likely a result of the higher endorsement of Aesthetic values by spatially gifted females. Spatially gifted females were significantly below both male groups in the proportion having Theoretical as their top-ranked value. Aesthetic values are associated with a tendency towards individualism and self-sufficiency. Betz and Hackett (1993) argued that women who viewed themselves as self-reliant and independent were more likely to have interests in non-traditional careers, such as engineering. The combination of Aesthetic values, Investigative interests, mathematical ability, and increased self-reliance and independence may indicate that the females identified as spatially gifted in this study are prime candidates for occupations in the sciences and engineering.

Educational and Occupational Preferences

Consistent with the literature on course preferences, males were more likely to select mathematics courses as their most preferred courses. Courses in the physical sciences were second for males. For females, there was a greater distribution across subject areas, with English courses being the top-ranked, followed by courses in math, the physical sciences, and art/music. This more even distribution provides evidence for the argument that females have more diverse interests versus males who are characterized as having a narrower focus on math and the sciences. There were not many differences in the order of courses preferenced by high versus low spatial ability individuals, with the exception of English courses which were selected by a higher proportion of low spatial ability individuals.

The gender differences that were found in educational course preferences were mirrored in males' and females' preferences for future occupations. Males were more likely to select a career in engineering, math, or computer science than females. This trend for increased endorsement of computer science in males is surprising since it was not selected as a favorite course by a large number of students in this study. Another surprising result was the fact that an equal amount of males and females selected a career in the natural, physical, or medical sciences. The most preferred future occupation for females was that of a doctor, followed by careers in science and the entertainment industry. Females were also more likely than males to preference a career in education, social science, or law.

In looking at the differences between the occupational preferences of spatially gifted individuals versus individuals in the low spatial ability group, we find a pattern of results that is in line with what we would expect to see. High spatial ability individuals chose careers in engineering, followed by careers in the sciences, math/computer science, and medicine. Of particular interest is the fact that spatially gifted individuals were more likely to preference a career as a teacher or in the social sciences, but these results are based on a small number of subjects. On the other hand, nearly a third of the low spatial ability individuals selected a career as a doctor, followed by careers in science, entertainment, and engineering. This points to a more eclectic selection of careers by individuals who may not excel at tasks requiring spatial abilities.

Interesting patterns emerged when comparisons of occupational preferences were made for the four experimental groups. While high spatial ability males selected engineering and math/computer science careers as their top two occupational preferences, spatially gifted females were more likely to endorse a career in science or in medicine. This difference may be a result of the value differences of women versus men, previously discussed in this chapter. Careers in education and the social sciences were ahead careers in engineering for spatially gifted females, which may reflect the value women place on having a career in which they are working with and helping others. On the other hand, the occupational preferences (i.e. engineering, math/computer science, and science) of spatially gifted males reflects a greater interest or desire to work with things and ideas. As for males in the low spatial ability group, they were more likely to select a career in engineering, science, and math/computer science. This supports the argument made by some researchers that males, in some cases, are less qualified or suited for science and engineering careers than the women who either switch majors away from engineering and the sciences or who never even pursue this avenue of study (Meade, 1991).

CHAPTER 6. CONCLUSION

In conclusion, let us review the list of interests and abilities identified by Benbow and Lubinski (1992) as being important for success in engineering and the physical sciences. High mathematical and spatial-mechanical reasoning abilities, intense Investigative vocational interests and Theoretical values, and preferences toward activities and hobbies involving contact with objects (i.e. tinkering and building) versus with people were identified as being keys to success in academic majors and careers in engineering in the physical sciences. How do the spatially gifted males and females in the present study match up with this interest and ability profile for success in engineering and the sciences? Both spatially gifted males and females possessed strong mathematical reasoning abilities and spatial-mechanical reasoning abilities. Spatially gifted males possessed intense Investigative vocational interests and theoretical values. For spatially gifted females, their scores on the Investigative interest scale were higher than those of the other three groups, but in comparison to the other five interests scales, Investigative interests were second to Artistic interests. As for values, spatially gifted females were more likely to endorsed Aesthetic values as their most prominent value, followed by Theoretical and Social values.

As for preferences for activities and hobbies involving contact with objects versus people, high spatial ability individuals reported significantly more involvement in tinkering now and in the past. While spatially gifted females reported more tinkering as a child than low spatial ability females, they were not significantly different (or higher) than low spatial ability males. As for current involvement in tinkering, spatially gifted females were even more similar to low spatial ability females in their tinkering involvement versus high and low spatial ability males. In looking at extracurricular activities, females, particularly those identified as being spatially gifted were more likely to be involved in art-related activities. This involvement may represent a combination for a preference for activities involving things and intense Artistic vocational interests and Aesthetic values. Based on the prominence of Social interests and values in the interest and value profiles of females in the present study and based on preferences for occupations involving working with and help others, it can be argued that spatially gifted females have an interest and preference in activities involving contact with people.

Overall, the spatially gifted males in the current study were more likely to be characterized by the profile of abilities and interests identified by Benbow and Lubinski (1992) as being important for success in engineering and the physical science. This finding is not surprising in lieu of the literature that shows women have more diverse interests and values, which may not be as well-matched to careers in the sciences and engineering. Beyond interests and values, women may also lack the level of spatial ability that is necessary to excel in science and engineering careers. As pointed out earlier, the current study adds to the literature on the under-representation of women in engineering and science by considering the unique profile of capabilities necessary to pursue these careers (i.e. spatial and mathematical ability coupled with intense realistic and investigative interests). While the literature has ignored the role ability or talent plays in under-representation, it may point to further barriers that keep qualified women from continuing in science and engineering careers. The current literature may also point to possible limitations of the current study, along with possible future directions to take.

Self-efficacy plays a prominent role in the literature on the lack of parity of women in the sciences and engineering (Betz & Hackett, 1983; Lent, Brown, & Larkin, 1986; Brown, Lent, & Larkin, 1989; Betz, 1994; Shaefer, Epperson, & Nauta, 1997;). Arnold (1993) identifies a decrease in the intellectual self-esteem, which is unrelated to actual performance, of women in their sophomore year of college as one of the most disturbing gender patterns. Betz (1994) outlines the vicious cycle of avoidance behavior that can occur as a result of low self-efficacy expectations in females. Low self-efficacy in math may lead to avoidance of math coursework, which is detrimental to math performance. Poor performance in math (i.e. SAT-M) results in a confirmation of the self-efficacy beliefs that originally initiated the cycle. A lack of knowledge about the level of their own abilities and unreasonably high expectations for themselves can further impact the self-efficacy beliefs of women. Schaefers et al. (1997) point out that women receive less self-efficacy information about their own skills in engineering, physical sciences, and mathematics than their male peers. Not knowing where their skills fall, females are more likely to believe that they are not skilled or competent in engineering and the sciences. This lack of knowledge is coupled with the tendency of women in the sciences to place unreasonably high expectations on themselves. Meade (1991) points out that women's expectations for grades become a major barrier for women persisting in engineering programs. While males may continue in engineering programs with a C-average, women, who have higher grade-point-averages, may perceive themselves as less competent and efficacious and switch to another major.

Females who are well qualified or possess the capabilities to pursue and excel in engineering and science may be thwarted in their pursuit of these careers by their own self-efficacy beliefs. Follow-up studies to this research may benefit from exploring the self-efficacy beliefs of spatially gifted females who possess the relative attributes (i.e. females selected from a gender-mixed sample and who also possess a high level of realistic interests) to excel in science and engineering versus the self-efficacy beliefs of spatially gifted males and spatially gifted females who were identified from a female population and do not have high realistic interests.

The lack of role models/mentors and encouragement for women in science and engineering may also lead qualified women to pursue other educational and vocational opportunities (Meade, 1991; Subotnik & Steiner, 1993; Anderson, 1995). Family members can be a strong source of support and can be important role models for women in science and engineering. At a more general level, Betz & Fitzgerald (1987) found that having a mother who worked outside of the home was a predictor of more non-traditional occupational choices in girls. Meade (1991) points out that 50% of female engineers reported having a close family member in the field of engineering. Research by Hacker (1981) revealed that 23% of women in engineering had a father who was an engineer, compared to 13% of men. Mentors also play an important role in encouraging women to pursue and continue in a career in engineering and the sciences. Subotnik and Steiner (1993) argued that having a positive experience with a mentor was critical for females pursuing and persisting in engineering and science programs. The most alarming part of this research is the lack of female faculty mentors available to women in engineering and science programs. Describing the hostile or null environment of engineering and science awaiting women, Betz (1994) points out that females in engineering and the sciences are often excluded from informal and discretionary interactions that are important to their career development and success because they do not have a same-sex mentor.

In regards to support and encouragement of females, many researchers have argued that adolescent females do not benefit from the same support for their talents in math and the sciences from parents, teacher, and counselors (Meade, 1991; Reis, Callahan, & Goldsmith, 1996; Anderson, 1995). Both Eccles (1994) and Callahan and Reis (1996) point to the tendency for parents to either underestimate the talents of their daughters in stereotypical male activities and occupations or to underestimate the value of math and the science for their daughters. The effects of socialization and gender stereotyping are also found in the school, with counselors and teachers being less likely to encourage girls' talents in math and the sciences (Meade 1991; Reis et al., 1996). Reis et al. (1996) suggest that gifted females are more likely than male peers to listen to advice from parents, teacher, and counselors. Halpern (1996), in an article on the public policy implications of sex differences in cognitive abilities, reviewed the literature showing that stigmatized groups (i.e. women and minorities) may be influenced by their beliefs about the intellectual inferiority of their group. These beliefs are influenced by the gender stereotypes about math, science, and engineering as male interests and careers. Females who may possess the relative attributes for success in engineering and the sciences may be receiving the message that they cannot and should not pursue their talents and interests in these fields.

The lack of encouragement for girls to pursue engineering, math, and science opportunities and careers has two potential results. First, a lack of encouragement and support leads to a general lack of knowledge by females about the careers and opportunities available to them in math and the sciences. Secondly, the lack of encouragement and de-valuing of math and the sciences for girls may contribute to females who possess the relative attributes being socialized away from engineering and science careers and into person-oriented careers. Meade (1991) and McLure and Piel (1978) both argue for the need for career education about occupations in engineering and the sciences for females. Females may be selecting careers outside of engineering because they lack information about what engineering entails and how their abilities and interests may be met by a career in engineering. Gottfredson (1981) argues that all to often individuals, particularly women, start to circumscribe their career choices before fully exploring all of their career options. This early narrowing of options results in a great loss for women and society as a whole. McLure and Piel suggest that career education include information about the course of study involved in a career in engineering and the sciences, which can be used by women to better prepare themselves for a future in engineering.

As already noted, vocational interests and values also play an important role in the under-representation of women in science and engineering fields. Anderson (1995) points out that women often decide to go into engineering because of their strengths in math and science and because of the practicality (e.g. economic) of a career in engineering. For women, choosing a career in engineering represents an academic choice. In contrast, males select a career in engineering because of their interests in tinkering, mechanics, and electronics, which are more closely in-line with the actual practice and work-related demands of a career in engineering. With this in mind, women may be less suited to an actual career in engineering because they have based their decision on factors that are less relevant to a job in engineering. Socialization and information play key roles in this area. With more information about the actual demands of a career in engineering and more experiences as children with activities involving tinkering (e.g. construction sets, models, etc.), women may be more informed and better able to select a career in engineering on the basis of a match between their interests, abilities, and values.

The literature on the barriers to women's selection of majors and careers in engineering and the sciences point to some important limitations of the current study. First and foremost, the literature on the important role of mentors and parental encouragement play in the selection of careers in engineering and the sciences provides a good argument for the assessment of these factors in the experiences of spatially gifted females. The current study did not assess parental and teacher support for educational achievement and future occupations. Follow-up studies should look at spatially gifted females' role models or mentors and the level of involvement they have with these mentors. Based on research showing parental occupation as a factor in females pursuit of careers in engineering and traditionally male-dominated careers, parental occupations of gifted females should be an investigated. Related to this, it may be useful to collect data on parental views of occupations for their daughters and parents' ratings of the value of math and science courses to their daughters' educational and occupational future. This may provide a measure of gender stereotyping of occupations by parents and a measure of parental support for the interests and abilities of the spatially gifted daughters.

A second limitation of the current study was that self-efficacy measures were not included. While Benbow and Stanley (1982) found no differences in estimates of math and science competence for males and females, it may be informative to see if differences exist in self-efficacy ratings of spatially gifted males and females for future academic majors and occupations. Analysis should include an investigation of the relationship between self-efficacy ratings to levels of parental and teacher support.

Another potential area of improvement would be to assess students' knowledge about different career options. The research indicates that females are more likely to lack knowledge about careers in engineering and the sciences, and this lack of knowledge may be a major barrier to pursuing and persisting in a career in engineering and the sciences. Information on spatially gifted females knowledge of engineering careers, self-efficacy ratings in engineering, math, and science careers, and levels of support may provide important clues for designing educational experiences and interventions to increase women's participation in engineering and the sciences.

Increasing women's participation in engineering and the science must also be given a word of caution. Lips (1992) and Eccles (1994) point to the need to reframe questions and research into women's under-representation in the engineering and sciences as a choice versus deficit on the part of women. Both argue that instead of focusing research studies on why women avoid educational and occupational careers in engineering and the sciences, researchers need to look at what factors attract males and females to their occupational choices. If individuals are choosing a career on the basis of faulty beliefs about their own efficacy and competence or on the basis of a lack of information and knowledge about their career options, then it is appropriate plan interventions that are designed to help individuals make better career choices. If individuals are selecting careers on the basis of accurate knowledge about their abilities, interests, and values, then the focus needs to be on developing ways to make careers in engineering and the sciences more attractive to individuals who may possess the right profile of interests, abilities, and values.

REFERENCES

Achter, J.A., Benbow, C.P., & Lubinski, D. (1996). Multipotentiality among the intellectually gifted: "It was never there and already it's vanishing." *Journal of Counseling Psychology, 43*, 65-76.

Achter, J.A., Benbow, C.P., & Lubinski, D. (1997). Rethinking multipotentiality among the intellectually gifted: Acritical review and recommendations. *Gifted Child Quarterly, 41*, 5-15.

Ackerman, P.L. (1989). Individual differences and skill acquisition. In P.L. Ackerman, R.J. Sternberg, & G. Glaser (Eds.), *Learning and individual differences: Advances in theory and research* (pp. 164-217). New York: Freedman.

Ackerman, P.L. (1996). A theory of adult intellectual development: Process, personality, interests, and knowledge. *Intelligence, 22*, 227-257.

Ackerman, P.L., Sternberg, R.J, & Glaser, R. (Eds.), (1989). *Learning and individual differences: Advances in theory and research.* New York: Freeman & Co.

Allport, G.W., Vernon, P.E. & Linzey, G. (1970). *Manual: Study of Values*. Boston: Houghton Mifflin.

Anderson, V. (1995). Identifying special advising needs of women engineering students. *Journal of College Student Development, 36*, 322-329.

Arnold, K. D. (1993). Undergraduate aspirations and career outcomes of academically talented women: A discriminant analysis. *Roeper Review, 15*, 169-175.

K. Arnold, K.D. Noble, & R. F. Subotnik. (Eds.) (1996), *Remarkable women: Perspectives on female talent development.* Cresshill, NJ: Hampton Press, Inc.

Baruch, R., & Nagy, J. (1977). *Females and males in potential scientist pool: A study of the early college years*. Washington, DC: National Science Foundation. Lips, H.M. (1992). Gender- and science-related attitudes as predictors of college students' academic choices. *Journal of Vocational Behavior, 40*, 62-81.

Benbow, C.P. (1988). Sex differences in mathematical reasoning ability in intellectually talented preadolescents : Their nature, effects, and possible causes. *Behavior and Brain Sciences, 11,* 169-183, 217-232.

Benbow, C. P. & Arjmand, O. (1990). Predictors of high academic achievement in mathematics and science by mathematically talented students: A longitudinal study. *Journal of Educational Psychology, 82*, 430-441.

Benbow, C.P., & Lubinski, D. (1993). Consequences of gender differences in mathematical reasoning ability: Some biological linkages. In M. Haug, R.E. Whalen, C. Aron, & K.L. Olsen (Eds.). *The development of sex differences and similarities in behavior.* Kluwer Academic Publishers in the NATO Series: London, England. pp. 87-107.

Benbow, C.P. & Lubinski, D. (1993). Psychological profiles of the mathematically talented: Some sex differences and evidence supporting their biological basis. In –

Benbow, C.P. & Lubinski, D. (1996). *Intellectual talent: Psychometric and social issues.* Baltimore: Johns Hopkins University Press.

Benbow, C. P. & Minor, L. L. (1986). Mathematically talented males and females and achievement in high school sciences. *American Educational Research Journal, 23*, 425-436.

Bennett, G.K. (1969). *Bennett Mechanical Comprehension Test: Forms S and T (test manual.* New York: Psychological Corporation.

Bennett, G.K. (1980). *Bennett Mechanical Comprehension Test (manual supplement).* New York: Psychological Corporation.

Betz, N. E. (1994). Career counseling for women in the sciences and engineering. In W. B. Walsh & S. H. Osipow (Eds.), *Career counseling for women* (pp. 237-261). Hillsdale, NJ: Lawrence Erlbaum Associates.

Betz, N. E., & Fitzgerald, L. F. (1987). *The career psychology of women.* Orlando, FL: Academic Press. Eccles, J. (1994). Understanding women's educational and occupational choices: Applying the Eccles et al. Model of achievement-related choices. *Psychology of Women Quarterly, 18*, 585-609.

Betz, N. E., & Hackett, G. (1983). The relationship of mathematics self-efficacy expectations to the selection of science-based college majors. *Journal of Vocational Behavior, 23*, 329-345.

Binet, A., & Simon, T. (1905). Methodes nouvelles pour le diagnostic du niveau intellectual des anormaux. L'annee psychologique, 11: 191-244. Humphreys, L.G. & Lubinski, D. (1996). Assessing spatial visualization: An underappreciated ability for many school and work settings. In Benbow, C.P. & Lubinski, D. (Eds.). (1996). Intellectual Talent: Psychometric and social issues. (pp. 116-140). Baltimore, MD: Johns Hopkins University Press.

Brown, S. D., Lent, R. W., & Larkin, K. C. (1989). Self-efficacy as a moderator of scholastic aptitude-academic performance relationships. *Journal of Vocational Behavior, 35*, 64-75.

Burt, C. (1949). Structure of mind: a review of the results of factor analysis. British *Journal of Educational Psychology, 19,* 176-199. In Elliot, J.C. & Smith, I.M. (1983). *An international directory of spatial tests.* Windsor, England: NFER-Nelson.

Callahan, C. M., Adams, C. M., Bland, L. C., Moon, T.R., Moore, S. D., Perie, M., & McIntire, J. A. (1996). Factors influencing recruitment, enrollment, and retention of young women in special secondary schools of mathematics, science, and technology. K. Arnold, K.D. Noble, & R. F. Subotnik. (Eds.) (1996). *Remarkable women: Perspectives on female talent development.* Cresshill, NJ: Hampton Press, Inc.

Callahan, C.M. & Reis, S. M. (1996). Gifted girls, remarkable women. K. Arnold, K.D. Noble, & R. F. Subotnik. (Eds.) (1996), *Remarkable women: Perspectives on female talent development.* Cresshill, NJ: Hampton Press, Inc.

Campbell, D. P., & Borgen, F. H. (unpublished manuscript). *Holland's theory and the development of interest inventories.* (Available from David P. Campbell, Center for Creative Leadership, Leader Way, Colorado Springs, CO or Fred H. Borgen, Psychology Department, Iowa State University, Ames, IA 50011).

Campbell, D. P., & Holland, J. L. (1972). A merger in vocational interest research: Applying Holland's theory to Strong's data. *Journal of Vocational Behavior*, 2, 353-376.

Casey, M.B., Nuttall, R., Pezaris, E., & Benbow, C.P. (1995). The influence of spatial ability on gender differences in mathematics college entrance test scores across diverse samples. *Developmental Psychology*, 31, 697-705.

Dawis, R.V., (1991). Vocational interests, values, preferences. In M. Dunnette & L. Hough (Eds.), *Handbook of industrial and organizational psychology* (2nd ed., Vol. 2, pp. 25-58). Palo Alto, CA: Consulting Psychologists Press.

Dawis, R. V. & Lofquist, L. H. (1984). *A psychological theory of work adjustment.* Minneapolis: University of Minnesota Press.

Eccles, J. (1994). Understanding women's educational and occupational choices: Applying the Eccles et al. Model of achievement-related choices. *Psychology of Women Quarterly, 18*, 585-609.

Ekstrom, R.B., French, J.W., & Harman, H.H. (1979). Cognitive factors: Their identification and replication (pp. 3-84). Multivariate Behavioral Research Monographs, No. 79-2. Guttman, R., Epstein, E.E., Amir, M., & Guttman, L. (1990). A structural theory of spatial abilities. *Applied Psychological Measurement, 14*, 217-236.

Elliot, J.C. & Smith, I.M. (1983). *An international directory of spatial tests.* Windsor, England: NFER-Nelson.

Ethington, C.A., & Wolfe, L. M. (1988). Women's selection of quantitative undergraduate fields of study: Direct and indirect influences. *American Educational Research Journal, 25*, 157-172. Lips, H.M. (1992). Gender- and science-related attitudes as predictors of college students' academic choices. *Journal of Vocational Behavior, 40*, 62-81.

Farmer, H. S., Wardrop, J. L., Anderson, M. Z., & Risinger, R. (1995). Women's career choices: Focus on science, math, and technology careers. *Journal of Counseling Psychology, 42*, 155-170.

Feingold, A. (1995). The additive effects of differences in central tendency and variability are important in comparisons between groups. *American Psychologist, 50*, 5-13.

French, J.W. (1951). Description of aptitude and achievement test in terms of rotated factors. *Psychometric Monograph #5*. In Elliot, J.C. & Smith, I.M. (1983). *An international directory of spatial tests*. Windsor, England: NFER-Nelson.

Friedman, L. (1995). The space factor in mathematics: Gender differences. *Review of Educational Research, 65*, 22-50.

Gallagher, S. A. (1987). An analysis of visual-spatial ability, intellectual efficiency, and learning style on mathematics achievement of gifted male and gifted females adolescents (Doctoral dissertation, University of North Carolina at Chapel Hill, 1987). Dissertation

Abstracts International, 48, 1733A. In Friedman, L. (1995). The space factor in mathematics: Gender differences. *Review of Educational Research, 65*, 22-50.

Gazzaniga, M.S. (1983). Right hemisphere language: A twenty-year perspective. *American Psychologist, 38*, 547-549.

Gottfredson, L.S. (1981). Circumscription and compromise: A developmental theory of occupational aspirations [Monograph]. *Journal of Counseling Psychology, 28*, 545-579.

Guttman, L. (1954). A new approach to factor analysis: The radex. In P.F. Lazerfeld (Ed.), *Mathematical thinking in the social sciences*. Glencoe, IL: Free Press.

Guttman, L. (1980). Integration of test design and analysis: Status in 1979. *New Directions for Testing and Measurement, 5*, 93-98. In Guttman, R., Epstein, E.E., Amir, M., & Guttman, L. (1990). A structural theory of spatial abilities. *Applied Psychological Measurement, 14*, 217-236.

Guttman, R., Epstein, E.E., Amir, M., & Guttman, L. (1990). A structural theory of spatial abilities. *Applied Psychological Measurement, 14(3)*, 217-236.

Guilford, J.P. (1967). *The nature of human intelligence*. New York: McGraw-Hill. In Lohman, D.F. (19--). Spatial abilities as traits, processes, and knowledge. In R.J. Sternberg

(Ed.), *Advances in the Psychology of Human Intelligence, Vol. 4*, pp.181-248, Hillsdale, NJ: Erlbaum.

Guilford, J.P. & Lacey, J.I. (Eds.) (1947). Printed classification tests. *AAF aviation psychology research program reports* (No. 5). Washington, DC: Government Printing Office. In Lohman, D.F. (19--). Spatial abilities as traits, processes, and knowledge. In R.J. Sternber (Ed.), *Advances in the Psychology of Human Intelligence.,* Hillsdale, NJ: Erlbaum. (*Vol. 4*, pp.181-248).

Hacker, S. L. (1981). Culture of engineering: Women, workplace, and machine. *Women's Studies International Quarterly, 4*, 341-353. Anderson, V. (1995). Identifying special advising needs of women engineering students. *Journal of College Student Development, 36*, 322-329.

Hansen, J.C., & Campbell, D.P. (1985). *Manual for the SCII* (4th ed.). Palo Alto, CA: Stanford University Press.

Harmon, L.W., Hansen, J.C., Borgen, F.C., & Hammer, A.L. (1994). *Applications and technical guide for the Strong Interest Inventory.* Palo Alto, CA: Consulting Psychologists Press.

Holland, J.L. (1985). *Making vocational choices* (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.

Humphreys, L.G., Davey, T.C., & Kashima, E. (1986). Experimental measures of cognitive privilege/deprivation and some of their correlates. *Intelligence, 10*, 355-370.

Humphreys, L.G., Lubinski, D., & Yao, G. (1993). Utility of predicting group membership and the role of spatial visualization in becoming an engineer, physical scientist, or artist. *Journal of Applied Psychology, 78*, 250-261.

Humphrey, L.G. & Lubinski, D. (1996). Assessing spatial visualization: An underappreciated ability for many school and work settings. In Benbow, C.P. & Lubinski, D. (Eds.). (1996). Intellectual Talent: Psychometric and social issues. (pp. 116-140). Baltimore, MD: Johns Hopkins University Press.

Humphreys, L.G., & Yao, G. (unpublished manuscript). *Predicting graduate majors.* University of Illinois at Champaign

Johnson, E. & Meade, A. (1987). Developmental patterns of spatial ability: An early sex difference. *Child Development, 58*, 725-740.

Kelley, T.L. (1928). *Crossroads in the Mind of Man.* Stanford, CA: Stanford University Press. In Smith, I.M. (1962). *Spatial ability: Its educational and vocational significance*. San Diego: Knapp.

Koussy, A. A. H. El. (1935). The visual perception of space. *British Journal of Psychology*, Monograph Supplement, 20. Smith, I.M. (1962). *Spatial ability: Its educational and vocational significance*. San Diego: Knapp.

Kuse, A.R. (1977). Familial resemblances for cognitive abilities estimated from two test batteries in Hawii. Unpublished doctoral dissertation, University of Colorado.

Lent, R. W., Brown, S. D., & Larkin, K. C. (1986). Self-efficacy in the prediction of academic performance and perceived career options. *Journal of Counseling Psychology, 33*, 265-269.

Lippa , R. (1998). Gender-related individual differences and the structure of vocational interests: The importance of the People-Things dimension. *Journal of Personality and Social Psychology, 74,* 996-1009.

Lips, H.M. (1992). Gender- and science-related attitudes as predictors of college students' academic choices. *Journal of Vocational Behavior, 40*, 62-81.

Lohman, D.F. (1988). Spatial abilities as traits, processes, and knowledge. In R.J. Sternber (Ed.), *Advances in the Psychology of Human Intelligence, Vol. 4*, pp.181-248, Hillsdale, NJ: Erlbaum.

Lohman, D.F. (1994). Spatial Ability. In Sternberg, R.J. (Ed.). *Encyclopedia of Human Intelligence, 2, j-z,* (pp.1000-1007). NY: MacMillan Publishing Co.

Lubinski, D., & Benbow, C.P. (1992). Gender differences in abilities and preferences among the gifted: Implications for the math/science pipeline. *Current Directions in Psychological Science, 1*, 61-66.

Lubinski, D. & Benbow, C.P. (1995). Optimal development of talent: Respond educationally to individual difference in personality. *Educational Forum, 59*, 381-392.

Lubinski, D., Benbow, C.P., & Ryan, J. (1995). Stability of vocational interests among the intellectually gifted from adolescence to adulthood: A 15-year longitudinal study. *Journal of Applied Psychology, 80*, 196-200.

Lubinski, D., Benbow, C.P., & Sanders, C.E. (1993). Reconceptualizing gender differences in achievement among the gifted: An outcome of contrasting attributes for personal fulfillment in the world of work. In K.A. Heller, F.J. Monks, & A.H. Passow (Eds.), *International handbook for research on the giftedness and talent.* Oxford, England: Pergamon Press.

Lubinski, D., & Dawis, R.V. (1992). Aptitudes, skills, and proficiencies. In M.D. Dunnette & L.M. Hough (Eds.), *The handbook of industrial/organizational psychology* (2nd ed., Vol. 3, pp. 1-59). Palo Alto, CA: Consulting Psychologists Press.

Lubinski, D., & Humphreys, L.G. (1990). Assessing spurious "moderator effects": Illustrated substantively with the hypothesized ("synergistic") relation between spatial and mathematical ability. *Psychological Bulletin, 107*, 385-393.

Marshalek, B., Lohman, D.F., & Snow, R.E. (1983). The complexity continuum in the radex and hierarchical models of intelligence. *Intelligence, 7*, 107-127. In Ackerman, P.L., Sternberg, R.J, & Glaser, R. (Eds.), (1989). *Learning and individual differences: Advances in theory and research.* New York: Freeman & Co.

McLure, G. T., & Piel, E. (1978). Career-bound girls and science careers: Perceptions of barriers and facilitating factors. *Journal of Vocational Behavior, 12*, 172-183.

McFarlane, M. (1925). A study of practical ability. *British Journal of Psychology*, Monograph Supplement, 8. In Smith, I.M. (1962). *Spatial ability: Its educational and vocational significance*. San Diego: Knapp.

McGee, M.G. (1979). *Human spatial abilities: Sources of sex differences*. New York, NY: Praeger Publishers.

McGinn, P.V. (1976). Verbally gifted youth: Selection and description. In D.P. Keating (Ed.), *Intellectual talent: Research and development*. Baltimore, MD: The Johns Hopkins University Press.

McNemar, Q. (1942). *The revision of the Stanford-Binet scale*. Boston: Houghton Mifflin.

Meade, J. (1991, September). The missing piece. *ASEE Prism, 1,* 19-22.

Michael, W.B., Guilford, J.P., Fruchter, B., & Zimmerman, W.S. (1957). Description of spatial visualization abilities. *Educational and Psychological Measurement, 17*, 185-199. In Elliot, J.C. & Smith, I.M. (1983). *An international directory of spatial tests*. Windsor, England: NFER-Nelson.

Myers, C.T. (1958). Some observations of problem-solving in spatial relations test. Research Bulletin RB-58-16, Educational Testing Service, New Jersey. In Smith, I.M. (1962). *Spatial ability: Its educational and vocational significance*. San Diego: Knapp, p.100.

National Science Foundation. (1990). Selected data on science and engineering doctorate awards: 19090 (Report NSF 91-310). Washington, DC: Author.

Prediger, D.J. (1976). A world-of-work map for career exploration. *Vocational Guidance Quarterly, 24*, 198-208.

Prediger, D.J. (1982). Dimensions underlying Holland's hexagon: Missing link between interests and occupations? *Journal of Vocational Behavior, 21*, 259-287.

Reis, S. M., Callahan, C. M., & Goldsmith, D. (1996). Attitudes of adolescent gifted girls and boys toward education, achievement, and the future. K. Arnold, K.D. Noble, & R. F. Subotnik. (Eds.) (1996). *Remarkable women: Perspectives on female talent development.* Cresshill, NJ: Hampton Press, Inc.

Robinson, J. G., & McIlwee, J. S. (1989). Women in engineering: A promise unfulfilled? *Social Problems, 36*, 455-472.

Rounds, J.B. & Tracey, T.J. (1992). Prediger's dimensional representation of Holland's RIASEC circumplex. *Journal of Applied Psychology, 78*, 875-890.

Rounds, J.B., Tracey, T.J., & Hubert, L. (1992). Methods for evaluating vocational interest structural hypotheses. *Journal of Vocational Behavior, 40*, 239-259.

Sattler, J. M. (1992). *Assessment of Children: Revised and updated third edition.* San Diego, CA: Sattler, Publisher, Inc.

Schaefers, K. G., Epperson, D. L., & Nauta, M. M. (1997). Women's career development: Can theoretically derived variables predict persistence in engineering majors? *Journal of Counseling Psychology, 44*, 173-183.

Schmidt, D.B., Lubinski, D., & Benbow, C.P. (in press). Vocational preferences among intellectually gifted 13-year olds reflect structural similarities of graduate students in top math/science departments: Uncovering attributes for scientific excellence through cross-validation. *Journal of Counseling Psychology.*

Shepard, R.N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science, 171*, 710-703.

Smith, I.M. (1962). *Spatial ability: Its educational and vocational significance*. San Diego: Knapp.

Snow, C.P. (1964). *The two cultures: And a second look.* Cambridge, England: Cambridge University Press.

Spearman, C. (1914). Theory of two factors. *Psychological Review, 21*, 101-115.

Stephenson, W. (1931). Tetrad-differences for verbal sub-test. *British Journal of Educational Psychology, 22*, 255-267. In Smith, I.M. (1962). *Spatial ability: Its educational and vocational significance*. San Diego: Knapp.

Stevens, G., & Hoisington, E. (1987). Occupational prestige and the 1980 U.S. labor force. *Social Science Research, 16*, 74-105.

Subotnik, R. F., & Steiner, C. L. (1992). Adult manifestations of adolescent talent in science. *Roeper Review, 15*, 164-169.

Thurstone, L.L. (1938). Primary mental abilities. *Psychometric Monographs* (No. 1). Chicago: University of Chicago Press.

Thurstone, L.L. (1950). *Some primary abilities in visual thinking*. Chicago: the University of Chicago Psychometric Laboratory Report, 59. In McGee, M.G. (1979). *Human Spatial Abilities: Sources of sex differences*. New York, NY: Praeger Publishers.

Thurstone, L.L. (1951). An analysis of mechanical aptitude. *University of Chicago Psychometric Laboratory Report, 62*. In Smith, I.M. (1962). *Spatial ability: Its educational and vocational significance*. San Diego: Knapp.

Tracey, T.J., & Rounds, J. (1993). Evaluating Holland's and Gati's vocational-interest models: A structural meta-analysis. *Psychological Bulletin, 113*, 229-246.

Vandenberg, S.G., & Kuse, A.R. (1978). Mental rotation: A group test of three-dimensional spatial visualization. *Perceptual Motor Skills*., 47, 599-604.

Vernon, P.E. (1950). *The structure of human abilities* (2nd ed.). London: Methuen.

Ware, N. C., Steckler, N. A., & Leserman, J. (1985). Undergraduate women: Who chooses a science major? *Journal of Higher Education, 56*, 73-84.

Wattanawaha, N. (1977). DIPT Classification Model for Spatial Tasks. Unpublished dissertation, Monash University, Australia.

Zimmerman, W.S. (1954). Hypotheses concerning the nature of spatial factors. *Psychometrika, 16*, 361-386. In Smith, I.M. (1962). *Spatial ability: Its educational and vocational significance*. San Diego: Knapp.