ACCOMPLISHMENTS OF TOP SCIENCE AND ENGINEERING GRADUATE STUDENTS AFTER GRADUATE SCHOOL

By

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INTRODUCTION

Overview

Two recurring issues have resurfaced in recent years: the importance of innovation in science and engineering to our nation's economic future (Domestic Policy Council, 2006; Friedman, 2007; National Academy of Sciences, 2005, 2010; Wooldridge, 2006) and the importance of increasing women's participation in this enterprise (Barreto, Ryan, & Schmitt, 2009; NAS Committee on Gender Differences in the Careers of Science, Engineering, and Mathematics Faculty, 2010; Shalala et al., 2007). The abundant interest in innovation echoes a long tradition of empirical research on the causes and correlates of scientific accomplishment (e.g., Dundar & Lewis, 1998; Garfield & Sher, 1966; Halpern et al., 2007; Jackson & Rushton, 1985; Newcombe et al., 2009; Park, Lubinski, & Benbow, 2007, 2008; Roe, 1951; Super & Bachrach, 1957; Terman, 1954; Webber & Lee, 2009; Wrenn, 1949; Zuckerman, 1977). Despite the extensive work in this area, gaps in knowledge remain.

For example, as is discussed in detail in the review that follows, a large body of research attests to the influence of individual differences in cognitive abilities, personality, and vocational interests on job performance and career accomplishment in general and, more specifically, in careers in science and engineering (S&E[1]). More

[1]The National Science Foundation has used the term science and engineering broadly, including agricultural, medical, behavioral, and social sciences (e.g., National Science Board, 2010). Those fields were excluded from S&E for the purposes of this study. In this study, science and engineering includes chemistry, biochemistry, physics, cell and molecular biology, math and computer science, and various forms of engineering.

recent work has suggested that communal and agentic lifestyle preferences and life circumstances such as marital status, parenthood, and spouse's income also affect accomplishment in S&E careers. Furthermore, it is not debated that attending a top science or engineering graduate program is both a signal of an individual's ability and commitment to S&E and, in many cases, a launching pad for a career of great accomplishment in S&E. However, to my knowledge, no research has investigated how the cognitive abilities, personality traits, vocational interests, and life priorities and circumstances of top graduate students in S&E jointly influence their accomplishment in S&E careers. This seems surprising given the concern over women's lower participation in S&E. In this dissertation, I examine this issue, replicating existing work on predictors of accomplishment in science and engineering careers and extending it to top graduate students in S&E. I find support for the roles of cognitive abilities, vocational interests, lifestyle preferences, and life circumstances in high accomplishment in science and engineering careers among top graduate students in science and engineering.

I begin the remainder of the introduction with an overview of the nature of career accomplishment. Then I consider how career accomplishment in general and in science and engineering relates to traditional individual differences variables, and follow that with a discussion of its relationships with lifestyle preferences and life circumstances. Next, I turn to the appropriateness of top science and engineering graduate students as a population for examination of career accomplishment in science and engineering, and I provide a review of the literature on career accomplishment

among this group. I conclude the introduction with a summary and a description of my aims and hypotheses for this study.

Career Accomplishment

The criterion of interest in this study is career accomplishment in science and engineering. Career accomplishment can be likened to long-term job performance, a term used in industrial/organizational psychology. Some researchers use job performance to describe the value that an employee's behaviors have for an organization (Motowidlo, 2003). Job performance is also conceptualized as productivity, or the results of these work behaviors rather than the behaviors themselves (Hunter & Schmidt, 1996). This is the definition of job performance that will be used in this paper.

Career accomplishment, then, can be defined as a person's accumulated record of productivity or output over a period of time, like a patenting or publication record, or the consequences of such, such as a high income or a position in an organization with seniority. These concrete indicators will be used to measure accomplishment in this study. Next, I turn to the relationships between accomplishment in S&E careers and traditional individual differences variables.

Accomplishment in S&E Careers and Individual Differences in Cognitive Abilities, Personality, and Vocational Interests

Research suggests that those who emerge as innovators in science and engineering share some specific attributes and experiences (Humphreys, Lubinski, & Yao, 1993; Jackson & Rushton, 1985; Lubinski & Benbow, 2006; Raskin, 1936; Roe, 1951; Super & Bachrach, 1957; Terman, 1954; Wai, Lubinski, & Benbow, 2009; Wrenn, 1949; Zuckerman, 1977). Although some might say that much research in this area is out of date, a number of findings over multiple decades have been consistent and should not be dismissed. The following review considers the relationships of job performance and accomplishment in general and in science with individual differences in cognitive abilities, personality traits, and vocational interests. I report on sex differences that have been found in each domain in order to shed light on the potential contributors to women's underrepresentation in science and engineering.

Cognitive Abilities

General Cognitive Ability

General cognitive ability, or general intelligence, has been defined by 52 prominent researchers of intelligence as

> ...a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts.

> Rather, it reflects a broader and deeper capability for comprehending our surroundings—"catching on," "making sense" of things, or "figuring out" what to do (Gottfredson, 1997, p. 13).

Because S&E careers are complex, they require a high level of general cognitive ability (Ceci, Williams, & Barnett, 2009; Gottfredson, 1986b, 1997; F. L. Schmidt & Hunter, 1998; Wai et al., 2009). Longitudinal and cross-sectional research also have suggested that employees migrate up or down the occupational prestige hierarchy in a manner consistent with individual differences in general cognitive ability (Wilk, Desmarais, & Sackett, 1995; Wilk & Sackett, 1996). Although some researchers debate the existence of talent for science (e.g., Ericsson, Roring, & Nandagopal, 2007; Howe, Davidson, & Sloboda, 1998; Howe, 1999), scientists and people with S&E graduate degrees have been shown to demonstrate high average levels of intelligence (Fig. 1; Ceci & Williams, 2010; Gibson & Light, 1967; L. R. Harmon, 1961; Wai et al., 2009). As well, there is general agreement that more cognitive ability seems to be advantageous for attaining certain accomplishments in science like patents, peer-reviewed science publications, and tenure at a top university (Kuncel, Hezlett, & Ones, 2004; Lubinski, Benbow, Webb, & Bleske-Rechek, 2006; Murray, 2003; Park et al., 2007, 2008; Wai, Lubinski, & Benbow, 2005).

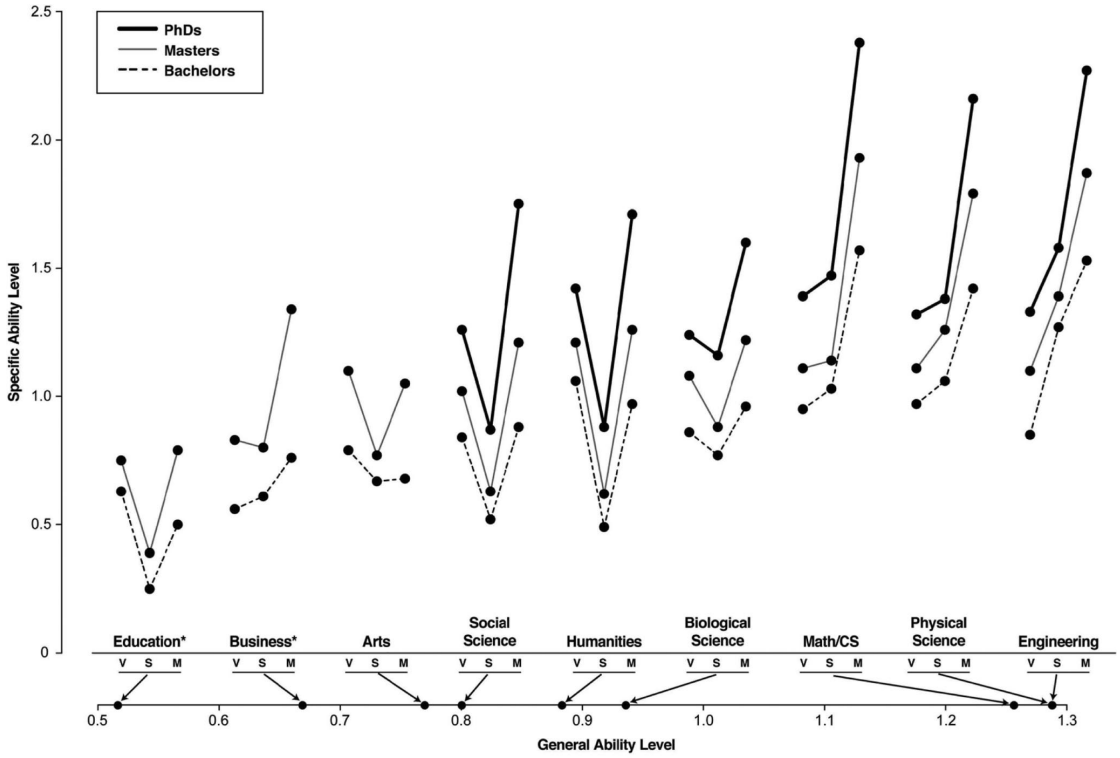

Figure 1: Average standard scores (z-scores) on general cognitive ability (x-axis) and verbal, spatial, and math abilities (y-axis) of Project Talent degree holders across fields. Standard scores were computed with entire population of Project Talent participants with complete ability data. Respective ns for each group were as follows (for bachelors, masters, and doctorates, respectively): engineering (1143, 339, 71), physical science (633, 182, 202), math/computer science (877, 266, 57), biological science (740, 182, 79), humanities (3226, 695, 82), social science (2609, 484, 158), arts (615, masters + doctorates = 171), business (2386, masters + doctorates = 191), and education (3403, masters + doctorates = 1505). Note: For education and business, masters and doctorates were combined because the doctorate samples for these groups were too small to obtain stability (n $<$ 30). Reprinted from Wai et al. (2009).

Specific Abilities

In addition to general cognitive ability, specific abilities also have been linked to career accomplishments. Different educational and occupational pursuits have different average levels and patterns of specific abilities (Figs. 1 and 2; Corno et al., 2002; Gottfredson, 1986a, 2003; Lubinski, 2000, 2004; Tyler, 1974; Williamson, 1965; Wai et al., 2009). The three specific cognitive abilities most relevant to educational and occupational accomplishment are quantitative, verbal, and spatial ability (Snow & Lohman, 1989; Carroll, 1993). There is evidence that high levels of quantitative and spatial abilities are particularly important for success in high-level S&E careers (Gottfredson, 1986b; Humphreys et al., 1993; Lubinski, Webb, Morelock, & Benbow, 2001; Shea, Lubinski, & Benbow, 2001; Super & Bachrach, 1957; Wai et al., 2009).

Patterns of specific abilities covary with interests. This covariation manifests on an individual level as an intellectual orientation; for example, people with quantitative and spatial ability that is stronger than their verbal ability also likely have interests in science, whereas people with verbal ability that is stronger than their spatial ability seem more likely to have interests that lead them to pursue education and careers in other areas (Figs. 1 and 2; Ackerman, 1996; Ackerman & Heggestad, 1997; D. B. Schmidt, Lubinski, & Benbow, 1998; Webb, Lubinski, & Benbow, 2007). Consistent with these findings, among the very able, those with verbal ability that eclipses their quantitative ability are *less* likely to pursue a career in S&E and more likely to pursue careers in areas requiring high verbal ability, like patent law or science journalism (Lubinski, Webb, et al., 2001; Park et al., 2007).

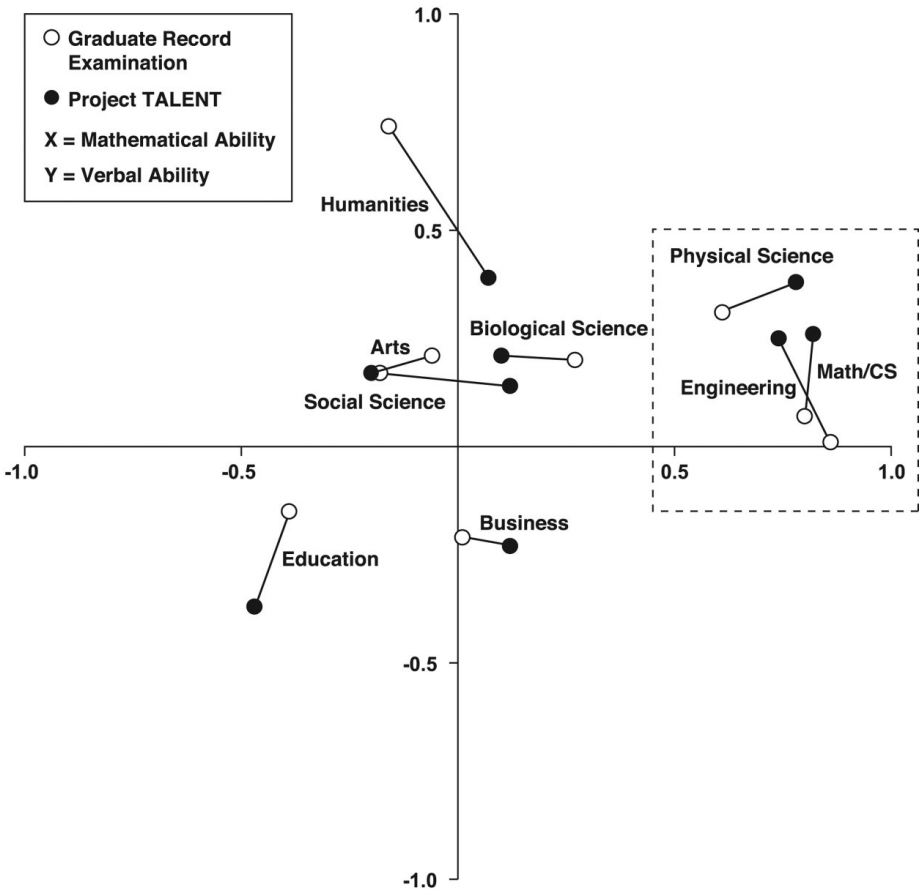

Figure 2: Average standard scores (z-scores) on quantitative (x-axis) and verbal ability (y-axis) of Graduate Record Exam (GRE) takers and Project TALENT graduate degree holders across fields. Standard scores were computed with entire population of GRE takers tested between July 1, 2002 and June 30, 2005 ($n >$ 1,245,000). For each GRE point 8,000 $< n <$ 102,000. Reprinted from Wai et al. (2009).

Sex Differences in Cognitive Abilities

Both general cognitive ability and levels and patterns of specific abilities have relevance to job performance and accomplishment. Research on sex differences in general and specific abilities suggests that because men demonstrate more variability in the abilities relevant to performance in science as well as higher means than women in quantitative and spatial ability, more of them may be anticipated to be highly accomplished in science and engineering careers in the U.S. Research on sex differences in general cognitive ability has shown negligible mean differences (Brody, 1992; Ceci et al., 2009; Deary, Thorpe, Wilson, Starr, & Whalley, 2003; Jensen, 1998; W. Johnson, Carothers, & Deary, 2008; Maccoby & Jacklin, 1974) and higher variability in general cognitive ability for males, along with higher proportions of males in the upper tail (Deary et al., 2003; Hedges & Nowell, 1995; W. Johnson et al., 2008). Evidence suggests that males have an advantage in spatial and quantitative abilities, while females have an advantage in verbal ability (Ceci et al., 2009; Deary, Penke, & Johnson, 2010; Geary, 1996, 2010; Hedges & Nowell, 1995; Maccoby & Jacklin, 1974; Strand, Deary, & Smith, 2006; Wai et al., 2009). In addition (at least in the U.S. and the U.K.), males have more variable scores than females have on spatial and quantitative ability tests (Cole, 1997; Deary, Irwing, Der, & Bates, 2007; Feingold, 1992; Hedges & Nowell, 1995; Lohman & Lakin, 2009; Maccoby & Jacklin, 1974; Strand et al., 2006), and there are higher proportions of males in the upper tail of quantitative ability (Hyde, Lindberg, Linn, Ellis, & Williams, 2008; Wai, Cacchio, Putallaz, & Makel, 2010). Outside the U.S. and U.K., differences are much less

consistent (Feingold, 1994b). Overall, cognitive abilities seem to be important contributors to accomplishment in S&E careers, at least in the U.S., and sex differences in cognitive abilities may be related to sex differences in S&E career accomplishment.

Personality Traits

Big Five Personality Traits

In addition to cognitive abilities, personality traits have been linked to job performance in general (Barrick & Mount, 1991; Caspi, Roberts, & Shiner, 2005; Judge, Higgins, Thoresen, & Barrick, 1999; Ozer & Benet-Martinez, 2006; Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007). With respect to the five-factor model of personality (i.e., extraversion, agreeableness, conscientiousness, emotional stability, and openness to experience; Digman, 1990), job performance has been shown to be positively related to all 5 of the dimensions when there is a match between the requirements of the job and the personality dimension in question (Hogan & Holland, 2003). More generally, conscientiousness, extraversion, and emotional stability have positive relationships with job performance, even when socio-economic status and cognitive ability are controlled (Roberts et al., 2007). Agreeableness and extraversion may lead to higher performance because both facilitate interpersonal interactions at work (Mount, Barrick, & Stewart, 1998). In addition, openness to experience has been shown to be related to creativity (Peterson & Carson, 2000; Peterson, Smith, & Carson, 2002), as well as creative accomplishments (Carson, Peterson, & Higgins, 2003).

Specific Facets of Personality

More specific personality dimensions are related to accomplishment in science and engineering in particular. Terman's (1955) study of "genius" found that students majoring in science in college had been more likely to display high levels of intellectual curiosity and lower levels of sociability at an early age than those who didn't major in science. With respect to the Adjective Check List (ACL), the measure of personality that was used in this study, the Creative Personality Scale (CPS) predicted scientific creativity with a correlation of .31 between scores on the CPS and creativity ratings of 57 mathematicians made by expert judges (Gough, 1979). This is consistent with other findings, as the CPS of the ACL has been linked to the Big Five personality dimension of Openness to Experience (Piedmont, McCrae, & Costa, 1991).

Sex Differences in Personality Traits

Research on the Big Five has shown that sex differences in personality exist across cultures (although the sizes of the differences vary). Men tend to be more open to ideas, assertive, and emotionally stable, while women tend to be more extraverted, agreeable, and conscientious (Costa, Terracciano, & McCrae, 2001; Feingold, 1994a; Schmitt, Realo, Voracek, & Allik, 2008). Because openness to experience (and more specifically, creative personality) and introversion may be particularly important for accomplishment in science and engineering, sex differences on these dimensions may be a potential contributor to sex differences in S&E career engagement and even accomplishment.

Vocational Interests

Whereas cognitive abilities and personality traits have been linked to performance and accomplishment in education and work, vocational interests more strongly affect choice in education and work (Dawis, 1991, 1992; Holland, 1996; Snow, 1996; Tyler, 1974). Vocational interests constitute a class of individual differences variables traditionally found in industrial/organizational and vocational counseling psychology (Armstrong & Rounds, 2008; Dawis, 1992; Dunnette, 1976; Dunnette & Hough, 1991, 1992; Rounds & Tracey, 1990). When an individual demonstrates strong interest in science and research and relatively less interest in other intellectual pursuits, he or she is significantly more likely to embark on, persist in, and accomplish highly in a career in S&E.

The RIASEC Model of Vocational Interests

The most prominent model of vocational interests is the Holland hexagon (Holland, Whitney, Cole, & Richards, Jr., 1969) or the RIASEC model (Fig. 3), with dimensions labeled *Realistic, Investigative, Artistic, Social, Enterprising, and Conventional* (Holland, 1959, 1996, 1997). The RIASEC model is supported in large and diverse samples and cross-culturally (Day & Rounds, 1998; Day, Rounds, & Swaney, 1998; Rounds & Tracey, 1996; Rounds & Armstrong, 2005). Investigative interests, or interests in learning and using one's knowledge to solve problems, are commonly among the top two interest dimensions of scientists (Hansen & Campbell, 1985; Lubinski & Benbow, 2006; Webb et al., 2007).

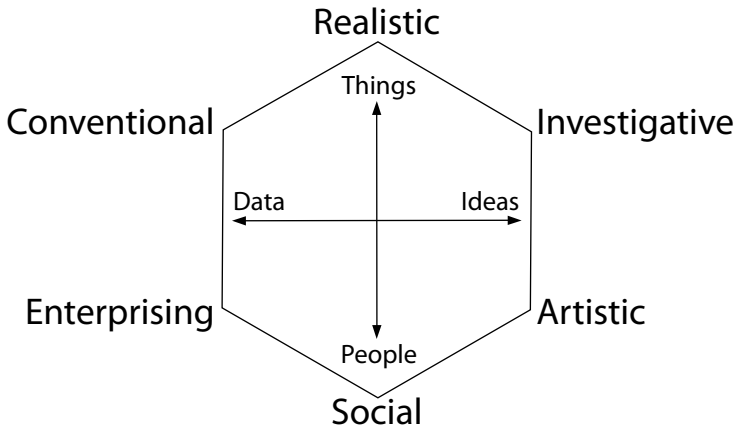

Figure 3: Holland's (1969) RIASEC hexagon, with Prediger's (1982) Things-People and Data-Ideas dimensions

People vs. Things

An elaboration of the RIASEC model that has been very important in the domain of research on career development of scientists and engineers is the people-versus-things dimension of vocational interests (Prediger, 1982). Among people with the requisite ability to pursue high-level careers in science, those with stronger interest in working with things than with people are more likely to pursue careers in S&E than those with stronger interest in working with people (Su, Rounds, & Armstrong, 2009). Individuals with high interest in working with people are more likely to pursue careers in medicine, social services, or business (Holland, 1996).

Sex Differences in Vocational Interests

Research on sex differences in vocational interests has shown that, on average, women are more interested in fields or jobs involving working with people or organic

content, while men are more interested in fields or jobs involving working with things or inorganic content (Geary, 2005, 2010; Lippa, 1998, 2005, 2006; Su et al., 2009). A recent meta-analysis of studies on sex differences in occupational interests (total $n >$ 500,000), for example, found that males were more interested than women in working with things ($d = 0.93$), in engineering ($d = 1.11$), in investigation ($d = 0.26$), in science ($d = 0.36$), and in mathematics ($d = 0.34$; Su et al., 2009). This tendency also holds true among participants in the top 1% of quantitative ability: among this group with the ability to pursue high-level careers in S&E fields, women are more interested in pursuing careers in people-oriented fields, while men are more interested in pursuing careers in things-oriented fields (Webb, Lubinski, & Benbow, 2002). In a recent review, Ceci et al. (2009) reported that the evidence strongly supported the view that sex differences in occupational interests were of primary importance to women's underrepresentation in academic science.

Taken together, the research on vocational interests suggests that interest in working with things more than people, investigative interests, and interests in science, engineering, and math are critical components of pursuit of a career in science or engineering. Women's lesser interest in these areas relative to men and greater interest in working with people makes them less likely to pursue careers in science in the first place[2]. However, it remains to be seen whether differences in vocational interests also relate to accomplishment among those who have already chosen a career in science or engineering.

[2]This difference also makes women who do pursue careers in S&E more different from the average woman than men who pursue careers in S&E are from the average man.

Integrative Models of Individual Differences

As reviewed above, much research in psychology has examined the relationships between single classes of individual differences variables (e.g., cognitive abilities, personality traits, and vocational interests) and work outcomes (e.g., occupation or job performance; Ackerman & Humphreys, 1990; Barrick, Mount, & Judge, 2001; Hunter & Hunter, 1984; Kanfer, Ackerman, Murtha, & Goff, 1995; Kanfer & Kantrowitz, 2002; Kuncel et al., 2004; F. L. Schmidt & Hunter, 1998). Fewer studies have examined the joint influence of abilities, personality, and vocational interests on work performance (e.g., Dawis & Lofquist, 1984; Austin & Hanisch, 1990; Kanfer, Wolf, Kantrowitz, & Ackerman, 2010). Typically, the contribution of each of these three predictor classes to work outcomes is studied in isolation, to the detriment of the field (Ackerman, 1997; Lubinski, 2000)[3].

Despite this trend, a few frameworks have been proposed to unite cognitive abilities, personality, and interests in prediction of educational and occupational behavior. Dawis and Lofquist and colleagues formulated the Theory of Work Adjustment (Dawis, England, & Lofquist, 1964; Dawis, Lofquist, & Weiss, 1968; Lofquist & Dawis, 1969; Dawis & Lofquist, 1984; Dawis, 2005) to describe the process of work adjustment, in which an individual has requirements that can be met by a work environment, and a work environment has requirements that can be met by an individual. The individual's requirements include satisfaction of vocational interests and needs,

[3]Because correlations among cognitive abilities, personality traits, and vocational interests are typically small, and moderate at their largest, the proportion of people who have the abilities, personality, and interests to choose and persist in S&E careers is substantially smaller than the proportion of people who have any one of those necessary characteristics; furthermore, the proportion of people who have what is required to become a S&E innovator is even smaller, because they make up only a subset of those who persist in S&E careers.

and the requirements of the job can be met with an individual's skills or abilities. To the extent that the requirements of both individual and work environment are met, the individual's tenure in the job results. Holland's (1966) theory of RIASEC types unites abilities, personality, and interests under the RIASEC headings, suggesting that there are ability strengths and weaknesses and behaviors (personality traits) that typically appear along with different vocational interests. Snow (1989, 1991) proposed aptitude complexes (where aptitude follows the broader definition of preparedness for learning and training) for organizing diverse individual differences to predict learning and performance more efficiently.

Most recently, Ackerman and his colleagues (Ackerman, 1996, 1997; Ackerman & Beier, 2003; Ackerman & Heggestad, 1997) have extended the notion of aptitude complexes to trait complexes by examining communalities among personality, cognitive abilities, vocational interests, and domain knowledge. In their model, interests motivate the selection of activities, personality and ability are the primary causes of success in these activities, and success leads to acquisition of domain–specific knowledge. Therefore, according to their model, interests should be more directly related to selection of and persistence in a S&E vs. non-S&E career, and ability and personality should be more directly related to accomplishment in the chosen career area.

Accomplishment in S&E Careers and Lifestyle Preferences and Life Circumstances

The literature reviewed below reveals that, in addition to cognitive abilities, personality traits, and vocational interests, lifestyle preferences, marital status, spouse's

income, and parenthood are also potentially related to accomplishment in science and engineering careers.

Lifestyle Preferences

Lifestyle preferences refer to life priorities including having a prestigious career, balancing work and family, being involved in the community, and having meaningful relationships. Lifestyle preferences are relevant to whether someone accomplishes highly in S&E because people naturally choose careers that are compatible with their lifestyle preferences (Gottfredson, 1981, 2005), and accomplishing highly in S&E typically demands a certain lifestyle. In general, one must work long hours to develop expertise (Ericsson, Krampe, & Tesch-Romer, 1993; Ericsson & Lehman, 1996; Eysenck, 1995; Jensen, 1996; Lubinski & Benbow, 2000, 2006; Simonton, 1988, 2004, 2008; Zuckerman, 1977). In addition, because knowledge becomes obsolete more quickly in S&E than in other fields (McDowell, 1982), these long hours must be maintained in order to maintain expertise in S&E. Several studies of scientists have found that unwavering dedication to work, often at the expense of engagement with family, friends, and the community, is a characteristic common to top scientists (Hoffer & Grigorian, 2005; Roe, 1951; Zuckerman, 1977). Little research has been attempted on lifestyle preferences relevant to work outcomes; published findings discussed below suggest that sex differences in lifestyle preferences may contribute to women's reduced propensity for high accomplishment in S&E careers.

Sex Differences in Lifestyle Preferences

Sex differences in lifestyle preferences and choices have been observed both among the general population and among groups with the capability to have successful high-level careers (Browne, 2002, 2004–2005; Pinker, 2008; Rhoads, 2004). Empirical support for gender differences in lifestyle preferences among the general population includes Hakim's (2006) work on lifestyle preferences in a British national survey, which showed that roughly 20% of British women are career-centered, choosing to focus on work regardless of external circumstances, while roughly 55% of men are career-centered. Among the population of college students, women seem less likely to pursue careers in S&E because of their perception that although careers in S&E may fulfill agentic life goals such as power, recognition, and success, they do not fulfill communal life goals like intimacy, altruism, and affiliation (Diekman, Brown, Johnston, & Clark, 2010).

Among intellectually talented populations, men and women in the Study of Mathematically Precocious Youth (SMPY) showed distinct differences in the number of hours they worked in their current jobs and were willing to work in their ideal jobs in their mid-30s and earlier in their lives (Benbow, Lubinski, Shea, & Eftekhari-Sanjani, 2000; Lubinski et al., 2006, Fig. 4). These participants had the ability to succeed in high-level S&E careers but varied in their levels of willingness to work long hours, with more women preferring to work fewer than 40 hours per week.

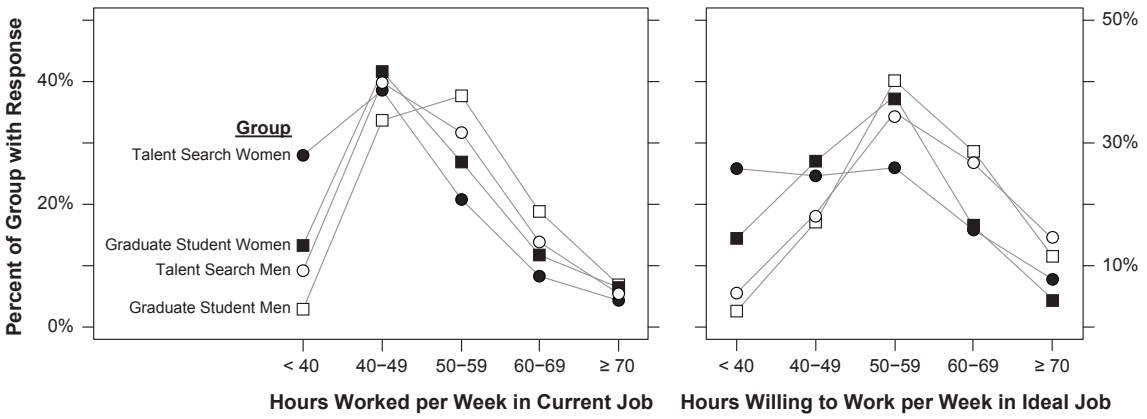

Figure 4: Number of hours talent search participants (male $n >= 1{,}425$ and female $n >= 736$) and graduate student participants (male $n >= 269$ and female $n >= 263$) worked per week and were willing to work per week in their ideal job, by sex. Participants were surveyed when they were in their mid-30s; they were asked how many hours per week they typically worked (left panel; homemakers were excluded from this question) and how many hours per week they were willing to work, given their job of first choice (right panel). Adapted from Lubinski and Benbow (2006).

Change Over Time in Lifestyle Preferences

Lifestyle preferences seem to be less stable over time, and are still changing long after abilities and interests stabilize, as they are affected by changes in life circumstances over the lifespan. Long hours are much easier to maintain when one has few competing priorities. A previous study of the sample that will be used in this study showed changes in lifestyle preferences from age 25 to age 36 that coincided with women becoming mothers—on average, mothers were less interested in working full-time at age 36 than the rest of the participants were, although there had been no significant differences in such lifestyle preferences among the groups 11 years earlier. Although the bulk of the changes occurred among the mothers only, they were large enough overall to manifest as sex differences in lifestyle preferences at age 36 among all participants—men and women, childless participants and parents (Ferriman, Lubinski, & Benbow, 2009).

Lifestyle preferences seem relevant to accomplishment in S&E careers. If people do navigate their career paths by choosing careers that are compatible with their lifestyle preferences, then sex differences and change over time in lifestyle preferences provide another potential explanation for sex differences in S&E career engagement and accomplishment.

Life Circumstances: Marital Status, Spouse's Income, and Parenthood

Beyond cognitive abilities, personality, vocational interests, and lifestyle preferences, marital status, spouse's income, and parenthood also seem to exhibit sex

differences that might predict differential accomplishment for men and women. Marital status and parenthood seem to affect the careers of men and women differentially such that married men and fathers are more likely to accomplish highly in S&E than their unmarried and childless counterparts, while married women and mothers are less likely to accomplish highly in S&E than their unmarried and childless counterparts.

Marital Status and Spouse's Income

Concerning marital status, women in academia are less likely to be married than their male colleagues (Jacobs & Winslow, 2004). Spouse's education level and income also may be related to accomplishment in S&E careers. Women who marry men with higher levels of education are less likely to accomplish highly in S&E careers, because they are more likely to drop out of the workforce altogether if their spouse's income is sufficient to support their family financially (Becker & Lindsay, 2004). Men who marry women with less education are more likely to stay in S&E for the same reason (Becker & Lindsay, 2004). Alternatively, because assortative mating also occurs, PhDs are likely to marry people who have PhDs, and then to experience the dual-career problem—it may be difficult to find jobs in the same place, and so one spouse may stop working involuntarily (Becker & Lindsay, 2004; Rudd, Morrison, Picciano, & Nerad, 2008).

Parenthood

Concerning parenthood, mothers spend the same number or fewer hours working professionally than their childless counterparts, while fathers spend more hours working professionally than their childless counterparts (Long, 2001). Additionally, taking a leave from work at any time during one's career has been hypothesized to be detrimental to one's ultimate career trajectory, so that careers of parents who want to reduce their work hours for a time to raise children are negatively impacted (Ceci et al., 2009), and this would seem to be especially germane for rapidly changing disciplines (McDowell, 1982).

Accomplishment in S&E Careers Among Top S&E Graduate Students

The importance of cognitive abilities, personality, and vocational interests for accomplishment in S&E careers is apparent, and lifestyle preferences and life circumstances also may be important contributing factors. If career accomplishment in S&E is the criterion of interest, several populations may be considered useful for study. Science and engineering students are an obvious choice, because education in science is necessary for a high-level career in science. Other choices might be graduates of degree programs in S&E or top achievers in S&E careers. I posit that choosing students in top graduate programs in S&E is an ideal choice for several reasons: cost-effectiveness, design advantages, and usefulness to anyone with interest in the success of graduate programs in training future S&E innovators.

Cost-effectiveness

Although students of high school and college age might seem appropriate for a longitudinal study of high accomplishment in S&E careers, high school and college student populations are not restricted enough to expect a large proportion of high achievers in S&E, even if they are limited to students with interest in S&E. Many thousands of students would have to be studied to obtain a large enough sample of participants with high accomplishments in S&E careers. This choice would be cost-prohibitive.

On the other hand, choosing students or graduates of top S&E graduate programs or people who have already accomplished highly in S&E would ensure that the group has a large proportion of high achievers, and therefore a smaller sample would be required. This choice, as a result, would be more cost-effective. However, choosing the most select groups would require less than ideal research designs for studying the differences between top performers and those who do not accomplish as highly in S&E careers.

Design Advantages

Retrospective study of high achievers in S&E careers such as Nobel prize winners (e.g., Zuckerman, 1977) or members of the National Academy of Sciences (e.g., Feist, 2006) is a good place to start when first exploring the factors related to high accomplishment in S&E careers. However, such studies lack control groups, which are necessary (if not sufficient) design features for researchers who aim to make causal

inferences. Prospective longitudinal designs, while not randomized experiments, are the best option available for examination of the influence of individual differences and life circumstances on high accomplishment in S&E careers.

Use of a prospective longitudinal design with top graduate students or graduates of top S&E programs would ensure that participants are motivated enough to pursue a graduate degree in S&E and have the aptitude necessary for admission to a top program, and perhaps also for high accomplishment. In addition, high achievers and other participants would be similar enough on these variables that they might all be expected to be high achievers. Therefore, any predictive variables that demonstrate differences between groups would be clear candidates for explaining differences in career outcomes.

Informativeness

Choosing graduates of top graduate programs in S&E for prospective study would be cost-effective, as a very large proportion of these graduates would be expected to accomplish highly in S&E. It also would be a good population for prospective longitudinal study. Study of graduate students has a clear benefit over study of graduates, however: potential informativeness for administrators of top S&E graduate programs. Selecting participants who have already graduated from top PhD programs would not confer any new knowledge about which students are likely to be successful to those programs, which invest many dollars and resources in training graduate students.

The Literature to Date on Top S&E Graduate Students' Career Accomplishment

Despite the clear value of studying S&E career accomplishment among top S&E graduate students, little research has been done in this area, and none to my knowledge on what factors (besides sex) predict accomplishment in this population. One news article in *Science* reported on the status of 30 doctoral students from Yale's molecular biophysics and biochemistry program 17 years after they started graduate school in 1991 (Mervis, 2008), and some cross-sectional data are available from the National Science Board (National Science Board, 2010).

Previous research on the sample of top S&E graduate students examined in this study showed that they had many of the characteristics one would expect to see among nascent science and engineering high achievers based on the research reviewed above. The men (n = 367) and women (n = 347) had high mean standardized test scores in math and verbal areas. They had high scores on creative personality and low scores on succorance (suggesting they are independent and assertive). They also had high investigative interests, and lower interests in other areas. In terms of their lifestyle preferences while in graduate school, they rated being successful in their careers and having full-time careers as very important (3.7 out of 5), while they rated having part-time work, either for a limited time or on a permanent basis as less important (2.3 and 1.9 out of 5, respectively). Some were married, engaged, or in a permanent relationship (33%), and few (<2%) had children (Lubinski, Benbow, Shea, Eftekhari-Sanjani, & Halvorson, 2001).

Eleven years later, these former top S&E graduate students had accomplished

highly in their careers in terms of income, position, and patenting rates of the group as a whole. However (patenting rates and occupations as scientists notwithstanding), whether their accomplishments occurred primarily in S&E fields has not been explicitly explored. Comparisons of participants in this group with respect to high career accomplishment included examinations of sex differences in outcomes only. The researchers only hinted at the potential importance of the sex differences observed in the hours participants worked and were willing to work (Lubinski et al., 2006), an indicator of career commitment.

Summary of the Research To Date

The research summarized above provides considerable evidence that cognitive abilities, personality traits, and vocational interests are important factors in accomplishment in S&E careers. Lifestyle preferences and how individuals respond to life circumstances also may be important factors in accomplishment in S&E careers. In addition, although top graduate students in S&E are a natural choice for exploring the impact of these factors on exceptional accomplishment in S&E careers, the review of the research in this area reveals that, to my knowledge, no research to date has explored whether any differences in cognitive abilities, personality traits, vocational interests, lifestyle preferences, or life circumstances portend differences in accomplishment in S&E careers among this group over the two decades following their enrollment in graduate school.

The Present Study

This study had three aims. First, I aimed to compare participants who were highly accomplished in S&E careers with other participants to assess if there were any differences between these groups in quantitative and verbal abilities[4], personality traits, vocational interests, or lifestyle preferences at the initiation of the study. Because the vast majority of participants who had children did so between the first and second surveys, and lifestyle preferences also seemed to change over that time, I also examined how lifestyle preferences differed between participants with exceptional S&E accomplishments and the other participants 11 years later.

Second, I wanted to add to the research looking at the joint influence of cognitive abilities, personality traits[5], vocational interests, and life circumstances on S&E career accomplishment. Because the sample was so select, and range restriction therefore would limit the likelihood of finding group differences in the first analysis, I performed logistic regression analyses to assess the extent to which individual differences in these areas operated within this select group to predict S&E accomplishment.

Finally, I aimed to compare the career and life satisfaction of highly accomplished participants and others to assess whether they differed substantially. Previous

[4]Because spatial ability was not measured in this data set, I was unable to test hypotheses about spatial ability in this study; this is a limitation I will return to in the discussion.

[5]The Adjective Check List (ACL), the measure of personality traits used in this study, has 37 scales. I examined all scales from the ACL for differences in profiles between highly accomplished participants in S&E and their peers, but sample size limitations demanded I include fewer scales in the regression analyses to avoid overfitting. Because the Creative Personality scale specifically has been linked to creative accomplishments, it was the one ACL scale that was included in the logistic regression analyses.

work on this group showed that participants reported high career and life satisfaction (Lubinski & Benbow, 2006), but not whether these differed based on participants' career accomplishments.

On the basis of previous research, I hypothesized that people who were highly accomplished in S&E careers relative to their same-sex peers likely 1) had higher quantitative ability and higher verbal ability (but quantitatively tilted profiles), 2) had higher creative personality, 3) had higher interest in mathematics, science, and investigation and lower interest in other areas, 4) had higher agentic lifestyle preferences and lower communal lifestyle preferences, 5) if male, were more likely to be married and have children; if female, were less likely to be married and have children, and 6) if married, were more likely to have a spouse with a high income because of assortative mating.

Chapter II

METHOD

Participants

The participants came from the S&E graduate student cohort of SMPY (Cohort 5; Lubinski, Benbow, et al., 2001; Lubinski et al., 2006). Participants were graduate students in 14 science and engineering (S&E) fields, and they were recruited in 1992 from departments ranked among the top 15 in each field (Gourman, 1989; National Research Council, 1987). Frequencies of participants in each field are presented by sex in Figure 24. Participants came from 53 departments in 19 universities (Fig. 25). Most participants were in the first or second year of their degree programs.

All participants were U.S. citizens. The mean age of the women at the time of the initial survey was 24.8 years, and the mean age of the men was 24.6 years. Participants' ages are presented in Figure 26. Caucasians made up 82 percent of the participants, Asians or Asian-Americans 9 percent, Blacks or African-Americans 3 percent, and Hispanics, Mexican-Americans, or Puerto Ricans 3 percent. Details about participants' races or ethnic backgrounds are presented in Figure 27.

Measures

Cognitive abilities, personality traits, vocational interests, lifestyle preferences, employment, patenting and publication rates, and life and career satisfaction were measured as described below.

Cognitive Abilities

Official Graduate Record Examination (GRE) scores were used to measure cognitive ability. GRE scores were assessed just prior to admission to graduate school and reported officially at the time of the initial survey. GRE scores are valid predictors of graduate grade point average, first-year graduate grade point average, comprehensive examination scores, publication citation counts, and faculty ratings (Kuncel, Hezlett, & Ones, 2001; Kuncel & Hezlett, 2007). The GRE-Quantitative (GRE-Q) showed a noticeable ceiling effect in this sample, which is to be expected given that the participants came from top S&E graduate programs. Approximately 130 participants out of the 607 for whom GRE scores were available obtained the top score (800) on the GRE-Q. This ceiling effect is likely to attenuate the relationship between quantitative ability and the criterion measures. The GRE Verbal (GRE-V) section did not demonstrate a ceiling effect.

Personality Traits

The Adjective Check List (Gough & Heilbrun, 1983) was used to measure personality attributes at the time of the first survey. It contains 300 items and 37 scales (Tables 1 and 2), all of which have a mean of 50 and a standard deviation of 10 in the general population of each sex.

Among normative samples, internal consistency estimates for men ranged from .56 to .95, with a median of .76; for women, alpha ranged from .53 to .94, with a median of .75. For men, test-retest reliability over 6 months ranged from .34 to .77,

Scale	Description
no. adj. checked	
no. favorable checked	
no. unfavorable checked	
communality	is reliable, considerate, and comfortable in interpersonal relationships
achievement	strives to be outstanding in pursuits of socially valued significance
dominance	seeks to control relationships and seeks/maintains leadership roles
endurance	persists in tasks undertaken
order	emphasizes neatness, organization, and planning
intraception	tries to understand the behavior of self and others
nurturance	engages in behaviors that provide benefits for others
affiliation	seeks and maintains many personal friendships
heterosexuality	seeks and enjoys interactions with opposite-sex peers
exhibition	tries to elicit the immediate attention of others
autonomy	acts independently of others or of social values/expectations
aggression	engages in behaviors that harm others
change	seeks novel experiences and avoids routine
succorance	solicits sympathy, affection, or emotional support from others
abasement	expresses feelings of inferiority through self-criticism
deference	seeks and maintains subordinate roles in relationships
counseling readiness	has problems in interpersonal relationships
self-control	is cautious, overcontrolled, conservative, patient, and quiet

Table 1: Names and descriptions of the scales in the Adjective Check List.

with a median of .65; for women, test-retest reliability over 1 year ranged from .45 to .86, with a median of .71 (Gough & Heilbrun, 1983). While the ACL has fallen out of use since the initiation of this study in 1992, perhaps due to the increasing popularity of the five-factor model (Digman, 1990), Piedmont et al. (1991) have presented the relationships between the ACL scales and the five factors of personality as measured

Scale	Description
self-confidence	is confident that goals will be achieved and is determined, assertive, and enterprising
personal adjustment	is energetic, industrious, outgoing, and self-confident
ideal self	is confident and seemingly well-adjusted but also somewhat narcissistic
creative personality	is clever, original, artistic, versatile, and imaginative
military leadership	is ambitious, organized, industrious and conservative
masculine attributes	is ambitious, assertive, impatient when frustrated, and stubborn
feminine attributes	is cooperative, considerate, and sympathetic
critical parent	is bossy, demanding, impatient, and suspicious
nurturant parent	is forgiving, appreciative, helpful, loyal, and stable
adult	is productive, work-centered, reliable, and ambitious
free child	is ebullient, enterprising, impulsive, and sensation-seeking
adapted child	is anxious, shy, and withdrawn
A-1	has strong instincts, enjoys festivity and is easily distracted
A-2	is indifferent to convention, has original thoughts and perceptions, is aesthetically sensitive and insightful
A-3	is conventional, easygoing, and forthright; respects rules; and is content with life role
A-4	is analytical, logical, intellectual, and self-disciplined

Table 2: Names and descriptions of the scales in the Adjective Check List.

by the NEO Personality Inventory (NEO-PI; Costa & McCrae, 1985), which will allow further generalization of the profiles that are presented here.

Vocational Interests

Vocational interests were measured at the time of the initial survey with the research version of the Strong Vocational Interest Inventory (SVII; Hansen & Campbell, 1985). The General Occupational Themes of the SVII measure Holland's (1996, 1997) 6 vocational interest themes, often abbreviated RIASEC: *realistic* (working with things and tools and working outdoors), *investigative* (scientific pursuits and

independent work), *artistic* (aesthetic pursuits and self-expression in an unstructured environment), *social* (contact with and helping people), *enterprising* (leadership roles in buying, marketing, and selling), and *conventional* (chains of command and well-structured tasks as in office practices).

Participants also completed the 23 Basic Interest Scales (BIS) of the SVII (Hansen & Campbell, 1985), which measure vocational interests at an intermediate level of generality—on a finer level than the General Occupational Themes allow (Armstrong, Smith, Donnay, & Rounds, 2004; Day & Rounds, 1997), but on a broader level than than the empirical occupational scales of the SVII (Campbell, Borgen, Eastes, Johansson, & Peterson, 1968; Day & Rounds, 1997). These scales measure interests in agriculture, nature, adventure, military activities, mechanical activities, science, mathematics, medical science, medical service, music/dramatics, art, writing, teaching, social service, athletics, domestic arts, religious activities, public speaking, law/politics, merchandising, sales, business management, and office practices. The BIS capture interests shared by people in different occupations involving similar activities (Campbell et al., 1968; Day & Rounds, 1997), but also distinguish among people with differences in vocational interests too subtle to be differentiated by their RIASEC scores, for example, in different college majors (Ralston, Borgen, Rottinghaus, & Donnay, 2004).

Lifestyle Preferences

Participants' lifestyle preferences were measured with 9 scales developed for this study from 57 items they completed as part of the biographical questionnaire.

The scales measure the importance participants placed on various aspects of life and work, including but not limited to having a family, working a limited number of hours, and having a prestigious career. Details about the scales and their development are presented in Appendix B. These scales were also completed at the time of the 11-year follow-up.

Employment

At the time of the 11-year follow-up, data were collected on whether participants were employed by someone else, self-employed, unemployed, homemakers, or still pursuing training. If participants were employed or self-employed, they also reported whether they were working full-time or part-time. If an individual was employed or still in training (e.g., as a postdoctoral research associate or medical resident), their job title and field were collected, as well as their income and the number of hours they worked per week. When participants' career information was incomplete, their 2003 job title and field were obtained if available online. Based on job title and field, participants' jobs were coded as one of more than 150 possible job types.

Each employed participant, postdoc, and medical resident was classified as having a S&E occupation if his or her job included a moderate amount of S&E content. Those participants without employment outside the home or with little or no S&E content in their jobs were classified as having occupations outside S&E.

Participants were classified as having senior S&E positions in industry in consultation with Dean Kenneth Galloway of the Vanderbilt University Engineering School

and his Associate Dean (summer, 2008). Anyone who had "Senior" in his or her job title or had another senior job title (e.g., Vice President) and an annual income greater or equal to $70,000 was classified as having a senior S&E position comparable to a tenure-track position at a Research I university. (Appendix C contains a complete list of qualifying job titles).

Patenting Record

Patenting data were available from the 11-year follow-up and the 16-year follow-up. Participants reported the number of patents they had obtained since completion of graduate school as part of the 11-year follow-up. The 16-year follow-up included a count of the number of patents participants had obtained from the records available on Google Patents.

For the 11-year survey, only participants who had obtained at least one patent reported the number of patents they had obtained. Because some of the participants who were missing patent data may not have responded to these items at all, I examined participants' patent data from the 16-year follow-up to see if anyone had a record of patenting that suggested that I should reexamine their 2003 patent data using public patenting records. These reexaminations resulted in changes to 3 participants' 2003 patent data. The rest of the participants with missing responses were imputed a zero.

Peer-reviewed S&E Publications & *h*-Indices

Publication data were available from the 11-year follow-up and the 16-year follow-up. Participants reported the number of peer-reviewed S&E articles that they had authored or co-authored since graduate school at the time of the 11-year follow-up. The 16-year follow-up included a count of the number of peer-reviewed S&E articles participants had authored or co-authored from the records available using Publish or Perish software (Harzing, 2011), which organizes information available on Google Scholar. The *h*-index (Hirsch, 2005) for each participant, which is thought to index the quality of an author's work, as judged by the number of citations the author receives, was also generated by Publish or Perish. An author's *h*-index is the largest number of scholarly articles they have authored or co-authored that has the same number of citations. For example, an author with an *h*-index of 20 has published no more than 20 articles with at least 20 citations.

For the 11-year follow-up survey, questions about articles were asked in a similar manner to questions about patents. Because some of the participants who were missing article data may not have responded to these items at all, I checked participants' publication data from the 16-year follow-up to see if anyone had a record of publication that suggested I should reexamine their 2003 publication data using publication records available on Google Scholar. These reexaminations resulted in changes to 3 participants' 2003 article data. Zeroes were imputed to the remaining participants who were missing data on articles.

Career and Life Satisfaction

Career satisfaction was measured on a 7-point scale. Life satisfaction was measured on a scale from 5 to 25 with the 5 items from Pavot and Diener's (1993) Satisfaction with Life Scale.

Procedure

Participants were identified and surveyed in 1992, followed up with a paper survey in 2003, and followed up using public online databases in 2008 and 2011.

Identification of Participants

In spring of 1991, departments ranked among the top 15 by Gourman (1989) and the National Research Council (1987) were mailed a letter requesting permission to survey their first- and second-year students. Department chairs were sent the protocols and told that the surveys would require approximately 1.5 hours of students' time. In spring of 1992, chairs who had agreed to contact their students about participation in the study were mailed packets of questionnaires and $15 cash for each student. The initial survey included questions about their demographics, education, families, accomplishments, activities, personal views, and life and occupational goals (Lubinski, Benbow, et al., 2001). Ninety-four percent of students returned the questionnaires.

Participants were approximately age 25 years at the time of the first survey. Women were oversampled in order to obtain equivalent representation by sex in this

sample. Departments were asked to pass the survey on to all eligible female graduate students and then to sample randomly an equal number of eligible male graduate students to complete and return it[1]. This procedure resulted in a sample consisting of 347 women and 367 men.

First Follow-up

In 2003 (when participants were approximately age 36 years), participants whose contact information could be found and verified were invited by email, phone, or letter to complete a second survey. This survey was web-based, and addressed areas similar to those addressed in the first survey but also included a detailed section on participants' employment history and career accomplishments (Lubinski et al., 2006). 297 women and 306 men responded to this web-based survey.

Second Follow-up

In 2008 (when participants were approximately age 41), publicly available information was collected about participants' careers using Google Patents (patenting record), Google Scholar (scholarly publication record), and a more general Google search (general employment information).

[1]Therefore the women in this sample more closely represent the population of women in top S&E graduate programs than the men in this sample represent the population of men in top S&E graduate programs.

Analytic Approach and Statistical Analysis

The statistical analysis was guided by the data available as well as by the decision to use multiple imputation.

Missing Data Imputation

The data set that was used for this study exhibits two types of missing data: wave nonresponse (e.g., an individual did not participate in the second wave of data collection, $n = 111$) and item nonresponse (i.e., an individual answers some but not all questions). Item nonresponse was generally low (i.e., <5%) for any single item. However, the individuals who did not respond varied across items, such that the data set included a mere 30 complete cases, less than 5% of the original number of cases.

As an initial approach, I attempted to recover data for variables that could be recovered based on information available in public records (e.g., participant's 2003 job title). Beyond that step, I used multiple imputation as implemented in the Amelia II software package (Honaker, King, & Blackwell, 2007; Horton & Kleinman, 2007; King, Honaker, Joseph, & Scheve, 2001; Rubin, 2004). Five imputed data sets were created. Results reported here combine inferences across the five data sets.

Classification of Participants as Highly Accomplishing in S&E Careers

Participants in science and engineering jobs were classified as accomplishing highly in science or engineering after graduate school or not on the basis of their job

position, income, patents, and publications. Participants needed to meet one of the criteria below to be considered highly accomplished in science or engineering:

- Job Position: participants in academia who had a tenure-track position in science or engineering at a Research I university (Carnegie Foundation for the Advancement of Teaching, 2000) were classified as accomplishing highly in S&E[2].

- Income: participants in a position in science or engineering in government or industry who earned an income of at least $90,000 per year (which was approximately equivalent to the 12-month salary of a tenure-track professor at a Research I university in 2003 dollars) were considered highly accomplished in S&E; those who had a senior government or industry position and earned more than $70,000 per year also were classified as accomplishing highly in S&E[3].

- Patents: participants who had been granted at least three patents between the time they obtained their terminal degree and 2003, or who had obtained at least .33 patents per year on average during that time were classified as accomplishing highly in S&E[4].

- Publications: participants who had authored or co-authored at least nine refereed science or engineering articles between the time they obtained their terminal degree and 2003 or at least 1.3 articles per year on average during this time were classified as accomplishing highly in S&E[5].

[2]12% of participants in the sample met this criterion.
[3]30% of participants in the sample met this criterion.
[4]10% of the sample met one of these criteria for patents obtained by 2003.
[5]10% of the sample met one of these criteria for articles authored or co-authored by 2003.

Participants who had not been classified as accomplishing highly in S&E based on 11-year follow-up data were reclassified if their 16-year patent or publication data indicated that they were accomplishing highly in S&E at that time. Because taking multiple sequential postdoctoral research positions is commonplace in the physical sciences, participants who indicated they were still in training in 2003 ($n = 36$), were classified on the basis of their 16-year data and additional data that were found about their current positions online. Thirty-three of these participants were found, and 10 of them were reclassified as highly accomplished in S&E on the basis of these new data. Across the five data sets, this procedure resulted in an average of 207 men (56%) and 142 women (41%) who were classified as highly accomplished in S&E careers and 160 men and 205 women who were not.

Among the group of participants who were not highly accomplished in S&E, 66% of the men and 62% of the women were employed in S&E areas. Figure 5 shows distributions of various career outcomes of those who were highly accomplished in S&E and other participants: income, patents obtained, peer-reviewed scientific articles authored or co-authored, and h-index.

Profile Analyses

Research has shown that people with similar psychological profiles tend to gravitate to similar careers (Dawis, 1991; Dawis & Lofquist, 1984; Hansen & Campbell, 1985; L. W. Harmon, 1989; Snow, Corno, & Jackson III, 1996). One of the aims of this study was to assess whether there were any differences in profiles of cognitive abilities, personality traits, vocational interests, and lifestyle preferences between the

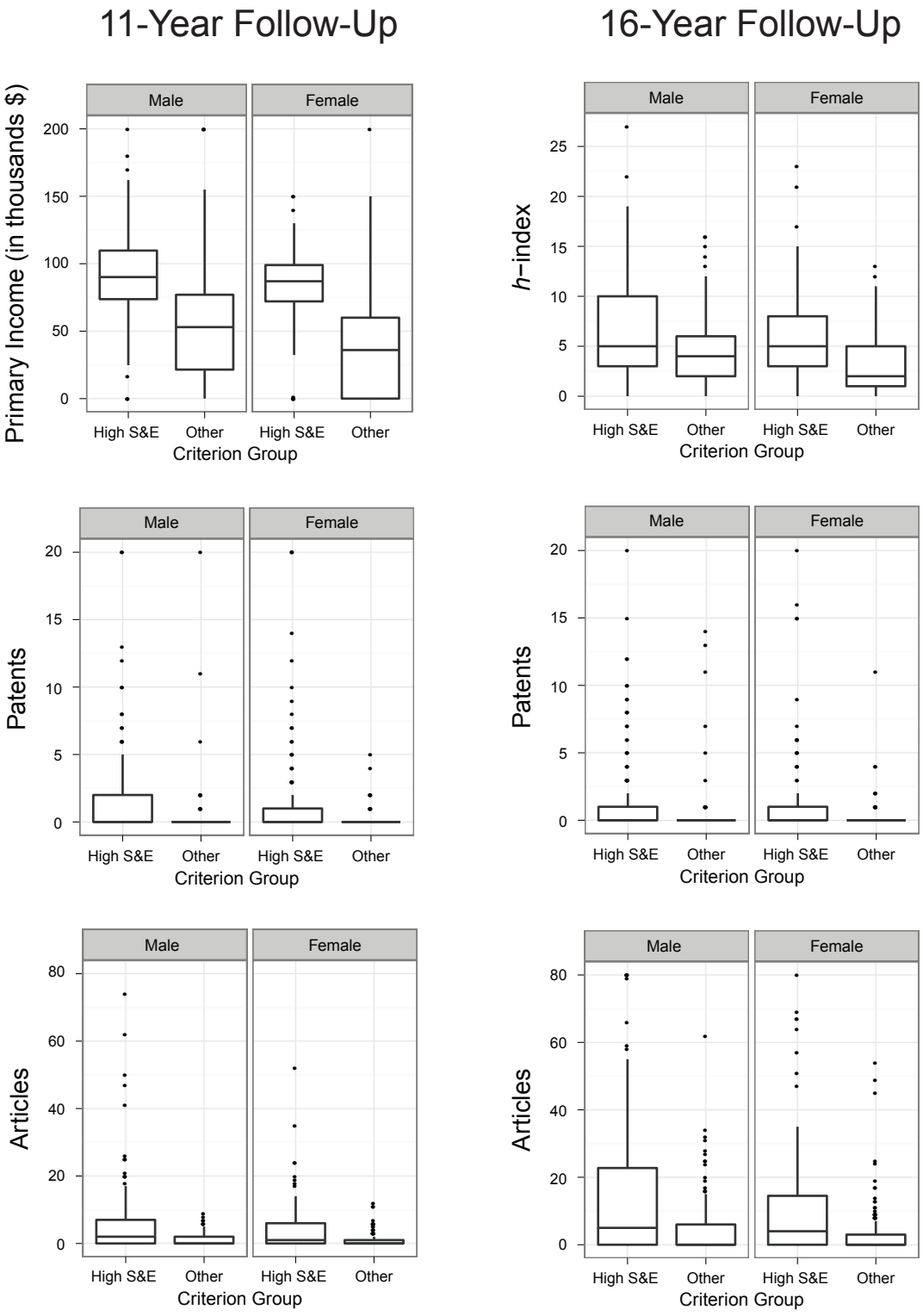

Figure 5: Comparison of career outcomes of highly accomplishing S&E group and other group.

participants who were accomplishing highly in S&E and their peers. Therefore, I used profile analysis as described in R. A. Johnson and Wichern (2002, pp. 318–323) to assess differences in mean profiles of the two groups, within sex, for each battery, or group of p scales with similar units. Mean profiles and pooled covariance matrices for each group were generated across imputed data sets using procedures described in Enders (2010), and these pooled values were used in the analysis of profiles. This procedure involved an F-test for parallel profiles, and, if the profiles were parallel, a second F-test for a difference in the levels of the profiles. If the profiles did not differ statistically significantly, then they were deemed coincident. For more details, see Appendix D.

Logistic Regression Analyses

A second type of analysis I used was logistic regression as implemented in the Zelig package for R (Imai, King, & Lau, 2007; Imai, King, & Stuart, 2008). Logistic regression was used to examine the relationships between high accomplishment in S&E and life circumstances, the joint influence of cognitive abilities, creative personality, and vocational interests on high accomplishment in S&E, and the joint influence of these individual differences variables and life circumstances on high accomplishment in S&E. I evaluated and compared models in several ways: I evaluated models overall

within imputations, I examined the discrimination[6] and calibration[7] of the combined models when applied to the average data set, I examined the statistical significance of individual predictors in the combined models, and I plotted the data from the average data set and the combined model to examine global and local fit.

Several statistics and tests to evaluate logistic models overall are readily available only for the models generated to fit the individual imputed data sets. Examples include the likelihood ratio test and the AIC (Akaike Information Criterion). While these pieces of information are useful for evaluating how individual models perform within imputed data sets, they are not easily computed for the single model that results from combination of the models that are generated for the individual imputed data sets. I presented the results of the likelihood ratio tests and the AICs, but more information is needed to assess the performance of the combined model. Therefore, I also performed the Hosmer-Lemeshow decile test to evaluate and compare the calibration of the combined models when they are applied to the average data set; generated ROC curves and computed the areas under the curves, or *c* statistics, as implemented in the pROC package for R (Robin et al., 2011), to evaluate and compare the discrimination of the combined models[8] when they are applied to the average data set (Figure 6 presents a typical ROC curve plot); and assessed the

[6]A model's discrimination is how well it can separate those who do and do not, in this case, become highly accomplished in S&E (Harrell, 2001). Model discrimination can be measured with the *c* statistic, or the area under a ROC curve. In this case, the *c* statistic is the chance that a predicted probability is higher for a participant who is highly accomplishing in S&E than for a participant who is not. Possible values range from 50% to 100%.

[7]A model's calibration is how well predicted probabilities correspond with observed proportions of participants who have become highly accomplished in S&E (Harrell, 2001). Model calibration can be measured with the Hosmer-Lemeshow statistic (Hosmer & Lemeshow, 2000).

[8]While ROC curves are not used much to evaluate individual differences variables, they are not unheard of in individual differences research (Humphreys & Swets, 1991).

statistical significance of individual predictors in the combined models using Wald z-tests. Finally, I plotted data from the average data set in order to assess visually the relationships between predictors and high accomplishment in S&E and the global and local fit of the combined model. Plots included scatterplots of the data, loess smoothed proportion curves, 100 bootstrapped loess smoothed proportions for each smoothed proportion curve (i.e., an approximate empirical confidence interval), and model-implied probability curves, all presented by sex. Figure 7 presents a panel from a typical figure.

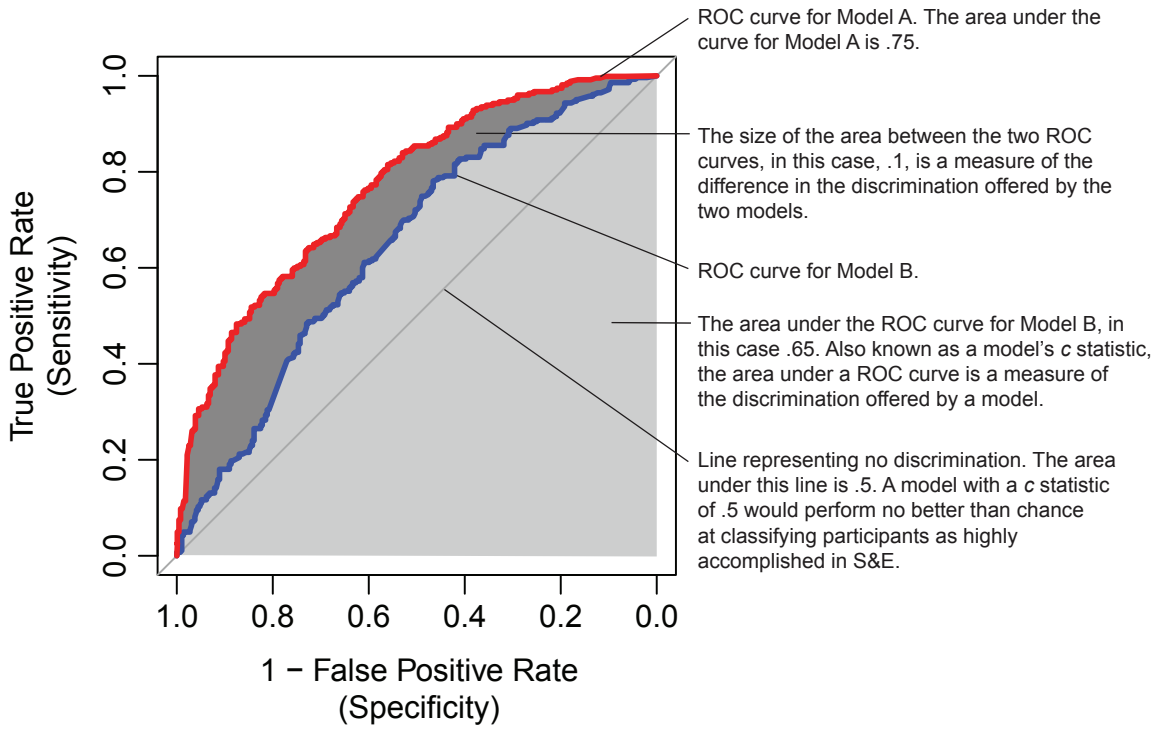

Figure 6: A typical ROC curve plot, showing the ability of each model to discriminate between the group of participants that is highly accomplished in S&E and the group that is not. When logistic regression analysis is used, each model generates predicted probabilities between 0 and 1. One approach to assessing how well the model discriminates between participants who were highly accomplished in S&E and other participants might involve choosing a single cutoff for classifying participants as highly accomplished in S&E, such as .5, and then looking at what proportion of the people with predicted probabilities above and below .5 are actually highly accomplished in S&E. A ROC curve shows how well the model discriminates at every possible cutoff value. A ROC curve is a plot of one minus the false positive rate (or the specificity; on the x-axis) and the true positive rate (or the sensitivity; on the y-axis) at each possible cutoff point. The model with the largest area under the ROC curve offers maximal discrimination between groups across cutoff points.

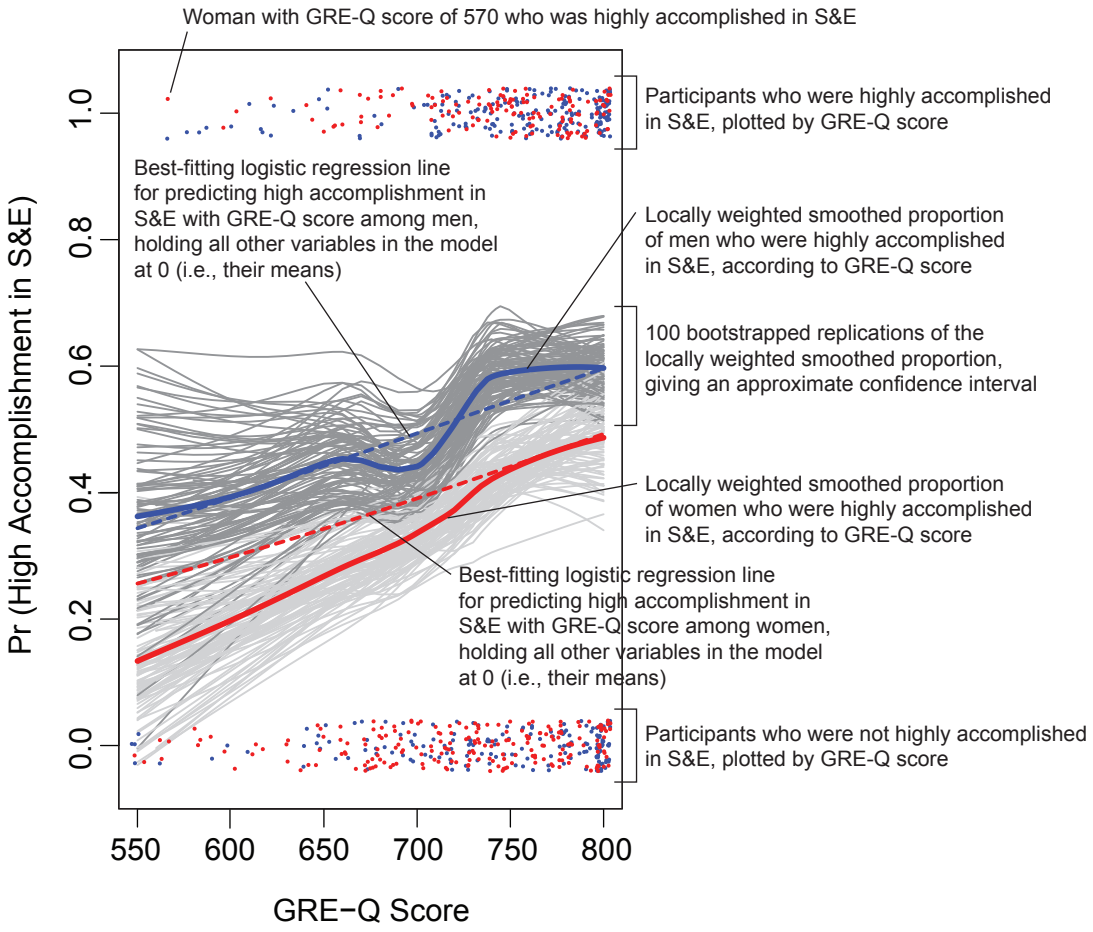

Figure 7: A panel from a typical plot, showing both the data and the model.

Chapter III

RESULTS

Among Profiles of Traditional Individual Differences Variables, Cognitive Abilities and Vocational Interests Profiles Distinguish Exceptional S&E Accomplishers from their Peers

Profiles of cognitive abilities and vocational interests distinguished participants who were exceptionally accomplished in S&E from the other participants, but profiles of personality traits did not.

Cognitive Abilities

Inspection of Figure 8 indicates that participants who accomplished highly in science and engineering careers after graduate school had slightly higher mean profiles on both the GRE-Quantitative and the GRE-Verbal; however, these differences were statistically significantly different from zero at the .05 level for women but not for men (possibly due to ceiling effects that were larger among the men: In this sample, 84% of men and 73% of women obtained a score on the GRE-Quantative of at least 700. Twenty-six percent of men and 13% of women attained an 800, the top score possible). For men, the result of the test for parallelism was consistent with parallel profiles, $F(1,\ 365) = 0,\ p = 0.98$, and the result of the test for coincident profiles given parallel profiles was close to significance but consistent with coincident profiles, $F(1,\ 365) = 3.39,\ p = 0.07$. For women, the result of the test for parallelism was

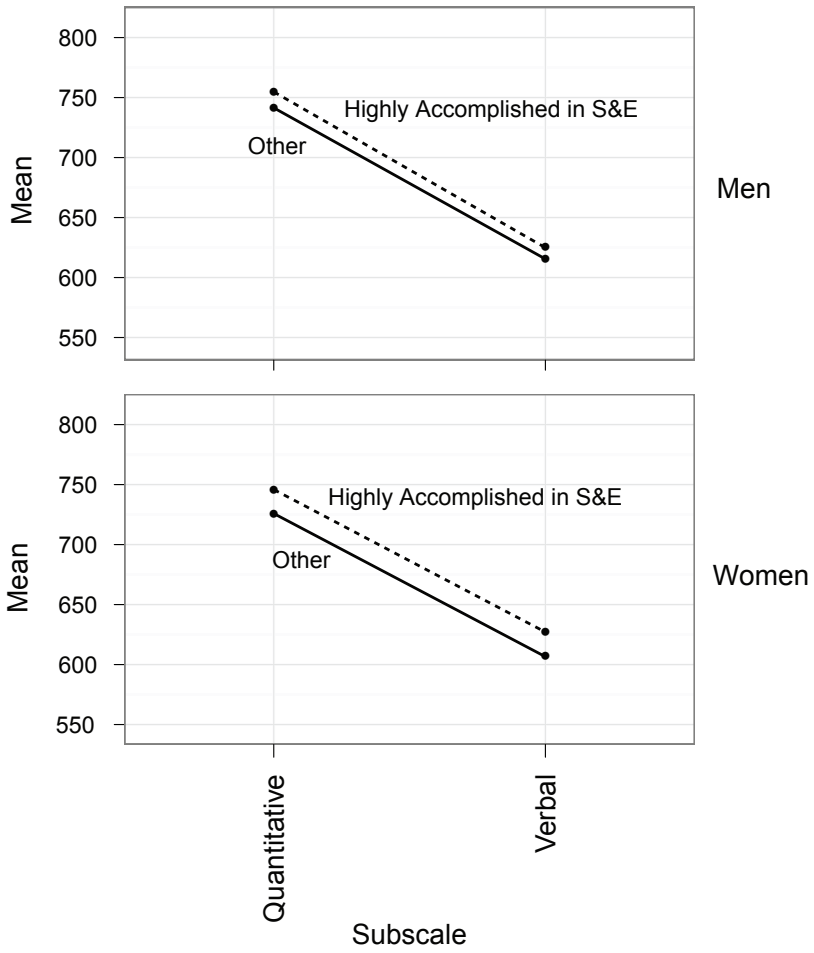

Figure 8: Average profiles from the mean data set of participants highly accomplished in S&E and other participants on the Graduate Record Exam. Possible score range: 200–800. Highly accomplished men in S&E careers $n = 206$, other men $n = 161$. Highly accomplished women in S&E careers $n = 139$, other women $n = 208$.

consistent with parallel profiles, $F(1, 345) = 0.08$, $p = 0.78$, but the result of the test for coincident profiles given parallel profiles suggested they were significantly different in level, $F(1, 345) = 6.04$, $p = 0.01$.

Personality Traits

Highly accomplishing participants in S&E careers did not significantly differ from the other participants in terms of personality traits (Figure 9). For men, the result of the test for parallelism was consistent with parallel profiles, $F(36, 330) = 0.79$, $p = 0.81$, and the result of the test for coincident profiles given parallel profiles was consistent with coincident profiles, $F(1, 365) = 1.77$, $p = 0.18$. For women, the result of the test for parallelism was consistent with parallel profiles, $F(36, 310) = 0.7$, $p = 0.9$, and the result of the test for coincident profiles given parallel profiles was consistent with coincident profiles, $F(1, 345) = 0.08$, $p = 0.78$.

Vocational Interests

Vocational interest profiles did seem to distinguish the participants who were highly accomplishing in S&E from their peers (Figures 10–11). For men, the test for parallel RIASEC profiles showed that they were significantly different, $F(5, 361) = 3.32$, $p = 0.01$. The women's RIASEC profiles also had significantly different shapes, $F(5, 341) = 2.89$, $p = 0.01$. Both men and women who were accomplishing highly in S&E careers had more interest in investigative vocations and less interest in social, enterprising, and conventional vocations on average than their same-sex peers.

With respect to their BIS profiles, the men displayed profiles that did not quite distinguish highly accomplished participants in S&E from their peers, while the women's profiles did differ. The result of the test for parallelism of the men's profiles was consistent with parallel profiles, although it was suggestive of a small difference

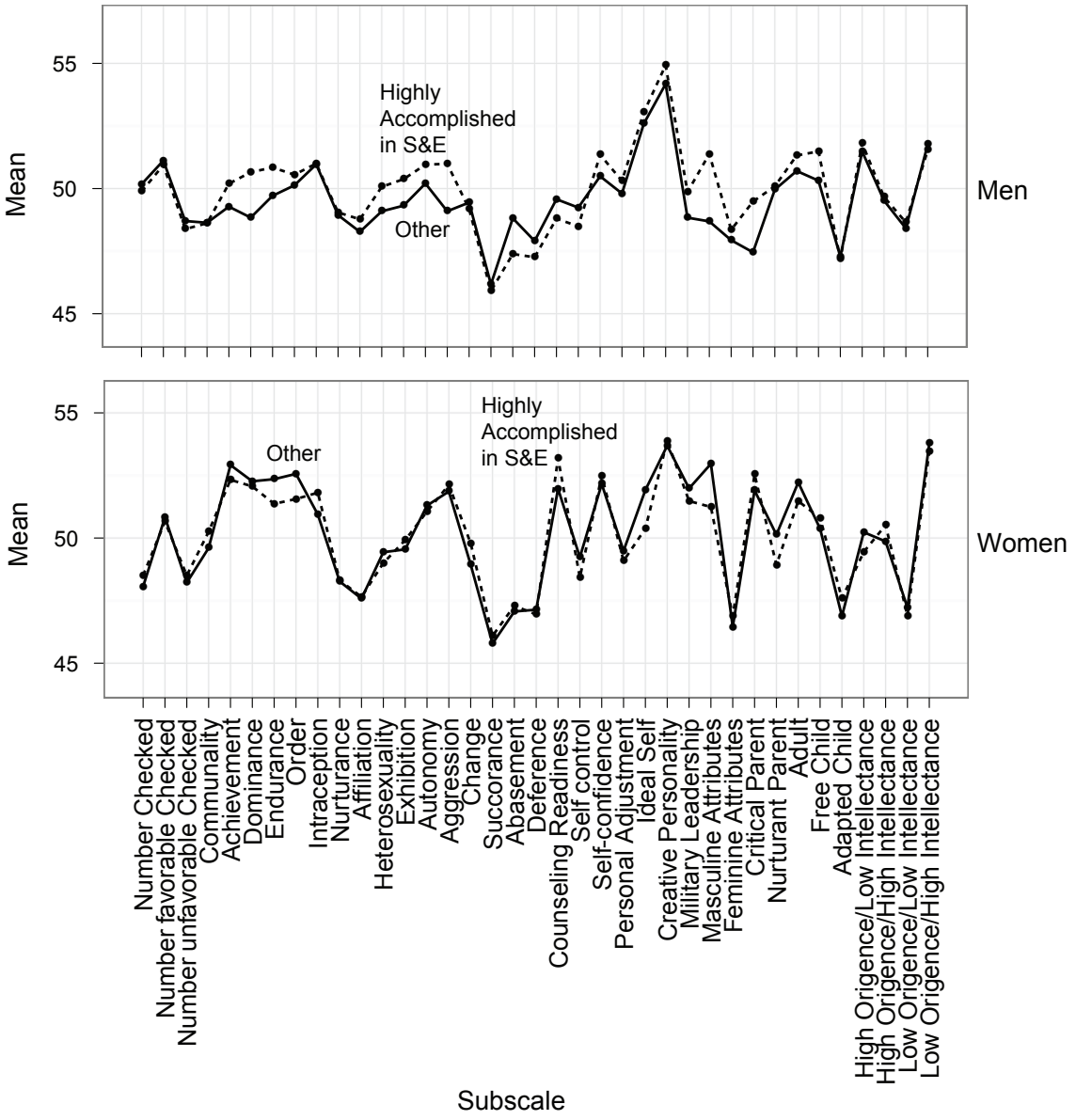

Figure 9: Average profiles from the mean data set of participants highly accomplished in S&E and other participants on the Adjective Check List. Normative mean within sex = 50, SD = 10. Highly accomplished men in S&E careers $n = 206$, other men $n = 161$. Highly accomplished women in S&E careers $n = 139$, other women $n = 208$.

in shape, $F(22,\ 344) = 1.48$, $p = 0.08$, and the result of the test for coincident profiles given parallel profiles was consistent with coincident profiles, $F(1, 365) = 0.33$, $p = 0.57$. The mean BIS profile of women who were accomplishing highly in S&E after graduate school differed in shape from that of their peers, $F(22,\ 324) = 1.81$, $p = 0.02$. Highly accomplished women in S&E careers were more interested in math, science, and mechanical activities than their peers, and less interested in social service, athletics, domestic activities, religious activities, merchandising, sales, and business management.

Among women, the cognitive abilities profiles and vocational interests profiles of those who were accomplishing highly in S&E careers differed from the profiles of their peers who were not. Among men, only RIASEC vocational interests profiles differed significantly between those participants who were accomplishing highly in S&E careers and those who were not.

Sex, Quantitative Ability, and Investigative and Reversed Social Vocational Interests Predict Accomplishment in S&E Careers

As the second aim of the study was to examine the prediction of high accomplishment in S&E with different classes of variables jointly, I examined how well sex, cognitive abilities, creative personality, and RIASEC vocational interests, all measured at the initiation of the study, predicted high accomplishment in S&E after graduate school using a logistic regression model.

This model, Model 1, combines inferences across the 5 imputed data sets and is presented in Table 3. Likelihood ratio tests of the model within each of the imputed

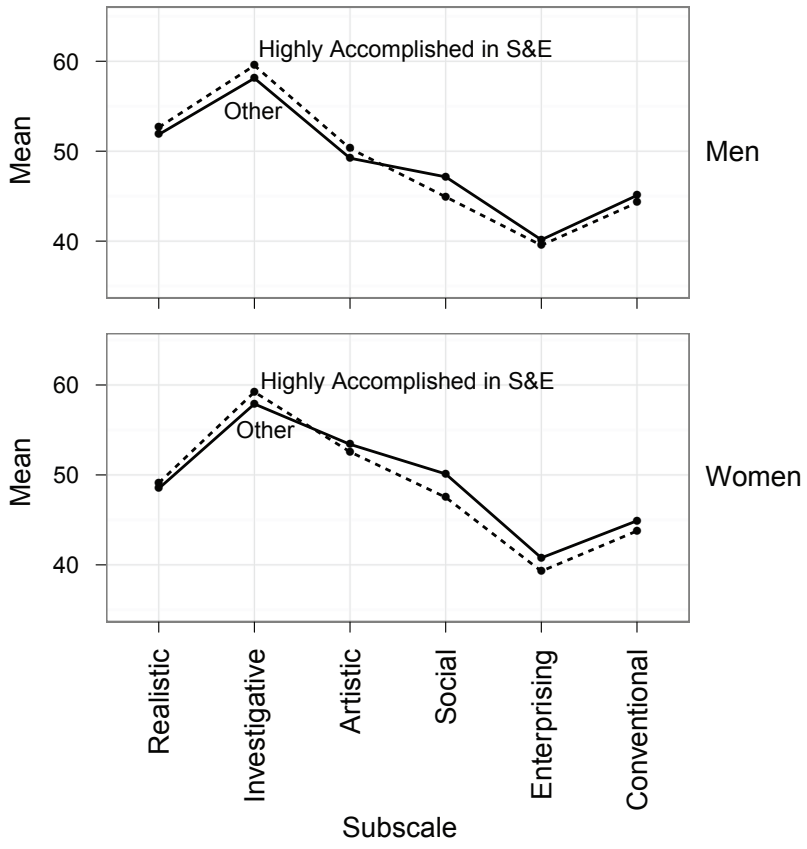

Figure 10: Average profiles from the mean data set of participants highly accomplished in S&E and other participants on RIASEC vocational interests. Normative mean = 50, SD = 10. Highly accomplished men in S&E careers $n = 206$, other men $n = 161$. Highly accomplished women in S&E careers $n = 139$, other women $n = 208$.

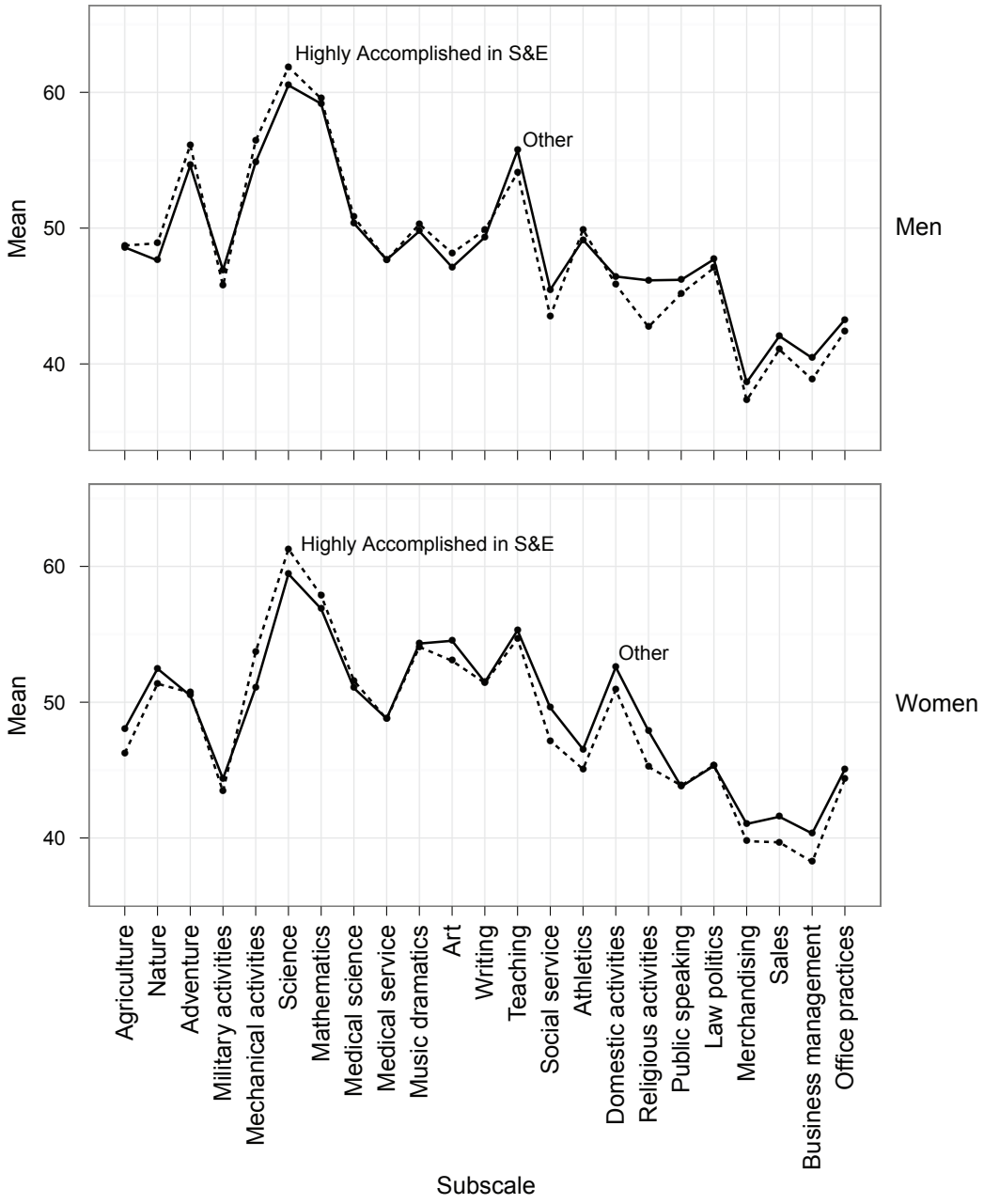

Figure 11: Average profiles from the mean data set of participants highly accomplished in S&E and other participants on the Basic Interest Scales of the Strong Vocational Interest Battery. Normative mean = 50, SD = 10. Highly accomplished men in S&E careers $n = 206$, other men $n = 161$. Highly accomplished women in S&E careers $n = 139$, other women $n = 208$.

data sets suggest this model offers a significant improvement over the null model. In the mean data set, it classified people better than chance (Figure 12), with a c statistic of 66.8%, 95% CI = 62.8–70.7%. Thirty-one percent of participants in the bottom quartile of predicted probabilities and 69% of people in the top quartile of predicted values were highly accomplished in S&E careers. With respect to the overall fit of the combined model to the mean data set, the hypothesis of good fit could not be rejected according to the Hosmer-Lemeshow goodness-of-fit test, which yielded a $\chi^2(8)$ of 6.091, $p = 0.637$.

Predictor	Coefficient	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.2731	0.1262	-2.1649	0.0151
Male	0.4187	0.1701	2.4615	0.0069
GRE-V	0.0219	0.0958	0.2290	0.4094
GRE-Q	0.2333	0.0937	2.4904	0.0064
Creative Personality	-0.0130	0.0881	-0.1480	0.4412
Realistic	0.0651	0.0949	0.6857	0.2465
Investigative	0.3615	0.0999	3.6205	0.0001
Artistic	-0.0732	0.0972	-0.7531	0.2257
Social	-0.3261	0.1032	-3.1610	0.0007
Enterprising	0.0081	0.1152	0.0703	0.4720
Conventional	-0.1205	0.1169	-1.0307	0.1513

Table 3: Logistic regression Model 1 coefficients, standard errors, and evaluation. Model 1 predicts high accomplishment in S&E from individual differences variables and sex. Male was coded as 0 for women and 1 for men. All other variables were standardized. Results are combined across 5 imputed data sets. Range of likelihood ratio tests within imputed data sets $\chi^2(10) = 52.817$–61.336, $p = .0000$–$.0000$. Range of AIC = 952.025–959.377.

Sex, GRE-Q, and investigative and reversed social interests were significant predictors of high accomplishment in S&E after graduate school, even when their contributions were considered jointly. Figure 13 shows the relationships of these

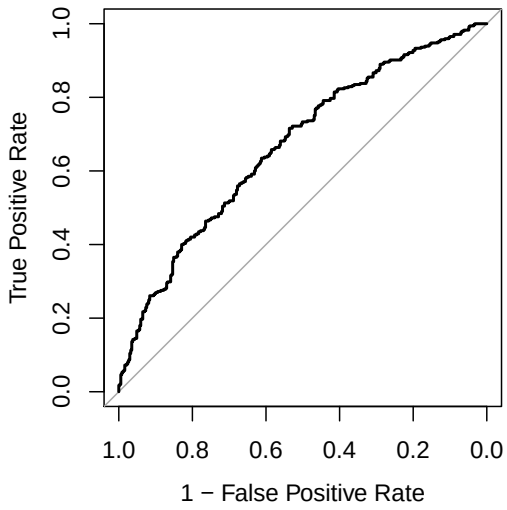

Figure 12: ROC curve showing classification performance of Model 1, which predicts high accomplishment in S&E from individual differences variables and sex. The c statistic, or area under the curve, is 66.8%; 95% CI = 62.8–70.7%.

variables to high accomplishment in S&E, plotting both the data and the model-implied best-fitting regression lines for men and women. In each panel, the best-fit line shows the relationship between the variable on the x-axis and accomplishment in S&E where the other variables are equal to 0 (i.e., at the sample mean, because the variables are standardized). According to this model, all other things being equal, a man had a .1 higher probability of being highly accomplished in S&E than a woman did. An increase of 1 SD (57 points) in GRE-Q score garnered an increase in a person's probability for high accomplishment in S&E of .06. An increase of 1 SD (6 points) in investigative interests resulted in an increase in a person's probability of high accomplishment in S&E of .09. Finally, an increase of 1 SD (10 points) in social interests reduced a person's probability of high accomplishment in S&E by .08.

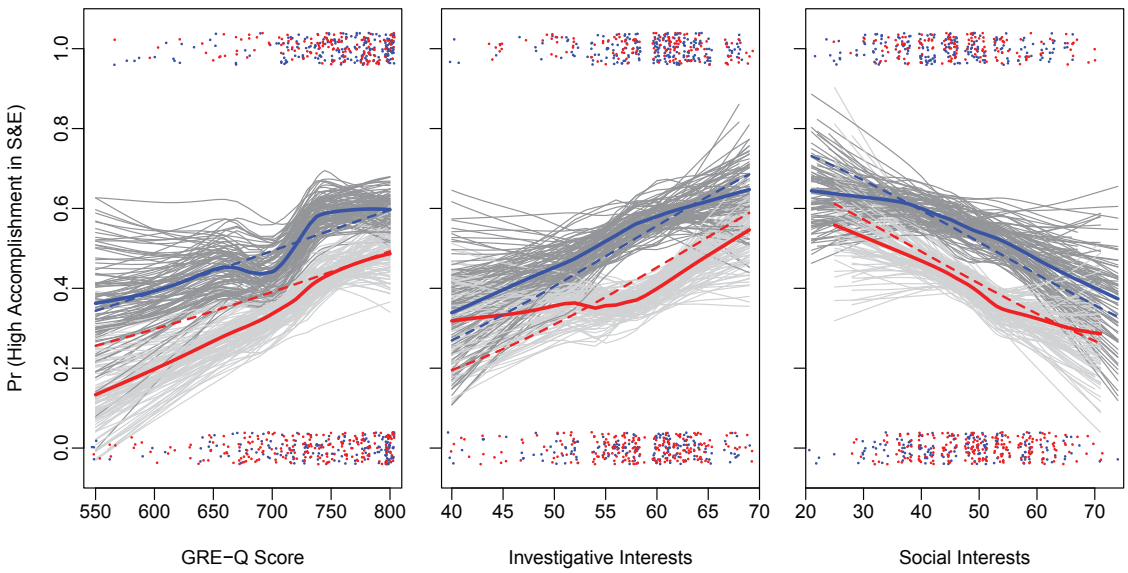

Figure 13: Relationships of GRE-Q, investigative vocational interests, and social vocational interests to propensity for high accomplishment in S&E. For investigative interests and social interests the normative population means = 50, SD = 10. Blue dots and lines represent men, red dots and lines represent women. Dots at the top and bottom of each panel represent individual participants who are highly accomplished in S&E and those who are not, respectively. Thick lines are locally weighted smoothed proportions of men and women who accomplished highly in S&E careers. Gray lines are 100 bootstrapped locally weighted smoothed proportions. Dotted lines show proportions of men and women who were highly accomplished in S&E estimated by Model 1, with all other variables held at their means. Highly accomplished men in S&E careers $n = 206$, other men $n = 161$. Highly accomplished women in S&E careers $n = 139$, other women $n = 208$.

Several things may be noted about Figure 13. First, examination of the individual data points at the top and bottom of the figure shows the ceiling effect present in the GRE-Q scores: most of the points are clustered within 100 points of the top score. In contrast, neither investigative interests nor social interests demonstrate ceiling or floor effects in this sample. Second, comparison of the best-fit regression lines with the smoothed proportions of men and women who were highly accomplishing in S&E careers confirms that the model fits reasonably well for men and women. Departures from fit occur mostly where data are sparse in this sample. However, one unexpected result is that the relationship of GRE-Q to high accomplishment in S&E evident in the smoothed proportion curve was not stronger among men with scores > 730. If, as one might anticipate based on the literature, the relationship between quantitative ability and probability of high accomplishment in S&E were the same across the whole range of quantitative ability, one would expect to see a *stronger* relationship above scores of 730 between GRE-Q and accomplishment in S&E because of this ceiling effect, not one as weak as is present here. Follow-up analyses showed that men with these scores were also likely to pursue high-accomplishing careers outside of S&E—in patent law, management consulting, or finance, for example, which might explain the unexpectedly low relationship between GRE-Q and probability of high accomplishment in S&E among top scorers.

Lifestyle Preferences Profiles at Age 25 and Age 36 Distinguish Women Who Are Highly Accomplishing in S&E Careers from their Peers

Men who were accomplishing highly in S&E displayed profiles of lifestyle preferences coincident with those of their peers (Figure 14), but the women who were highly accomplishing in S&E demonstrated different profiles from the other women (Figure 15). For men, the result of the test for parallelism of the 1992 lifestyle preferences profiles was consistent with parallel profiles, $F(8, 358) = 0.48$, $p = 0.87$, and the result of the test for coincident profiles given parallel profiles was consistent with coincident profiles, $F(1, 365) = 0.62$, $p = 0.43$. For women, the test for parallelism of the 1992 profiles showed they were statistically significantly different $F(8, 338) = 2.2$, $p = 0.03$. Women who were accomplishing highly in S&E careers 11–16 years later rated success and autonomy as more important, and friendships, children, limited full-time work hours, leadership at work or in the community, having a high salary or lots of money, and having a part-time career as less important than their peers did.

With respect to profiles of their 2003 lifestyle preferences, for men, the result of the test for parallelism of the profiles was consistent with parallel profiles, $F(8, 358) = 1.38$, $p = 0.2$, and the result of the test for coincident profiles given parallel profiles was consistent with coincident profiles, $F(1, 365) = 2.71$, $p = 0.1$. For women, the test for parallel profiles showed they were significantly different, $F(8, 338) = 3.29$, $p = 0.001$. Highly accomplished women in S&E careers placed more importance on success in their careers, having a high salary, and having a prestigious job or employer, while their peers placed more importance on children and having limited work hours.

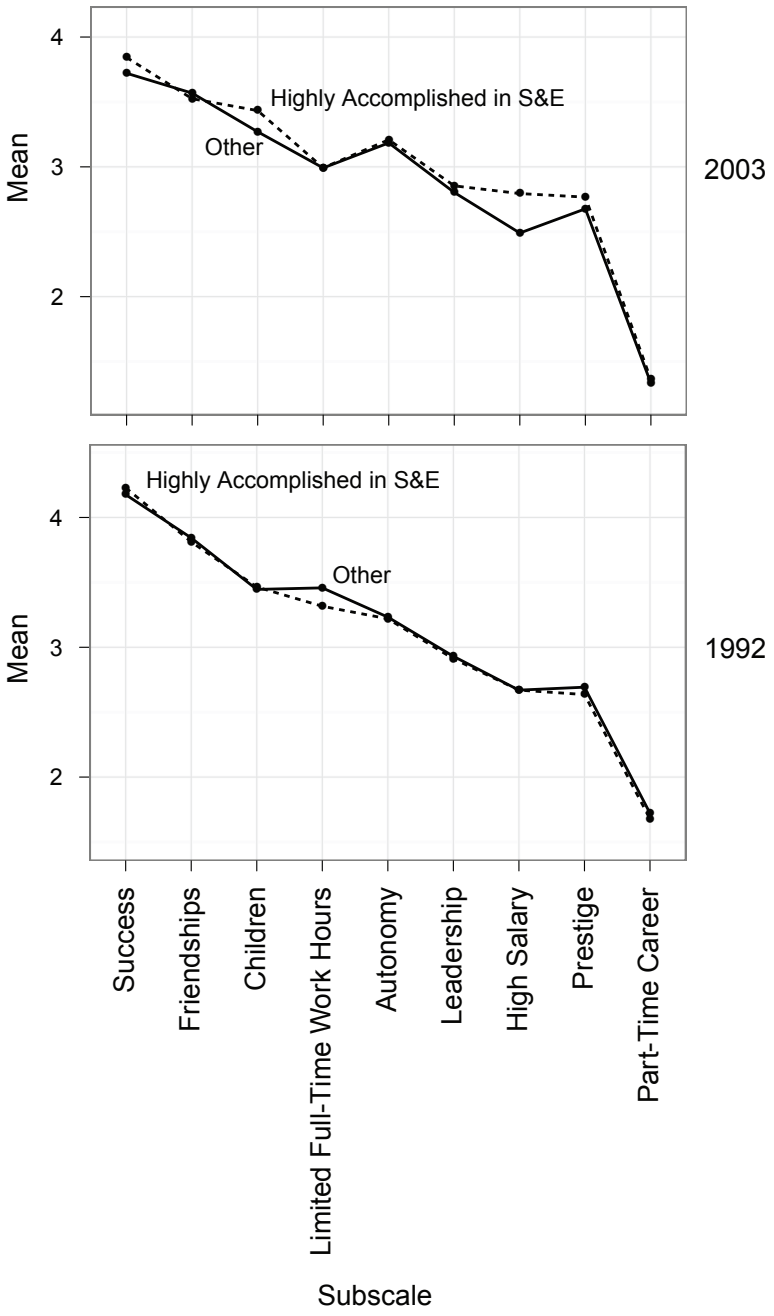

Figure 14: Average profiles from the mean data set of men highly accomplished in S&E and other men on the lifestyle preferences scales developed for this study. 1 = Not important at all, 2 = A little important, 3 = Important, 4 = Very important, 5 = Extremely important. Highly accomplished men in S&E careers $n = 206$, other men $n = 161$.

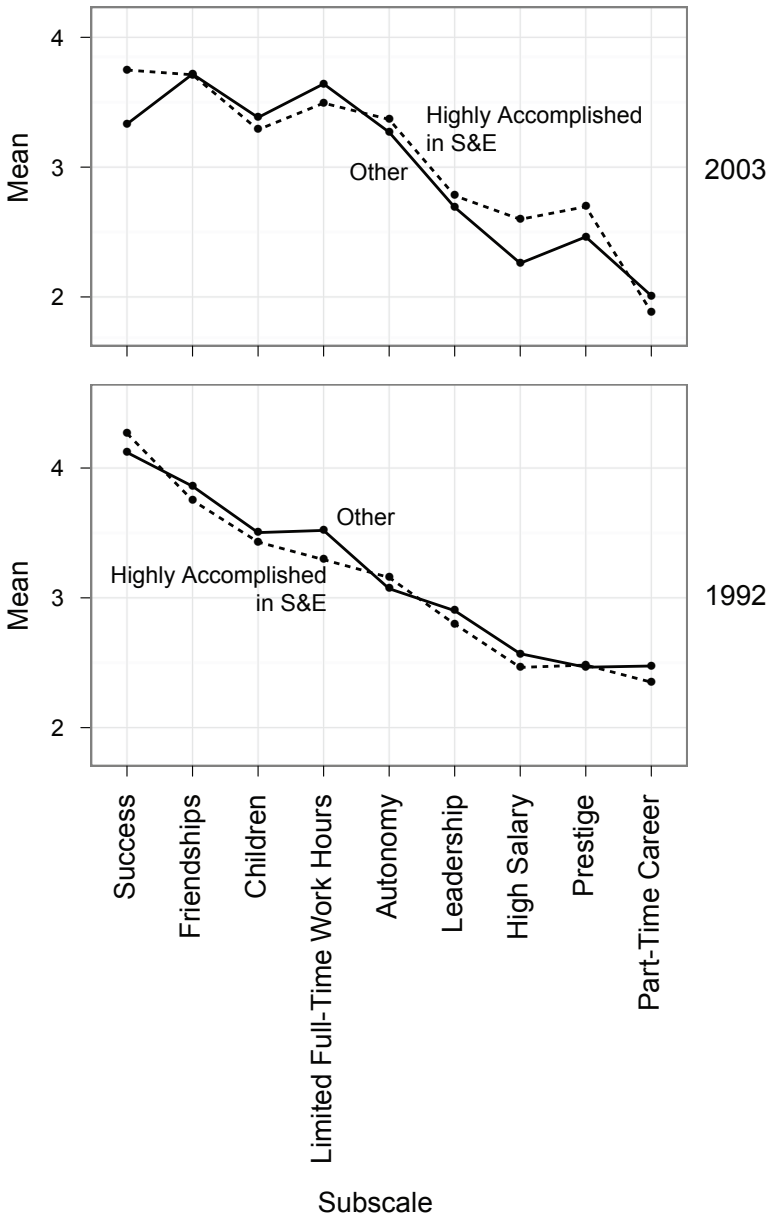

Figure 15: Average profiles from the mean data set of women highly accomplished in S&E and other women on the lifestyle preferences scales developed for this study. 1 = Not important at all, 2 = A little important, 3 = Important, 4 = Very important, 5 = Extremely important. Highly accomplished women in S&E careers $n = 139$, other women $n = 208$.

Parenthood is Moderated by Sex in its Relationship to Accomplishment in S&E Careers

Marital status and parenthood seem to be especially relevant to accomplishment in S&E careers. However, because most participants were not yet parents at the time of the initial survey, I examined the relationships of marital status and parenthood at the time of the 11-year follow-up to high accomplishment in S&E after graduate school.

Eighty-five percent of men who were accomplishing highly in S&E after graduate school were married at that time, compared with 73% of men who were not accomplishing highly in S&E. Among women, 78% of those who were accomplishing highly in S&E after graduate school were married, compared with 84% percent of their female peers.

The vast majority of participants with children were married (95%). Fifty-eight percent of the highly accomplished men in S&E careers had children, vs. 43% percent of their peers. Forty-two percent of the highly accomplishing women in S&E careers had children, vs. 53% percent of their peers.

In a second logistic regression model (Model 2), I examined the contributions of sex, marital status, and parenthood, along with interactions of marital status and parenthood with sex, to prediction of high accomplishment in S&E careers. This model combines inferences across the 5 imputed data sets and is presented in Table 4. Likelihood ratio tests of the model within each of the imputed data sets suggest this model offers a significant improvement over the null model. It classified people better than chance, with a c statistic of 62.2%, 95% CI = 58.2–66.3%, but worse than

Model 1 ($Z = 2.008$, $p = .045$; Figure 16). Thirty-four percent of participants in the bottom quartile of predicted probabilities and 64% of participants in the top quartile of predicted probabilities were highly accomplished in S&E careers. The Hosmer-Lemeshow goodness-of-fit test was not appropriate for this model, as it had no continuous predictors. However, in the mean data set, most predicted probabilities lay within 3 percentage points of the actual proportions of participants who were accomplishing highly in S&E. Predictions among married participants fit better, because most participants were married at the time of the follow-up ($n = 575$).

Predictor	Coefficient	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.1473	0.2593	-0.5682	0.2850
Male	-0.0810	0.4099	-0.1976	0.4217
Married	-0.0266	0.3651	-0.0729	0.4709
Parent	-0.4087	0.2915	-1.4022	0.0804
Male x Married	0.4165	0.5304	0.7853	0.2161
Male x Parent	0.7722	0.3437	2.2470	0.0123

Table 4: Logistic regression Model 2 coefficients, standard errors, and evaluation. Model 2 predicts high accomplishment in S&E from marriage, parenthood, and sex. Male, parent, and married were coded 0 or 1, with 0 assigned to women, childless participants, and single, separated, divorced, and widowed participants, and a 1 assigned to men, parents, and married participants. Results are combined across 5 imputed data sets. Range of likelihood ratio tests $\chi^2(5) = 26.144$–39.490, $p = .0000$–$.0000$. Range of AIC = 962.705–977.580.

Unlike in the previous model, sex was not a statistically significant predictor of high accomplishment in S&E. However, the coefficient for the interaction of sex and parenthood status was statistically significantly different from zero. Figure 17 shows the relationships of these variables to high accomplishment in S&E, plotting both the data and the model.

Although the coefficient for the interaction of sex and marital status was not

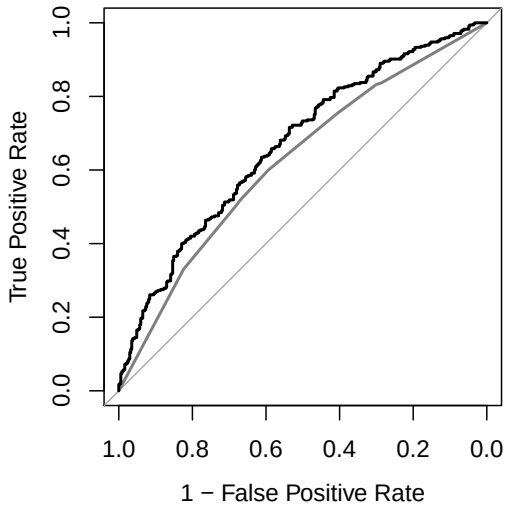

Figure 16: ROC curve showing classification performance of Model 2 (grey) in comparison with Model 1 (black) for prediction of high accomplishment in S&E. The c statistic for Model 2 is 62.2%; 95% CI = 58.2–66.3%. The c statistic for Model 1 is 66.8%. Model 1 offers better discrimination than Model 2 does according to DeLong's (1988) test for two correlated ROC curves ($Z = 2.008$, $p = .045$).

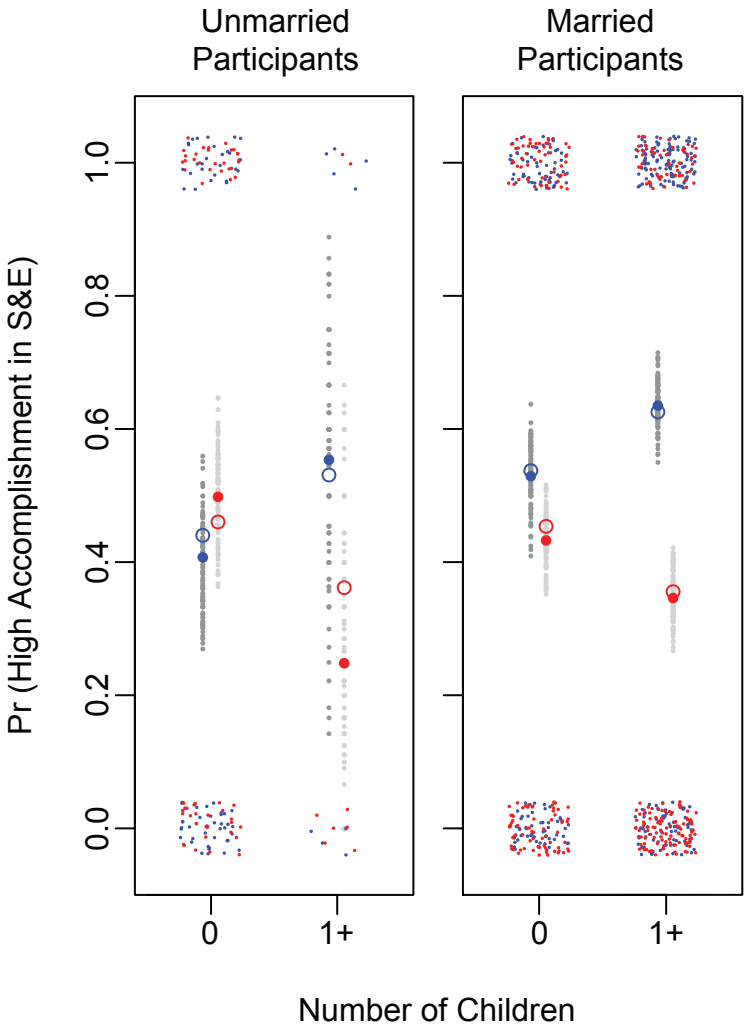

Figure 17: Relationships of sex, marital status, and parenthood to propensity for high accomplishment in an S&E career. Blue dots represent men, red dots represent women. Dots at the top and bottom of each panel represent individual participants who are highly accomplished in an S&E career and those who are not, respectively. Large red and blue dots are smoothed proportions of men and women, respectively, who accomplished highly in S&E careers. Gray dots are 100 bootstrapped proportions. Open circles show the proportions of men and women who were estimated by Model 2 to be highly accomplished in S&E careers. Highly accomplished men in S&E careers $n = 206$, other men $n = 161$. Highly accomplished women in S&E careers $n = 139$, other women $n = 208$.

statistically significant, it is worth noting that unmarried women without children were as likely or more likely than unmarried men without children to be highly accomplished in S&E, and that this trend was reversed among married participants and parents. The greatest difference between men and women in propensity for high accomplishment in an S&E career occurred between married fathers and married mothers. Married mothers had between a 25% chance and a 45% chance of being highly accomplished in S&E, while the range of probabilities for married fathers was 55–75%. Additionally, fathers were more likely than their same-sex peers to be highly accomplishing in S&E, while mothers were less likely than their same-sex peers to be so.

Quantitative Ability, Investigative Interests, and Reversed Social Interests Predict High Accomplishment in S&E; Fathers are More Likely to Be Highly Accomplishing in S&E than Mothers with the Same Quantitative Ability, Investigative Interests, and Reversed Social Interests

In a third logistic regression model, I examined the contributions of individual differences measured at the initiation of the study and life circumstances at the 11-year follow-up on high accomplishment in S&E, combining the predictors from the previous two models into one model.

This model combines inferences across the 5 imputed data sets and is presented in Table 5. Likelihood ratio tests of the model within each of the imputed data sets suggest this model offers significant improvements over Model 1 (it offered a

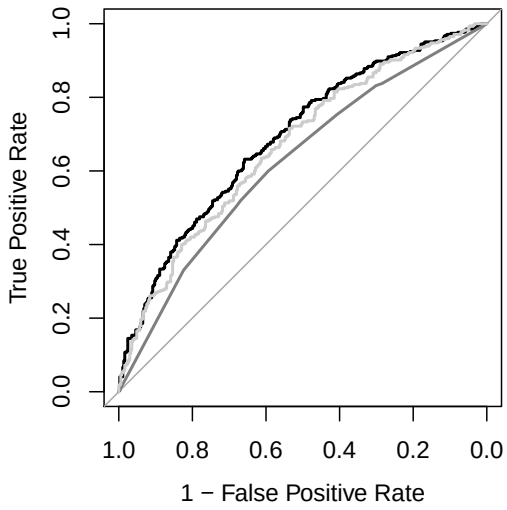

Figure 18: ROC curve showing classification performance of Model 3 (black) in comparison to Models 1 (light gray) and 2 (dark gray) for prediction of high accomplishment in S&E. The c statistics for Models 1, 2, and 3 were 66.8%, 62.2%, and 69.0%; Model 3 95% CI = 65.2–72.9%. Model 3 offers a significant improvement in discrimination over Model 1 ($Z = 2.36$, $p = .018$) and Model 2 ($Z = 3.93$, $p < .0001$) according to DeLong's (1988) test for two correlated ROC curves .

significant improvement in 4 out of 5 data sets) and Model 2. In the mean data set, it classified people significantly better than Model 1 ($Z = 2.36$, $p = .018$) and Model 2 ($Z = 3.93$, $p < .0001$), (Fig. 18), with a c statistic of 69.0%. Twenty-seven percent of participants in the bottom quartile of predicted probabilities and 71% of those in the top quartile of predicted probabilities were highly accomplished in S&E. Table 6 compares Models 1, 2, and 3 in terms of the proportions of participants in the top and bottom quartiles of predicted probabilities that were highly accomplishing in S&E careers. The overall model fit of the combined model to the mean data set was good according to the Hosmer-Lemeshow goodness-of-fit test, which yielded a $\chi^2(8)$ of 4.023 and was insignificant ($p = 0.855$).

Predictor	Coefficient	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.1311	0.2786	-0.4704	0.3190
Male	-0.3200	0.4047	-0.7907	0.2146
GRE-V	0.0072	0.1000	0.0716	0.4714
GRE-Q	0.2536	0.0947	2.6780	0.0037
Creative Personality	-0.0175	0.0916	-0.1908	0.4244
Realistic	0.0674	0.0968	0.6968	0.2430
Investigative	0.3643	0.0999	3.6451	0.0001
Artistic	-0.0713	0.0986	-0.7233	0.2347
Social	-0.3293	0.1019	-3.2327	0.0006
Enterprising	0.0128	0.1163	0.1097	0.4563
Conventional	-0.1334	0.1183	-1.1279	0.1297
Married	0.0236	0.3913	0.0604	0.4759
Parent	-0.3217	0.3067	-1.0487	0.1472
Male x Married	0.5174	0.5309	0.9746	0.1649
Male x Parent	0.6773	0.3602	1.8802	0.0300

Table 5: Logistic regression Model 3 coefficients, standard errors, and evaluation. Model 3 predicts high accomplishment in S&E from individual differences variables and marriage, parenthood, and sex. Male, parent, and married were coded 0 or 1, with 0 assigned to women, childless participants, and single, separated, divorced, and widowed participants, and a 1 assigned to men, parents, and married participants. All other variables were standardized. Results are combined across 5 imputed data sets. Range of likelihood ratio tests comparing Model 3 to Model 1 $\chi^2(4) = 7.327$–22.074, $p = .0001$–$.1196$. Range of likelihood ratio tests comparing Model 3 to Model 2 $\chi^2(9) = 35.401$–42.112, $p = .0000$–$.0000$. Range of AIC = 945.304–953.495.

GRE-Q and investigative and reversed social interests were statistically significant predictors of high accomplishment in an S&E career after graduate school, even when their contributions were considered jointly with marriage and parenthood. Although the parenthood by sex interaction was statistically significant in Model 2, its coefficient decreased slightly when it was incorporated into this model and was therefore no longer statistically significant. As in Model 2, the interaction of sex and marital status was not statistically significant. Figure 19 shows the relationships of quantitative ability, investigative interests, and social interests to propensity for being

Model	Q1 %	Q4 %
1	31	69
2	34	64
3	27	71

Table 6: Comparison of Models 1, 2, and 3 in terms of the proportion of participants in the top and bottom quartiles of predicted probabilities who were highly accomplished in S&E careers.

highly accomplished in an S&E career among single participants, married childless participants, and married participants with children. The parenthood by sex interaction is not statistically significant, and the propensities for high accomplishment in S&E do not differ for men and women who are unmarried without children and who are married without children; however, the men and women who are married and do have children have significantly different propensities for high accomplishment in S&E careers at the same levels of quantitative ability and investigative and social interests, as indicated by the lack of overlap in their bootstrapped confidence bands in regions with higher concentrations of data points.

Spouse's Income is Related to Accomplishment in S&E; the Functional Form Differs for Men and Women

Spouse's income also seems to be a variable that is relevant to accomplishment in an S&E career. I examined the relationship between spouse's income and accomplishment in an S&E career among married participants only (average n across datasets = 558).

The average annual income of the spouses of highly accomplishing men in S&E

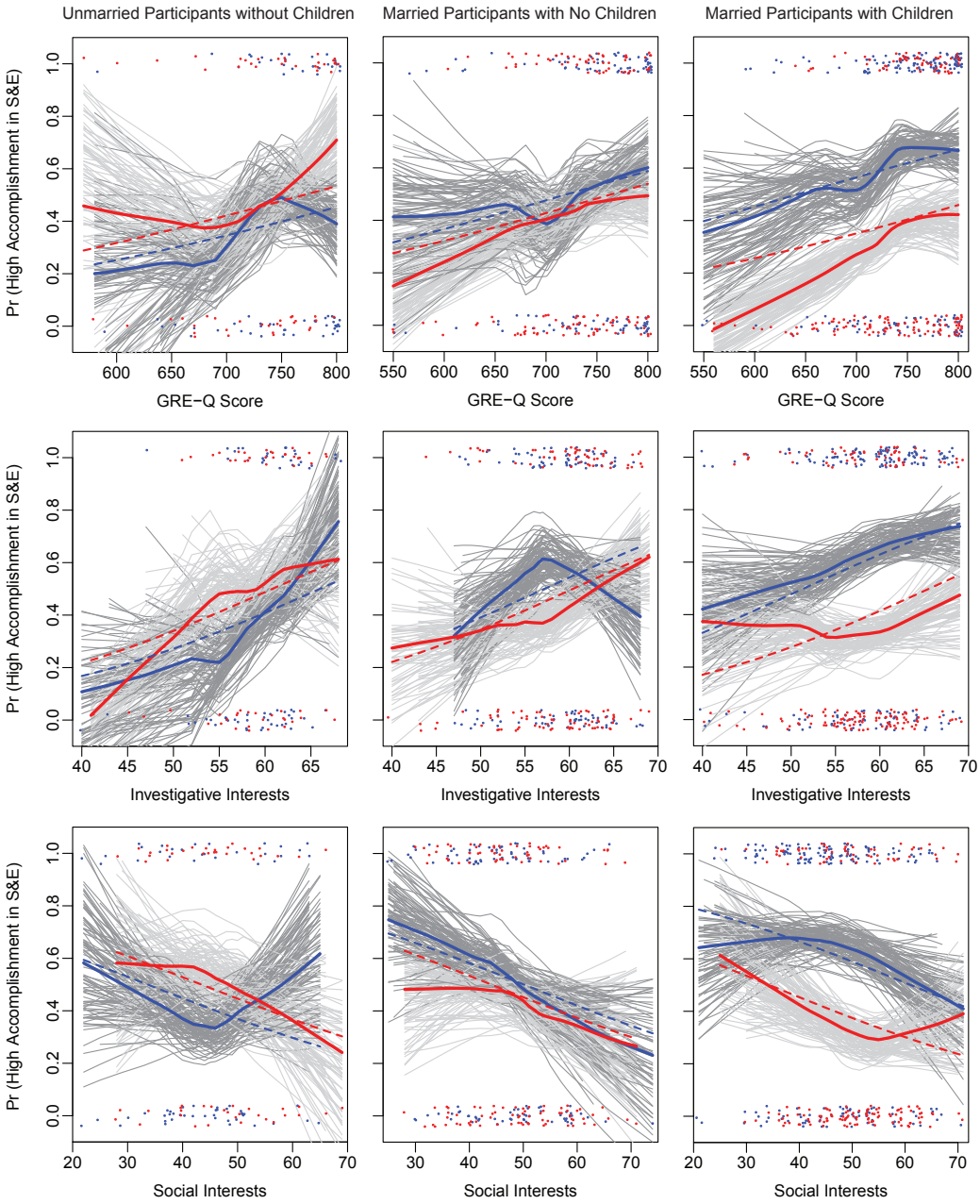

Figure 19: Relationships of sex, marital status, parenthood, GRE-Q, investigative vocational interests, and social vocational interests to propensity for high accomplishment in an S&E career. Normative means of investigative interests and social interests = 50, SD = 10. Blue and red dots represent individual men and women, respectively participants. Thick blue and red lines are smoothed proportions of men and women, respectively, who were highly accomplished in S&E careers. Gray lines are 100 bootstrapped smoothed proportions. Blue and red dotted lines show proportions of men and women, respectively, who are accomplishing highly in S&E as estimated by Model 3, with all other variables held at their means. Highly accomplished men in S&E careers $n = 206$, other men $n = 161$. Highly accomplished women in S&E careers $n = 139$, other women $n = 208$.

careers was $42,877 vs. $39,999 for the spouses of the remaining men. The average annual spouse's income of highly accomplishing women in S&E careers was $82,276 vs. $65,465 for the spouses of the remaining women.

To assess the value added by including spouse's income as a predictor, I ran a series of logistic regression analyses that paralleled those previously discussed but included married participants only, and included spouse's income as a predictor where appropriate. Like Model 1, Model 1a included sex, cognitive abilities, and vocational interests. Like Model 2, Model 2a included sex, parenthood, and spouse's income, with interactions. Finally, as Model 3 included all variables from Models 1 and 2, Model 3a included all of the variables from Models 1a and 2a.

These models are presented in Tables 8 – 10. Likelihood ratio tests of the models within each of the imputed data sets suggest Models 1a and 2a offer significant improvement over the null model, and that Model 3a offers significant improvement over Model 2a but not Model 1a (improvement over Model 1a was significant in 2 out of the 5 data sets). In the mean data set, Model 3a classified participants best (Fig. 20), with a c statistic of 70.7%; 95% CI = 66.5–74.9%, but not significantly better than Model 1a, which had a c statistic of 69.0%; 95% CI = 64.7–73.2%. Table 7 compares Models 1a, 2a, and 3a in terms of the proportions of participants in the top and bottom quartiles of predicted probabilities that were highly accomplishing in S&E careers. All three combined models fit the mean data set well, according to the Hosmer-Lemeshow goodness-of-fit test, which yielded a $\chi^2(8)$ of 3.226 for Model 1a ($p = 0.919$), of 7.481 for Model 2a ($p = 0.486$), and of 7.078 for Model 3a ($p = 0.528$).

Model diagnostics suggest that spouse's income does not seem to add much

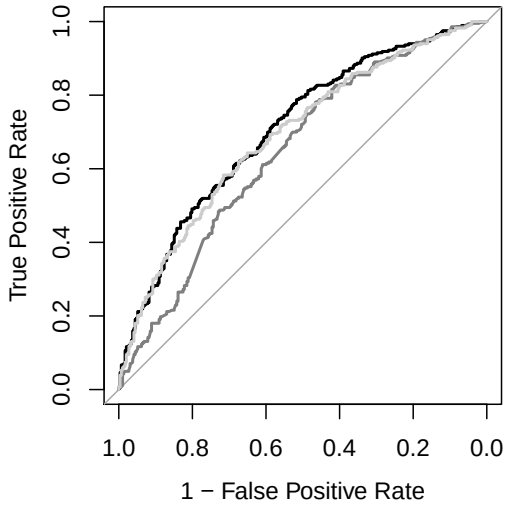

Figure 20: ROC curve showing classification performance of Model 3a (black) in comparison with Models 1a (light gray) and 2a (dark gray) for prediction of high accomplishment in S&E. The c statistic for Model 3a is 70.7%; 95% CI = 66.5–74.9%. The c statistic for Model 2a is 64.6%; 95% CI = 60.2–69.1%. The c statistic for Model 1a is 69.0%; 95% CI = 64.7–73.2%. Model 3a offers a small but not statistically significant improvement in discrimination over Model 1a according to DeLong's (1988) test for two correlated ROC curves ($Z = 1.89$, $p = .059$).

Model	Q1 %	Q4 %
1a	28	72
2a	28	61
3a	25	72

Table 7: Comparison of Models 1a, 2a, and 3a in terms of proportion of participants in top and bottom quartiles of predicted probabilities who were highly accomplished in S&E.

Predictor	Coefficient	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.2901	0.1612	-1.7990	0.0360
Male	0.6069	0.2271	2.6726	0.0038
GRE-V	0.0429	0.1062	0.4042	0.3430
GRE-Q	0.2326	0.1182	1.9673	0.0246
Creative Personality	-0.0181	0.1073	-0.1686	0.4330
Realistic	0.0545	0.1193	0.4566	0.3240
Investigative	0.3460	0.1131	3.0596	0.0011
Artistic	-0.0501	0.1122	-0.4462	0.3277
Social	-0.3615	0.1201	-3.0099	0.0013
Enterprising	0.0264	0.1287	0.2051	0.4187
Conventional	-0.0954	0.1360	-0.7012	0.2416

Table 8: Logistic regression Model 1a coefficients, standard errors, and evaluation. Model 1a predicts high accomplishment in S&E from individual differences variables and sex. Male was coded 0 or 1, with 0 assigned to women and 1 assigned to men. All other variables were standardized. Results are combined across 5 imputed data sets. Range of likelihood ratio tests $\chi^2(10) = 53.839$–58.293, $p = .0000$–$.0000$. Range of AIC = 719.564–757.903.

to prediction of high accomplishment in an S&E career when cognitive abilities, vocational interests, and other life circumstances are already accounted for. However, Figure 21 shows that a logistic model is inappropriate for modeling the relationship between spouse's income and the probability of high accomplishment in S&E, as, at least for men, the relationship is neither linear nor monotonically increasing. This misspecification results in underestimation of the relationship between spouse's income and probability of high accomplishment in S&E. It seems that although spouse's

Predictor	Coefficient	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.3355	0.2274	-1.4754	0.0701
Male	0.5319	0.2864	1.8568	0.0317
Parent	-0.3182	0.2859	-1.1130	0.1329
Spouse's Income	0.3236	0.1549	2.0895	0.0183
Male x Parent	0.6585	0.3740	1.7606	0.0392
Male x Spouse's Income	-0.2657	0.2161	-1.2295	0.1094

Table 9: Logistic regression Model 2a coefficients, standard errors, and evaluation. Model 2a predicts high accomplishment in S&E from parenthood, spouse's income, and sex. Male and parent were coded 0 or 1, with 0 assigned to women and childless participants and a 1 assigned to men and parents. Spouse's income was standardized. Results are combined across 5 imputed data sets. Range of likelihood ratio tests $\chi^2(5)$ = 27.357–38.962, p = .0000–.0000. Range of AIC = 727.646–775.428.

income has a positive linear relationship with propensity for high accomplishment in S&E among women, for men this relationship is different—below a spouse's income of $50,000, the relationship between spouse's income and propensity for high accomplishment in S&E is negative, while above $50,000 it is positive. Even though the logistic model appears to be inadequate for modeling this relationship, the bootstrapped confidence intervals show that the differences between men and women are worth exploring further.

Exceptionally Accomplished Participants in S&E Careers Are More Satisfied with Their Careers Than Their Peers, But Equally Satisfied with Their Lives

Because an aim of this research was to further understanding of the determinants of productive *and* happy lives, this investigation included a follow-up assessment of the relationships among participants' career outcomes and their concurrent

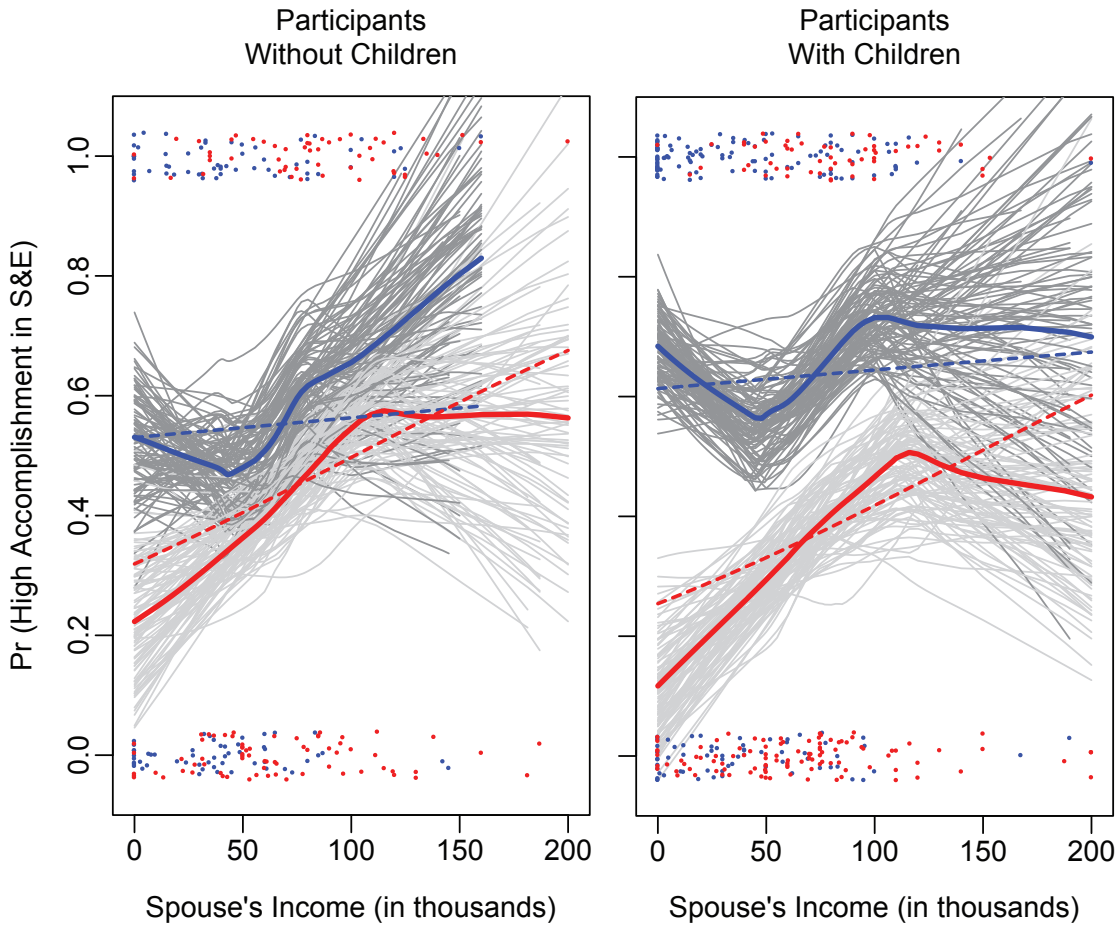

Figure 21: Relationships of sex, parenthood, and spouse's income to propensity for high accomplishment in S&E. Blue dots and lines represent men, red dots and lines represent women. Dots represent individual participants. Thick lines are smoothed proportions of men and women, respectively, who were highly accomplished in S&E careers. Gray lines are 100 bootstrapped smoothed proportions, showing empirical confidence intervals. Dotted lines show proportions of men and women, respectively, who were highly accomplished in S&E as estimated by Model 3a, with all other variables held at their means. Highly accomplished men in S&E careers $n = 174$, other men $n = 118$. Highly accomplished women in S&E careers $n = 109$, other women $n = 174$.

Predictor	Coefficient	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.2684	0.2637	-1.0175	0.1545
Male	0.3888	0.3221	1.2070	0.1137
GRE-V	0.0262	0.1098	0.2385	0.4058
GRE-Q	0.2371	0.1199	1.9773	0.0240
Creative Personality	-0.0162	0.1138	-0.1420	0.4435
Realistic	0.0600	0.1202	0.4988	0.3089
Investigative	0.3440	0.1170	2.9408	0.0016
Artistic	-0.0504	0.1144	-0.4400	0.3300
Social	-0.3614	0.1209	-2.9894	0.0014
Enterprising	0.0052	0.1402	0.0368	0.4853
Conventional	-0.0887	0.1487	-0.5966	0.2754
Parent	-0.2324	0.3173	-0.7325	0.2319
Spouse's Income	0.3189	0.1639	1.9456	0.0258
Male x Parent	0.5631	0.4049	1.3908	0.0821
Male x Spouse's Income	-0.2856	0.2227	-1.2821	0.0999

Table 10: Logistic regression Model 3a coefficients, standard errors, and evaluation. Model 3a predicts high accomplishment in S&E from individual differences variables and parenthood, spouse's income, and sex. Male and parent were coded 0 or 1, with 0 assigned to women and childless participants and a 1 assigned to men and parents. All other variables were standardized. Results are combined across 5 imputed data sets. Range of likelihood ratio tests comparing Model 3a to Model 1a $\chi^2(4) = 4.161$–16.147, $p = .0028$–$.3846$. Range of likelihood ratio tests comparing Model 3a to Model 2a $\chi^2(9) = 26.124$–36.285, $p = .0000$–$.0019$. Range of AIC = 719.522–761.741.

career and life satisfaction. Previous work on this sample showed that they were highly satisfied with their careers and their lives overall (Lubinski et al., 2006). But whether their satisfaction with life and career related to their accomplishment at work remained unexplored.

Both highly accomplished participants in S&E careers and other participants reported high satisfaction with their careers and lives (Figs. 22 and 23). Career satisfaction but not life satisfaction varied by accomplishment level, with the participants who were highly accomplished in S&E being more satisfied with their careers (Tables 11 and 12).

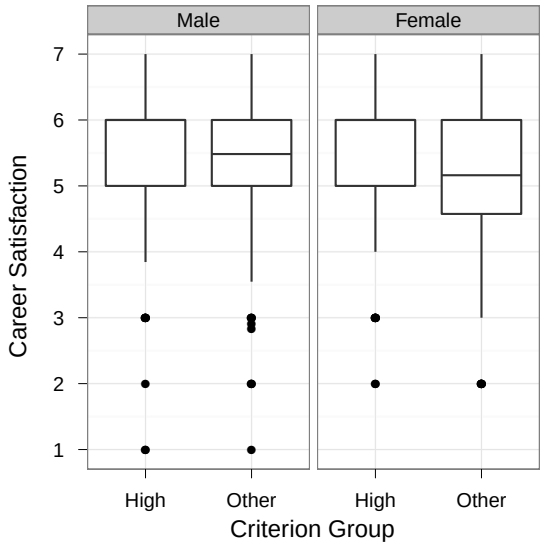

Figure 22: Bar plot of participants' career satisfaction at the time of the 11-year follow-up.

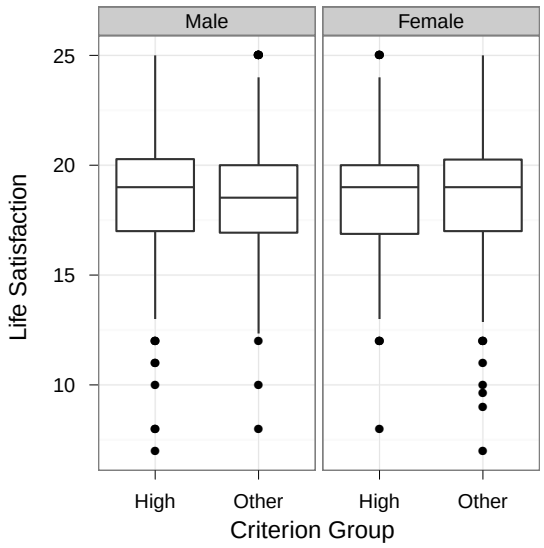

Figure 23: Bar plot of participants' life satisfaction at the time of the 11-year follow-up.

Predictor	Coefficient	Std. Error	t-stat	p-value
(Intercept)	5.2605	0.0802	65.5612	<0.0001
High S&E	0.2748	0.1054	2.6085	0.0110
Male	0.1262	0.1042	1.2107	0.2294

Table 11: Linear regression Model 4 coefficients, standard errors, and evaluation. Model 4 predicts career satisfaction from gender and accomplishment in S&E. Male and High S&E were coded 0 or 1, with 0 assigned to women and participants who were not highly accomplished in S&E and a 1 assigned to men and participants who were highly accomplished in S&E. Results are combined across 5 imputed data sets. Range of multiple R-squared = .0146–.0225. Range of adjusted R-squared = .0118–.0197. Range of $F(2, 711) = 5.254$–8.166, $p = .0003$–$.0054$.

Predictor	Coefficient	Std. Error	t-stat	p-value
(Intercept)	18.6843	0.3126	59.7707	<0.0001
High S&E	-0.0886	0.3983	-0.2224	0.8278
Male	0.0291	0.3705	0.0787	0.9383

Table 12: Linear regression Model 5 coefficients, standard errors, and evaluation. Model 5 predicts life satisfaction from gender and accomplishment in S&E. Male and High S&E were coded 0 or 1, with 0 assigned to women and participants who were not highly accomplished in S&E and a 1 assigned to men and participants who were highly accomplished in S&E. Results are combined across 5 imputed data sets. Range of multiple R-squared = .0010–.0037. Range of adjusted R-squared = .0000–.0006. Range of $F(2, 711) = 0.3462$–1.326, $p = .2661$–$.7075$.

Chapter IV

DISCUSSION

This study examines the relationships between traditional individual differences attributes, lifestyle preferences and circumstances, and noteworthy accomplishments in S&E among top U.S. S&E graduate students. Approximately half of the 367 men and 347 women identified and assessed as first- or second-year graduate students and who were subsequently followed up 11 and 16 years later were considered highly accomplished in S&E. If not in a tenure-track S&E position at a Research I university, participants classified as highly accomplished in S&E had job titles and salaries (and/or patent and publication records) commensurate with the professoriate in S&E at top U.S. universities. This is an exceptionally high level of accomplishment.

When compared with the final models reported on here, which classified over 70% of participants in the top and bottom quartiles of predicted probabilities correctly (i.e., 73% of Q1 were not highly accomplished in S&E, and 71% of Q4 were highly accomplished in S&E), models including only traditional individual differences attributes measured prior to or during the first years of graduate school (abilities, interests, and personality) and sex revealed an impressive degree of forecasting efficiency on their own. Indeed, in the first model, which included sex, both GRE scores, the six RIASEC dimensions, and the ACL's creative personality scale, all assessed at time one, 69% of participants in the top and bottom quartiles of predicted probabilities were correctly classified (i.e., 69% of Q1 were not highly accomplished in

S&E, and 69% of Q4 were highly accomplished in S&E). Even among this highly select sample of world class graduate students, therefore, assessments readily available at the time they enter graduate school portend exceptional accomplishment in S&E years after they complete their formal education. For such a select sample, the magnitude of this differentiation is substantively quite meaningful. These findings suggest that future studies on life circumstances and lifestyle preferences, and the role these variables play in structuring occupational accomplishments, should take into account more distal individual differences variables and the predictive validity that they hold for outcomes observed later in life. Although I fully anticipate that lifestyle choices and circumstances will contribute added value to the prediction of noteworthy accomplishments in S&E (as they indeed do in this study), relative to traditional measures of ability, interests, and personality, the magnitude of their unique value remains an empirical question. They contributed much less than expected here.

Moreover, it is likely that future researchers will achieve more impressive forecasts based on more appropriate and comprehensive initial assessments than those obtained here. In this study, the GRE-Q was markedly restricted in range for this special population, and spatial ability was not measured. Future research should incorporate assessments of mathematical and spatial reasoning abilities with sufficient ceilings. Furthermore, the profile analyses conducted in this study were designed in part to offer clues as to which scales of the BIS might be especially good candidates for inclusion in future research on the prediction of long-term occupational accomplishment in S&E. Those that surfaced as particularly promising were Science and Mechanical Activities (positively related to accomplishment in S&E), and Social

Services, Religious Activities, Merchandising, Sales, and Business Management (negatively related to accomplishment in S&E). Strategic use of the Basic Interest Scales is likely to afford more validity than the RIASEC offers in longitudinal research on accomplishments in S&E among exceptionally talented S&E graduate students. Indeed, the more molecular BIS were designed to add refinement to occupational classification systems and the prediction of group membership within RIASEC occupational categories, and they are underutilized in this regard (Liao, Armstrong, & Rounds, 2008; Rounds, 1995). The evidence presented here suggests that they do indeed have value for the purpose for which they were designed.

The importance of taking into account more distal individual differences, and conducting more comprehensive and focused initial assessments in research designs, before assigning causal force to predictor-assessments conducted within the same time frame as criterion-assessments has surfaced in other psychological contexts. For example, Judge, Jackson, Shaw, Scott, and Rich (2007) conducted a compelling meta-analysis of the value added by self-efficacy, one of the most extensively researched constructs for predicting performance in learning and work settings in all of psychology. After controlling for more distal individual differences, namely, general cognitive ability and the big five personality dimensions, measures of self-efficacy were found to have little unique value in predicting performance. Gottfredson (2004) has done the same in health psychology by assessing socioeconomic status in addition to general intelligence, for uncovering the relative influence of these constructs on individual differences in health outcomes. Other examples of this general phenomenon exist as well (cf. Sanders, Lubinski, & Benbow, 1995, & examples therein).

Now I will turn to a more fine-grained examination of the variables that differentiate participants who developed into high achievers in S&E from the remainder of the sample. I will discuss the extent to which these findings support preexisting empirical findings and suppositions found in the scientific literature and present suggestions for future research throughout.

Cognitive Abilities

Previous research suggested that cognitive abilities are important predictors of long-term accomplishment in complex careers, including careers in S&E (Kuncel et al., 2004; Lubinski & Benbow, 2006; Murray, 2003; Park et al., 2007, 2008; Wai et al., 2005). Whether this would remain the case among top S&E graduate students had not been explored. I hypothesized that quantitative ability measured before graduate school would be directly related to long-term accomplishment in S&E careers even among this select group, and the results were largely consistent with this hypothesis. While differences in profiles of cognitive abilities between men who were accomplishing highly in S&E careers and their same-sex peers were too small to be statistically significantly different from zero (likely as a result of ceiling effects[1], at least in part), the highly accomplishing men in science had slightly higher quantitative ability than their peers, the profiles of women who were accomplishing highly in S&E careers were significantly higher in level than the profiles of their peers (in both quantitative and

[1]In this sample, the SD of GRE-Q scores was 56 (the mean GRE-Q score was 741, the median score was 750), while the SD for the GRE-V was 91 (with a mean score of 618, and a median score of 627).

verbal ability), and regression analyses showed that individual differences in quantitative ability were positively related to high accomplishment in S&E when all other predictors held constant. Top scorers, if not highly accomplished in S&E careers, were likely to be highly accomplished in careers outside of S&E.

On the other hand, while highly accomplishing participants' verbal ability was higher than that of their peers (again, not statistically significantly so for men) individual differences in verbal ability before graduate school were not related to accomplishment in S&E careers once quantitative ability was accounted for. I predicted that participants who were highly accomplished in S&E careers would have higher verbal ability than their peers, but lower verbal ability than quantitative ability, or relative strength in quantitative areas. Prior work has shown that people high in quantitative ability and lower in verbal ability are more likely to pursue careers in science and engineering than those with relative strength in verbal areas (Park et al., 2007; Lubinski, Webb, et al., 2001; Wai et al., 2009). Since all participants in this study had already chosen careers in S&E at one point or another, that the vast majority of them had stronger ability in the quantitative area (94% of men, 91% of women) is to be expected. However, quantitative ability and verbal ability are not independent of each other— in fact, they are correlated[2] and both measures of general cognitive ability (Carroll, 1993). In light of these circumstances, that individual differences in verbal ability did not contribute anything unique to prediction of high accomplishment in S&E is not surprising.

[2]The correlation between GRE-Q and GRE-V in this sample was $r = 0.39$.

Personality Traits

Previous work has suggested that creative personality is related to accomplishment in S&E (Gough, 1979), and that personality is related to job performance more broadly (Barrick & Mount, 1991; Caspi et al., 2005; Judge et al., 1999; Ozer & Benet-Martinez, 2006; Roberts et al., 2007). I hypothesized that participants who ended up accomplishing highly in S&E demonstrated higher creative personality in graduate school, but within this restricted sample, there was no evidence of a significant relationship. This sample of top S&E graduate students demonstrated high creative personality, on average, relative to the general population (roughly 0.5 SD above the mean of the general population), which suggests that it may be relevant to pursuit of a career in S&E. However, differences in personality profiles between participants who were highly accomplished in S&E and their same sex peers were too small to be statistically significantly different from zero, and individual differences in creative personality added nothing unique to prediction of high accomplishment in S&E in regression analyses.

Beyond restrictions of sample size, one potential explanation for these results involves the variability in personality requirements of jobs that may be held by those considered highly accomplishing in S&E. Previous research has suggested that personality traits are related to job performance when the traits match the requirements of the job (Hogan & Holland, 2003). Although careers held by those who are highly accomplishing in S&E may have similar personality requirements, they weren't distinguishable from the personality requirements of the jobs held by participants in this

study who weren't accomplishing highly in S&E. What seems more likely is that various S&E jobs that may be held by people who are highly accomplished have different personality requirements or other differences, and these were not revealed because of aggregation across jobs. Further work on the contributions of personality traits to accomplishment in S&E careers among top graduate students is necessary.

Vocational Interests

Vocational interests varied between participants who were highly accomplished in S&E careers and their same-sex peers in ways that were consistent with previous work and hypotheses. Previous work suggested that those who accomplish highly in S&E careers are likely to have more interest in investigation, mathematics, and science than those who do not accomplish highly in S&E careers (Hansen & Campbell, 1985; Lubinski & Benbow, 2006; Su et al., 2009; Webb et al., 2007), and I hypothesized that this would also be true over the long term among this select population of top S&E graduate students. Men and women who ended up accomplishing highly in S&E careers had higher interest in investigation, math, and science and lower interests in other areas during graduate school than their same-sex peers. Furthermore, individual differences in investigative interests and (reversed) social interests were predictive of accomplishment in S&E careers when examined jointly with cognitive abilities, creative personality, sex, and life circumstances.

These results were inconsistent, however, with Ackerman's (Ackerman, 1996, 1997, 1997; Ackerman & Beier, 2003) predictions about the role of vocational interests in selection of, persistence in, and accomplishment in careers. He and his

colleagues have suggested that vocational interests are more important to vocational choice than to accomplishment. The group of participants who were not as highly accomplished in S&E at the time of the follow-ups did include some participants who were employed outside of S&E (34% of the men and 38% of the women), and their interest in math, science, and investigation was correspondingly lower; however, the majority of participants who weren't as highly accomplished in S&E held S&E jobs, and their interests also differed from those of participants who were highly accomplished in S&E. Intuitively, it makes sense that interest, in addition to personality and cognitive ability, would contribute to accomplishment as well as job selection and persistence, because interest, relative to boredom, would facilitate persistence in difficult tasks (Van Iddekinge, Putka, & Campbell, 2011). Perhaps interest drives not only selection of a career and persistence therein, but also accomplishment therein, through its contribution to zeal.

Lifestyle Preferences

Previous research suggested that accomplishment in a S&E career may be related to lifestyle preferences: if long work hours are generally necessary for excellence in a S&E career (Ericsson et al., 1993; Ericsson & Lehman, 1996; Jensen, 1996; McDowell, 1982; Simonton, 1988, 2004, 2008; Zuckerman, 1977), or are even perceived to be so (Diekman et al., 2010), perhaps people with higher agentic preferences and lower communal preferences will be more likely to become successful in S&E careers. Among this sample of top S&E graduate students, lifestyle preferences profiles did not differ between men who were highly accomplishing in S&E careers and their peers

either during graduate school or afterward. In contrast, lifestyle preferences profiles did differ between highly accomplishing women in S&E careers and their peers in ways that were mostly consistent with hypotheses. These findings are consistent with previous work, which indicates that more variation exists among the lifestyle preferences of women than among those of men (Hakim, 2000, 2006).

During graduate school, the women who did not end up accomplishing highly in S&E careers rated having limited full-time work hours, a part-time career, friendships, and children as more important than the women who were accomplishing highly in S&E 11 years later, consistent with hypotheses, but they (the women who did not end up accomplishing highly) also placed more importance on having a high salary or lots of money, which was inconsistent with hypotheses. Assuming people take their preferences into consideration when making decisions about their careers, these results suggest that differences in lifestyle preferences may be responsible, in part, for differences in accomplishment in S&E careers among women who are top S&E graduate students.

Furthermore, these differences in lifestyle preferences among women persisted over time. After graduate school, the women who were accomplishing highly in S&E careers rated all of the agentic lifestyle preferences as more important than their peers did, and they rated the communal preferences as less important than their peers did (except for friendship, which the groups rated as equally important). These results suggest that women's lifestyle preferences are relevant to their concurrent level of accomplishment in S&E careers as well.

Life Circumstances

I hypothesized that accomplishment in S&E careers would relate to marriage and parenthood differently for men and women in this sample of top S&E graduate students: highly accomplished men would be more likely to be married and have children than their peers, while highly accomplished women in S&E careers would be less likely to be married and have children than their peers. Examination of the differences between highly accomplished participants in S&E and their same-sex peers showed that there were at least small differences in proportions who were married and parents, and that the direction of the differences varied by sex. In comparison with their peers who weren't highly accomplished in S&E careers, higher proportions of highly accomplished men in S&E careers were married and fathers, while lower proportions of highly accomplished women in S&E careers were married and mothers.

In addition, when the joint relationships of these 11-year follow-up variables with high accomplishment in S&E were examined, the interaction of sex and parenthood was statistically significant. Although the interactions of sex with marital status and sex with parenthood were not statistically significant at the $\alpha = .05$ level in the models that included age 23 individual differences in cognitive abilities and vocational interests, the data plots showed that parenthood had different relationships with high accomplishment in S&E careers for men and women. In estimates of who was most likely to be accomplishing highly in S&E careers, married fathers were the most likely, followed by unmarried and divorced fathers, married men with no children, unmarried women with no children, married women with no children, and unmarried men with no children, and finally married mothers and unmarried

and divorced mothers were least likely to be highly accomplished in S&E careers. This result is consistent with evidence that unmarried childless women earn more than unmarried childless men (Farrell, 2005) and that mothers work fewer hours per week than their childless counterparts, while fathers work more hours per week than theirs (Long, 2001). Other researchers cite fertility and lifestyle choices as a major cause of women's underrepresentation in science (Ceci & Williams, 2011; Ceci et al., 2009).

There are many possible explanations for these results. One is that men and women in top S&E graduate programs who marry and have children are more different from each other initially, on average, on things that relate to accomplishment in S&E careers, such as lifestyle preferences, than men and women who don't marry and have children, and these differences remain in force after they marry and have children. Another possibility is that men and women in top S&E graduate programs are similar to begin with, but they respond differently on average to having children—perhaps men more often prefer to work harder or longer hours to provide for the family, while women more often prefer to take on child care responsibilities and as a consequence want more balance between work and life outside of work[3].

Prior research on this sample supports the second explanation: while students who ended up being mothers and fathers between 1992 and 2003 desired working

[3]Either way, after children enter the picture, women in this population are much more likely than men to stay at home with their children (100% of the 22 homemaking parents in this sample were women) or to work part-time (96% of the 24 parents who were working part-time were women). Thirty-two percent of homemaking mothers in this sample indicated that raising their children was the most important thing they could be doing and did not mention any other factors in their decision to be a full-time homemaker. Twenty-seven percent of homemaking mothers mentioned moving for their spouse's job or dissatisfaction with their own job or job options in addition to the desire to be at home full-time with their children as factors in the decision to stay home full-time.

during the week only, flexible work schedules, and limited full-time work at similar levels in 1992, these preferences changed significantly among the women who became mothers during the next 11 years, but they did not change among the fathers. In 2003, mothers rated these things as much more important than fathers, childless men, and childless women did. While there were small differences in these areas in 1992 between the men who became fathers and the other men, and between the women who became mothers and the other women, none were statistically significant (Ferriman et al., 2009).

There are other potential explanations. This study cannot rule out discrimination against mothers, for example, as a mechanism for the differences observed between mothers and childless women and between mothers and fathers in accomplishment in S&E. However, because unmarried childless women are more likely than unmarried childless men to be highly accomplishing in S&E, it is clear that women as a whole are not being discriminated against. Other researchers have found that contemporary evidence fails to support discrimination as a primary cause of women's underrepresentation in science (Ceci & Williams, 2011; NAS Committee on Gender Differences in the Careers of Science, Engineering, and Mathematics Faculty, 2010). Another possibility is that men who are accomplishing highly in S&E may be more desirable to women for marriage and fatherhood than other men, while women who are accomplishing highly in S&E careers may be less desirable to men for marriage and motherhood. Men who are on track to become highly accomplished in S&E may be more interested in marriage and fatherhood than their peers, and women who are on track to become highly accomplished in S&E careers may be less interested

in marriage and parenthood than their peers. Or these findings may result from a combination of these mechanisms.

Another potential explanation involves the activities of the participants' spouses. Perhaps highly accomplishing men have more support from spouses who work outside the home part-time or not at all, and highly accomplishing women have less support because their husbands are likely to be working also. The results on the incomes of the participants' spouses shed light on this issue. I hypothesized that participants who were married and highly accomplished in S&E would be more likely to have a spouse with a high income, because prior research has suggested that assortative mating occurs. However, if both spouses have high incomes, one may drop out of the workforce altogether, because one of those incomes is not necessary (Becker & Lindsay, 2004; Rudd et al., 2008). If someone is going to scale back his or her work hours, it is typically the wife who reduces hours or drops out of the workforce (Raley, Mattingly, & Bianchi, 2006). It seems that assortative mating is present in this sample, but the consequences manifest themselves somewhat differently between men and women. As women's spouses' incomes go up, the women are more likely to be highly accomplishing in S&E careers. Among men, assortative mating is clear above spouse's incomes of $50,000 per year: as their spouses' incomes rise, so does their probability of being highly accomplished in S&E careers. When a male participant's spouse is making less than $50,000 per year, his chances of accomplishing highly in an S&E career go up as his spouse's income goes down. That is, once a male participant's spouse is making less than $50,000, it seems that the burden of being the breadwinner goes on his shoulders and he responds by increasing his effort at work. Alternatively, once a

participant is highly accomplished in an S&E career, perhaps a couple can afford for the wife to reduce her work hours. This seems to be especially true among parents, who have the unique dilemma of either caring for their children themselves, at the cost of an additional income, or delegating child care if both parents choose to work.

Satisfaction with Career and Life

Finally, career satisfaction was higher among participants who were accomplishing highly in S&E careers, but life satisfaction did not differ between the groups. It seems that, although highly accomplishing top S&E graduate students in S&E careers derive more satisfaction with their careers from their success therein, their peers still have happy, fulfilling lives. This may, in part, result from increased opportunity to take advantage of the benefits of lifestyle factors such as exercise, recreation, relationships, community involvement, and volunteering, all of which have demonstrated positive impact on mental health (Walsh, 2011).

Limitations and Areas for Further Research

This study had several limitations. The first was my inability to measure cognitive abilities comprehensively and entirely accurately. As I acknowledged earlier, much research attests to the importance of spatial ability for educational and occupational development in S&E (e.g., Gohm, Humphreys, & Yao, 1998; Humphreys et al., 1993; Lohman, 1988, 1994; Smith, 1964; Shea et al., 2001; Webb et al., 2007; Wai

et al., 2009); however, although spatial ability likely affected the intellectual orientation of these participants (see Fig. 1), it was not measured in this sample, and I was unable, therefore, to assess the strength of participants' spatial ability relative to their quantitative and verbal ability, and furthermore, how these differences might have been related to success in engineering vs. the physical sciences (although field-specific analyses were not a part of this work; see below). In addition, because the students in this sample came from top S&E departments, and top departments select students with high GRE-Quantitative scores, their GRE-Quantitative scores exhibited ceiling effects, especially among the men[4]. This truncation limited the variability of individual differences in quantitative ability that could be observed, biased any estimates of standard errors toward zero, and attenuated the relationships observed between quantitative ability and the outcomes relative to the true relationships.

Second, sample size limited the links that could be drawn between personality and accomplishment in S&E and the finer-grained BIS vocational interests. Because the BIS capture interests shared by people in different occupations involving similar activities but also distinguish among people with differences in their interests too subtle to be differentiated by their RIASEC scores, their inclusion in future research on accomplishment in S&E among to graduate students would be most informative. In addition, it is possible that life circumstances would contribute less to prediction of high accomplishment in S&E if personality and finer-grained vocational interests were taken into account.

[4]Thirty percent or more of those who take the GRE attain a score greater than 700 on the Quantitative section. In this sample, 84% of men and 73% of women did so. Twenty-six percent of men and 13% of women attained the top score possible (800).

Third, although previous research has shown that the importance of different measures of productivity varies across fields (Porter & Umbach, 2001), analyses by field were not a part of this work. Even within science and engineering, different measures of productivity are important in different fields—publication in peer-reviewed journals, for example, and patenting, are not as important in some fields as they are in others. This may also be true across sectors—for example, journal publication may be more valuable in academia than in industry. I have tried to accommodate these differences by incorporating various measures of accomplishment in the criterion variable. However, sample size limited my ability to do detailed analyses by field.

An additional limitation of this study is that my outcome variable represents the state of participants' accomplishments when a significant portion of their careers is yet to come. Most participants were in their early 30s in 2003 and are currently in their early 40s. Although the outcome variable was purposefully inclusive, some participants who were not considered highly accomplished in S&E may nevertheless become so in the coming years. For example, if this study were replicated with a sample who were 20 years older, the participants may include women who were devoting considerably more time and effort to childcare in their 30s, whose children have grown up, and who have consequently re-entered the work force with a vengeance.

Finally, while I have tried to provide compelling evidence of causal relationships, I must acknowledge that while temporal precedence is present in several cases, the conclusions that can be drawn from this study are merely correlative in nature. Future research should incorporate measures of spatial, verbal, and quantitative abilities with high ceilings; larger sample sizes to allow analyses of the contributions of personality

and vocational interests measured at the finer-grained level available in the BIS by field; examination of different outcomes with different importance across fields; and measures of accomplishment over time.

Conclusions and Implications

In this study, I examined the contributions of traditional individual differences variables, lifestyle preferences, and life circumstances to exceptional accomplishment in S&E careers within this population of top S&E graduate students. Quantitative ability and vocational interests predicted long-term accomplishment in science and engineering careers in this group, suggesting that top S&E graduate students succeed in science and engineering careers at least in part based on these attributes. Life circumstances add predictive power when combined with traditional individual differences in prediction of high accomplishment in S&E among this group. Lifestyle preferences and life circumstances have important relationships with accomplishment in science and engineering careers that warrant further study. However, because they were measured simultaneously with several aspects of S&E career accomplishment, to what extent lifestyle preferences and life circumstances exert a causal influence requires further investigation. Regardless of their accomplishment in their careers, participants were satisfied with their lives, suggesting there are multiple paths to a meaningful life.

The results of this study can inform the larger issues of American competitiveness in innovation in science and engineering and women's participation therein. It cannot be emphasized enough that while this study ostensibly may be examining the

processes and outcomes in the careers of top S&E graduate students as a group or as a number of subgroups, it is comprised of data about individuals. Individuals make decisions based on their individual and family circumstances, their aptitudes, interests, personalities, and preferences, and the opportunities presented to them. Accordingly, recruitment and retention of top graduate students in science and engineering for opportunities to contribute to the economy of innovation that focus on those who have high quantitative ability, high interest in investigation, and lower interest in social vocations are most likely to be fruitful. If child care arrangements are preventing able women from participating who would like to, perhaps their employers should be flexible in their work arrangements in order to retain them. Women desiring flexible arrangements should seek employers who are receptive to their preference, will value their contributions, and will encourage their career development (O'Brien & Hapgood, 2011). On the other hand, if mothers prefer to withdraw from the workforce to raise children, their employers and others should accept that their choice will allow them to take a different approach to developing a healthy and fulfilling life.

Appendix A

DESCRIPTIVE FIGURES

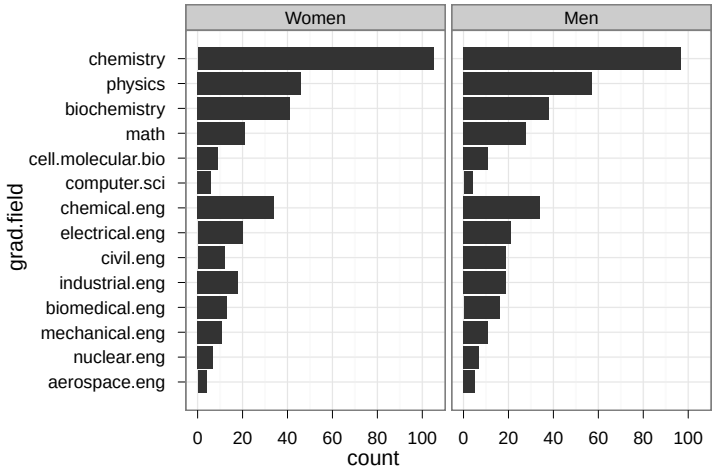

Figure 24: Participants' graduate fields of study in 1992, by gender. $n = 714$.

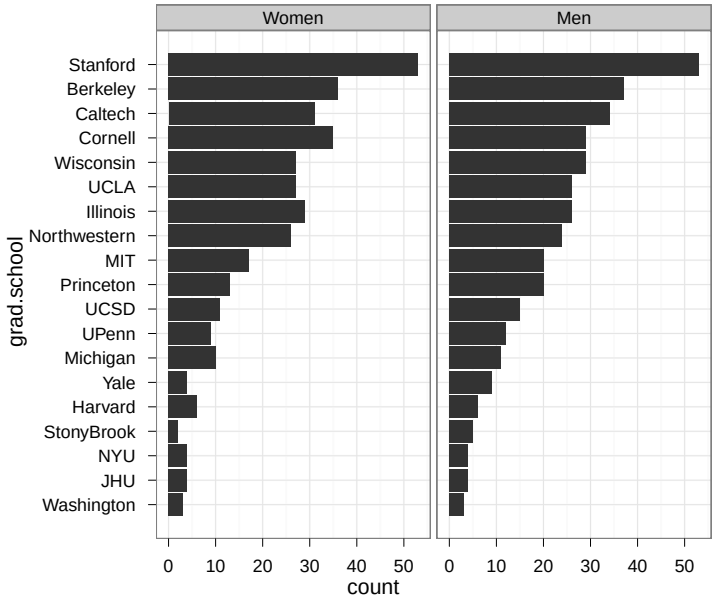

Figure 25: Participants' graduate schools in 1992, by gender. $n = 714$.

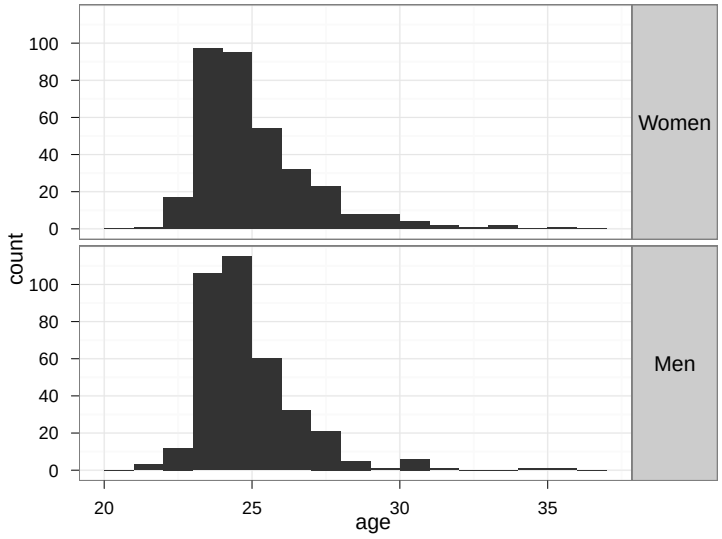

Figure 26: Participants' ages in 1992, by gender. $n = 709$.

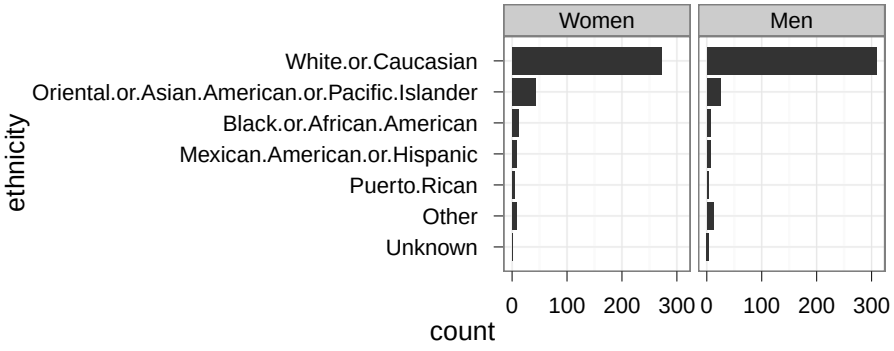

Figure 27: Participants' ethnic groups, by gender. $n = 714$.

Appendix B

LIFESTYLE PREFERENCES SCALES

Lifestyle preferences were measured with nine scales developed from a set of 44 work and 13 life preferences items. Development of these scales was a natural outgrowth of my previous work examining gender differences and change over time in the individual items (Ferriman et al., 2009). Participants were asked to rate the importance of aspects of work and life on a scale from 1 to 5, where 1 meant not important and 5 meant extremely important. The 57 work and life preferences items were reduced into 9 scales using exploratory factor analysis. First, I performed a factor analysis with varimax rotation on all 57 items, which resulted in a 22-factor solution with chi-square (573) = 636.57, $p = 0.03$. However, only 13 of those factors had eigenvalues greater than 1.

Of those 13 factors, 9 were of interest: having a leadership role at work or in the community, having a full-time job with limited hours, having strong friendships, having autonomy, having a high salary, having children, being successful, having a part-time career, and having a prestigious career. All of these factors may be related to choosing and persisting in a high-accomplishment research career in S&E. The items that loaded primarily on factors other than these were eliminated from consideration as potential predictors. Of the remaining items, those that had factor loadings less than .4 were also eliminated. 33 items were left after this step.

I created each scale score by finding the mean of each person's scores on the

items that loaded on each factor. Reliability coefficients for the scales are presented in Table 13.

	Alpha
Leadership	.74
Limited Full-Time Work Hours	.80
Friendship	.72
Autonomy	.70
High Salary	.79
Children	.67
Success	.61
Part-time Career	.70
Prestigious Career	.75

Table 13: Coefficient alpha for the nine lifestyle preferences scales.

Appendix C

JOB TITLE TABLES

	Job Title	Job Specialty
1	Analyst	Management consulting
2	Associate	Management consulting
3	Associate	Hedge fund analysis
4	Associate	Management consulting
5	Associate Analyst	Health Economics
6	Associate Director	Academic Programming
7	Director of Customer Advocacy	Difficult customer management
8	Director of Global Research	Asset management
9	Director of Operations	Operations management
10	Director, Business Development	
11	Finance Manager	Finance
12	Group Leader	Consumer products R&D
13	Group Program Manager	consumer web site
14	head of desk trading	trading
15	Instructional Specialist	
16	Manager	Marketing research & business development
17	manager of universal services	analysis and management
18	managing director	private company investing
19	Managing Director	Research in the field of Marketing
20	Managing Director	Financial Services / Banking
21	Partner	Business Consulting
22	Planning Analyst	Strategic Planning and Analysis
23	President	Marketing analytics
24	Principal	Venture Capital
25	Product Manager	Marketing
26	Project Manager	
27	Project Manager	Heavy Civil Construction
28	Project Manager	Industrial capital projects
29	Safety Project Manager	Automotive Safety
30	Senior Analyst/Developer	Commodities trading and sales systems
31	Senior Associate	Management Consulting
32	Senior Vice President	Quantitative financial research
33	Sr. Regulatory Associate	Regulatory Affairs International - CMC
34	Strategy Consultant	Automotive
35	Vice President	Quality Control

Table 14: Job titles and fields classified as non-science and engineering: Executive positions.

	Job Title	Job Specialty
1	Account Consultant	Sales
2	Adjunct professor	Radiology
3	Assistant Professor	Operations Management
4	Assistant Professor	Emergency Medicine
5	Assistant Professor	Speech Science
6	Assistant Professor	Management and Organizations
7	Associate	Litigation – Intellectual Property
8	Associate Professor	Operations Management
9	Attorney	Patent Litigation
10	Attorney (associate)	Patent law
11	Co-owner	Native Plant Sales
12	Consultant/Investor	Technology consulting/Real estate devel.
13	Digital Artist	3D Modeling
14	Economist	Corporate Governance, Org. Behavior
15	Herbalife Distributor	Health & nutrition
16	Lawyer	Intellectual property
17	Museum Education Teacher	Teaching activities of 1840s to kids
18	Patent Attorney	Intellectual property
19	patent attorney	medical apparatus patents and software
20	Patent Counsel	Chemical and Biotechnology patent prosecution
21	Physician	
22	Physician	
23	research assistant professor	science education
24	Research Associate	Consumer products R&D
25	Roman Catholic Priest	parish work
26	technical consultant	technical editing
27	winemaker	making still red and white wine

Table 15: Job titles and fields classified as non-science and engineering: Non-executive positions.

	Job Title	Job Specialty
1	AAAS Congressional Science Fellow	
2	CEO	Biotech company
3	CEO	Computer software & other tech.
4	chief scientific officer	textile chemistry
5	Chief, Division of USEPA	Drinking water regulations
6	CTO	detection of online payment fraud
7	Design Manager	Integrated Circuit Design
8	Development Manager	Simulation Software Development
9	Director of business consulting	Software development
10	Director, Microwave Engineering	semiconductor design
11	Director of Product Development	catalog of scientific products
12	Director of Product Engineering	Instrumentation Design
13	Director of Product Management	Software
14	Director, Tech. & Strategic Rsch.	tech. & market analysis
15	Director of Theoretical Physics	
16	Director, Bio. Process Improvement	jack of all trades
17	Director, Intellectual Property	patents and intellectual property
18	Engineer/Branch Head	Satellite Communications
19	Engineering Group Leader	Semiconductor processing
20	Engineering Group Leader	semiconductor industry
21	Executive	Electronics Manufacturing
22	Founder, Director of Business Devel.	Biosurgery
23	Founder and CTO	Software devel. for data mining
24	General Manager	Chemical Manufacturing
25	Group Leader	Medicinal Chemistry
26	Group Leader	Gene Expression
27	Head, Chemistry & H.T. Discovery	High throughput synthesis
28	Lead Clinical Research Scientist	R&D of antiepileptic drugs
29	Lead Network Modeling Engineer	Software development
30	Lead Scientist	Inorganic Chemistry
31	Lead System Engineer	Nuclear Power Plant Systems
32	Manager	Technology-based consulting
33	Manager Research & Development	Anti-aging skin care products
34	Manager, Cancer Discovery Chem.	Chemistry research management
35	Manager, Microfluidics Engineering	Chemical Engineering
36	Manager, Systems Development	Mathematical software devel.
37	Office Chief	Environmental Engineering
38	Planetary Scientist, Aerospace Engineer	Lead for human analog missions
39	President & CEO	B2B Software
40	Principal Engineer	microprocessor process engineering

Table 16: Job titles and fields of jobs classified as senior-level positions.

	Job Title	Job Specialty
1	Principal Engineer	Medical device R&D
2	Principal Engineer	Environmental Engineering
3	Principal Research Scientist	Cell Biology/Cell Biology
4	Principal Research Scientist	Mouse Molecular Genetics
5	Principal Scientisst	Signal transduction/biochemistry
6	Principal scientist	Gas and ambient air analysis
7	Principal Scientist	discharge lighting
8	Principal Scientist	Protein Crystallography
9	Principal Software Engineer	Computer graphics
10	principal technical staff member	telecom engineer
11	Product Engineering Group Leader	Flash Memory
12	Product Line Manager	Multiprocessor Semiconductors
13	Program Director/Group Leader	Molecular biology of oncology
14	program manager, R&D	organic chemistry
15	project leader	ultrafast laser spectroscopy
16	Project Leader	Material Science / Chemistry
17	Project Manager	GMP Production Facility/Software
18	Project Manager	Semiconductor Process Integration
19	R&D Manager	mobile internet software
20	Regional Manager	Plastics / Industry
21	Regional Medical Scientist	Pharmaceuticals R&D
22	Scientific Application Manager	Gene Expression, Bioinformatics
23	Section Manager	IT - currently Intranet technologies
24	Senior Biomedical Engineer	Project management & software devel.
25	senior chemist	analytical chemistry
26	Senior Chemist	Product Development
27	Senior Chemist	Organometallic chem. & polymers
28	Senior Criticality Safety Engineer	Criticality Safety
29	Senior Director	Biocatalysis in Pharmaceuticals
30	Senior Engineer	tech. devel., medical devices
31	Senior Engineer	Aircraft integration and test engineer
32	Senior Engineer	Millimeter wave design & devel.
33	Senior Engineer II	software simulations
34	Senior Engineer II	Electrical Engineering
35	Senior engineering staf	Communications system analysis
36	Senior Fellow	Analytical Chemistry
37	Senior Fellow	Infectious Disease
38	Senior Geotechnical Engineer	Geotechnical Engineering
39	senior member of technical staff	analog circuit design
40	Senior member of technical staff	materials science

Table 17: Job titles and fields of jobs classified as senior-level positions.

	Job Title	Job Specialty
1	Senior Member of Technical Staff	Software Research and Development
2	Senior Member of Technical Staff	Energetic Materials Chemistry
3	Senior Member of Technical Staff	Electrical Engineering
4	Senior Principal Research Engineer	Surfactant Science
5	senior process engineer	semiconductor manufacturing
6	Senior Process Engineer	Lithography
7	Senior Project Engineer	Solid State Electronics
8	Senior Quality Assurance Engineer	software
9	Senior research biochemist	immunology
10	Senior Research Chemist	Formulation Science
11	Senior Research Chemist	Polymer and Organic Synthesis
12	Senior research engineer	process modeling and optimization
13	Senior Research Investigator	Medicinal Chemistry
14	Senior research scientist	Chemistry
15	Senior research scientist	physics/materials science
16	Senior Research Scientist	Synthetic Polymer Chemistry
17	Senior Research Scientist	toothbrush R&D
18	Senior Research Scientist	Combinatorial Chemistry
19	Senior Research Scientist	Geophysical Inversion Problems
20	Senior Research Scientist	Inorganic Materials and Ceramics
21	Senior Research Scientist	Bio-organic chemistry
22	senior rf engineer	rf circuit design
23	senior scientist	medicinal chemistry
24	senior scientist	biomedical engineering
25	senior scientist	chemical engineering
26	Senior scientist	Hydrodynamics, numerical modeling
27	Senior Scientist	pharmaceutical chemistry
28	Senior Scientist	biotech assay development
29	Senior Scientist	Metabolic Chemistry
30	Senior Scientist II	Medicinal Chemistry
31	Senior Scientist II – Group Leader	Synthetic Organic Chemistry
32	Senior software engineer	computer programming development
33	Senior Software Engineer	C programming for mechanical CAD
34	Senior Software Engineer	C++
35	Senior Software Engineer	Signal Processing
36	Senior Software Engineer	
37	Senior staff engineer	Operations Analysis
38	Senior Staff Scientist	Nuclear MR spectroscopy
39	Senior Staff Software Engineer	UNIX system software design
40	Senior Systems Analyst	Software Testing

Table 18: Job titles and fields of jobs classified as senior-level positions.

	Job Title	Job Specialty
1	Senior Systems Analyst	Clinical Information Systems
2	Senior Technical Associate	research
3	Senior Technical Staff Member	Computer Sciences
4	software development manager	mathematical software
5	Sr Research Scientist	Cell biology
6	Sr Subsurface Engineer	oil/gas well completions
7	Sr. CAD Researcher	Comp. architecture performance analysis
8	Sr. Engineering Manager	Semiconductor processing devel.
9	Sr. Environmental Engineer	Environmental Compliance
10	Sr. Manager	Database Marketing
11	Sr. Member of technical Staff	Semiconductor Device Technology
12	Sr. Principal Research Engineer	Chemical Reaction Engineering
13	Sr. Process Engineer	Semiconductor Processing
14	Sr. Research Engineer	Fuel Cell Research
15	Sr. System Engineer	DSP engineer
16	SrVP/Chief Technology Officer	product development
17	Supervisor	Computer vision, machine learning
18	Systems Engineer Senior Staff	Radar System Engineering
19	Team Leader/Tech. Staff	Software development
20	Technology Leader	Chemical Engineering
21	Technology Manager	Resins and Coatings; silicones
22	Technology Manager	Chemist
23	VP of Engineering, Founder	High performance optical components
24	VP of Business Development	Software Mergers and Acquistions
25	VP, Senior Analyst	Biotechnology
26	Named Fellow	Physics of Particle Accelerators
27	Named Fellow	Immunology

Table 19: Job titles and fields of jobs classified as senior-level positions.

Appendix D

PROFILE COMPARISONS

Comparison of 2 profiles with one set of complete data using the method of profile analysis described in R. A. Johnson and Wichern (2002) is straightforward. It involves examination of 2 mean profiles and performing two tests on them—one for similar shape, or parallel profiles[1], and one for similar level[2]. These tests require 1 mean profile for each group, and a covariance matrix, which is formed by pooling 1 covariance matrix for each group. However, since I used multiple imputation, I had 5 data sets and needed to combine inferences across these data sets.

Multivariate pooling of inferences as part of the data analysis process arising from using multiple imputation involves computation of a pooled vector of estimates for each group and a pooled covariance matrix from the imputed data sets. One way this can be done in this case is as follows: Each group has a vector of means, or a profile, computed from each of m data sets, $\hat{\boldsymbol{\theta}}_{\boldsymbol{m}}$, and these are combined by finding their mean across data sets. The result is a mean mean profile for each group, $\bar{\boldsymbol{\theta}}$. The second quantity that must be computed is a mean covariance matrix for each group, the average within-imputation covariance matrix, $\bar{\boldsymbol{V}}$. Similarly, it is the mean of the covariance matrices from the m imputed data sets, $\boldsymbol{V}_m$. The third quantity for each group, the between-imputation covariance matrix, $\boldsymbol{V}_B$, is a covariance matrix

[1]The test for parallel profiles was done by assessing whether the null hypothesis that $\mu_{1i} - \mu_{1i-1} = \mu_{2i} - \mu_{2i-1}, i = 2, 3, ...p$ was acceptable. If the profiles were not parallel by this metric, they were deemed significantly different, and the assessment was concluded.

[2]If the profiles were parallel, the second assessment tested the null hypothesis that the profiles had the same level, $\mu_{1i} = \mu_{2i}, i = 1, 2, ...p$.

that estimates the variances and covariances among the vectors of means from the imputed data sets. Finally, the total covariance matrix for each group $\boldsymbol{V}_T$ is a weighted sum of the average within-imputation covariance matrix and the between-imputation covariance matrix.

The next logical step might be to use the mean mean profile for each group, $\bar{\boldsymbol{\theta}}$, and the total covariance matrix for each group, $\boldsymbol{V}_T$, in the profile analysis as described above, pooling $\boldsymbol{V}_{T1}$ and $\boldsymbol{V}_{T2}$ to form the pooled covariance matrix. However, what reference distribution this quantity follows is rather unstable and depends on both the sample size and the number of imputations. Li, Raghunathan, and Rubin (1991) have proposed a more stable alternative to the total covariance matrix, the adjusted total covariance matrix $\boldsymbol{V}_{\tilde{T}}$, which is also computed from the average within-imputation covariance matrix $\bar{\boldsymbol{V}}$ and the between-imputation covariance matrix $\boldsymbol{V}_B$, but under the assumption that an equal fraction of data is missing from each parameter in the mean vector[3] $\hat{\boldsymbol{\theta}}_{\boldsymbol{m}}$. The adjusted total covariance matrix $\boldsymbol{V}_{\tilde{T}}$ for each group is computed using the average relative increase in variance (ARIV) due to nonresponse across the components of the mean vector. The ARIV is a function of the average within-imputation covariance matrix, the between-imputation covariance matrix, and the number of imputed data sets M.

For profile analysis, the adjusted total covariance matrix for each group may be used in computation of a statistic that follows an F distribution with $k-1$ degrees of freedom in the numerator and degrees of freedom in the denominator that have been

[3]This assumption holds in this data set for most batteries, and Li et al. (1991) have shown that these statistics are fairly robust to violations of this assumption.

adjusted based on the number of imputed data sets and the ARIV (Li et al., 1991). However, Li and colleagues assumed a very large sample and the adjusted degrees of freedom they propose do not take the sample size into account.

As previously mentioned, item nonresponse in this data set was generally low; therefore, the ARIV for every battery was very close to zero. Consequently the adjusted total covariance matrix $\boldsymbol{V}_{\tilde{T}}$ was essentially the same as the average within-imputation covariance matrix $\bar{\boldsymbol{V}}$ for each group, and the adjusted denominator degrees of freedom suggested by Li et al. were in some cases 1,000 times the sample size for each group. Therefore, I ran the profile analyses several ways:

- I ran the profile analysis in each imputed data set as though it were complete data.
- I ran the profile analysis in the average data set, which was formed by taking the mean value of each variable for each person across the 5 imputed data sets.
- I ran the pooled profile analysis as described above, using the mean mean profile and adjusted total covariance matrix for each group. As a reference distribution, I used the F-distribution with $k - 1$ degrees of freedom in the numerator and $n - 2$ in the denominator, as is specified by Johnson and Wichern (2002, pp. 318–323). This approach is a more conservative test than one using the adjusted degrees of freedom suggested by Li et al. (1991).

Finally, I examined the conclusions for each battery and each sex across these different analysis approaches. Out of the 12 sets of analyses (6 batteries, one for each sex), 8 found the same result for every version of the analysis (that is, in each

imputed data set, in the average data set, and pooling across imputed data sets). The batteries that did not were the GRE among men, the BIS among men, the 1992 lifestyle preferences among women, and the 2003 lifestyle preferences among men. The outcome of the pooled analysis was the more conservative test (i.e., found no difference between participants who were highly accomplishing in S&E careers and their peers) in 3 of these 4 cases—for the GRE among men, the BIS among men, and the 2003 lifestyle preferences among men. For the 1992 lifestyle preferences among women, the analyses found a significant difference in the shape of the profiles in 4 of the 5 imputed data sets, in the average data set, and in the pooled analysis. In every case, I reported the outcome of the pooled analysis.

Appendix E

VALUES ANALYSES

Values, as measured by the Study of Values (Allport, Vernon, & Lindzey, 1970), are personality-related orientations based on Spranger's (1928) 6 types: theoretical (values discovery of truth and thinks in empirical, critical, and rational terms), economic (values utility and practical knowledge and tends to judge matters in terms of tangible financial implications), aesthetic (values form and harmony and is interested in the artistic side of life), social (values altruistic/philanthropic love of others and is kind, unselfish, and sympathetic), political (values personal power, influence, renown, and leadership), and religious (values unity and tries to comprehend the cosmos and relate it to the self).

These six orientations have been shown to be somewhat stable from adolescence to adulthood among mathematically gifted participants (Lubinski, Schmidt, & Benbow, 1996) and are related to creativity (Helson & Crutchfield, 1970) and educational and occupational choice (Achter, Lubinski, Benbow, & Eftekhari-Sanjani, 1999; Allport et al., 1970; Dawis, 1991; Huntley & Davis, 1983; D. B. Schmidt et al., 1998; Wai et al., 2005). However, evidence suggests they have similar external correlates to vocational interests and little or no incremental validity in prediction of a variety of external criteria beyond vocational interests measured by the Strong General Occupational Themes (RIASEC) and Basic Interest Scales (BIS; D. B. Schmidt et al., 1998). Although the SOV may measure vocational interests, its value may be

found in its forced-choice scoring or its use of behavioral scenarios (e.g., if you were a university professor and had the necessary ability, would you prefer to teach (a) poetry; (b) chemistry and physics?; Kopelman, Rovenpor, & Guan, 2003).

Because some items in the SOV use dated or noninclusive language, minor language modifications were made to incorporate gender-neutral and updated language. A similar modernization of the SOV was recently undertaken by Kopelman et al. (2003). In both cases, the changes made did not appear to attenuate reliability or validity relative to the 1970 version.

The values profiles of S&E leaders and other participants were compared (Figure 28) and no significant differences were found between participants who were highly accomplished in S&E and those who weren't.

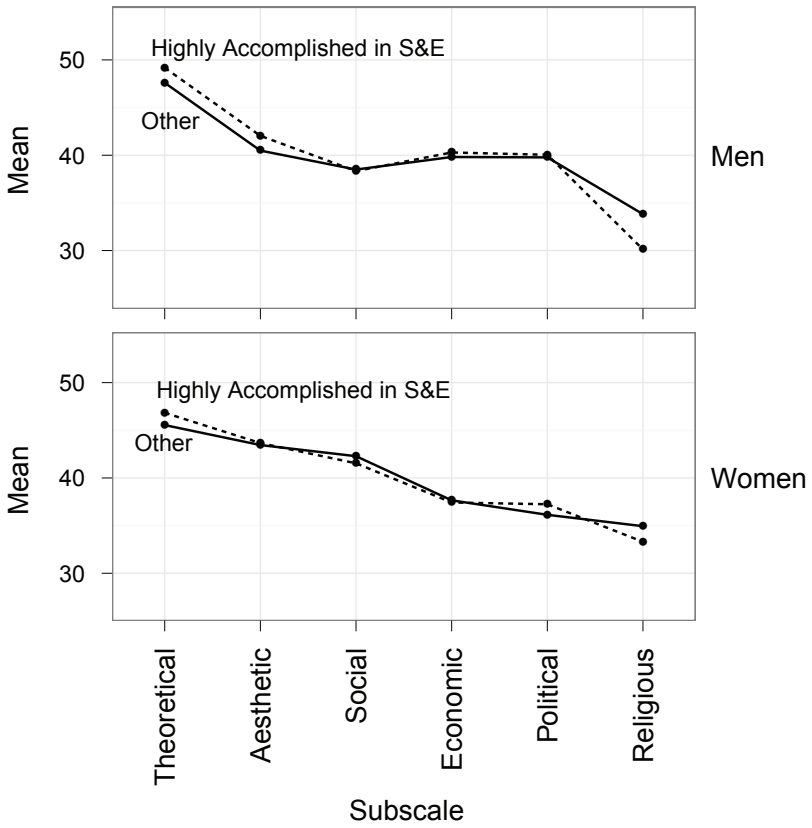

Figure 28: Average profiles of participants highly accomplished in S&E and other participants on the Study of Values. Normative mean = 40. Male $n = 367$. Female $n = 347$.

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