CHAPTER 15

Individual Differences at the Top
Mapping the Outer Envelope of Intelligence

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In his 1998 James McKeen Cattell Award Address at the American Psychological Society (now the Association for Psychological Sciences), "The Power of Quantitative Thinking," Paul E. Meehl observed:

> Verbal definitions of intelligence have never been adequate or commanded consensus. Carroll's (1993) *Human Cognitive Abilities* and Jensen's (1998) *The g Factor* (books which will be definitive treatises on the subject for many years to come) essentially solve the problem. Development of more sophisticated factor analytic methods than Spearman and Thurstone had makes it clear that there is a *g* factor, that it is manifested in either omnibus IQ tests or elementary cognitive tasks, that it is strongly hereditary, and that its influence permeates all areas of competence in human life. What remains is to find out what microanatomic or biochemical features of the brain are involved in the heritable component of *g*. A century of research – more than that if we start with Galton – has resulted in a triumph of scientific psychology, the foot-draggers being either uninformed, deficient in quantitative reasoning, or impaired by political correctness. (Meehl, 2006, p. 435)

Those tomes will indeed remain on the bookshelves of scholars for decades. Carroll (1993) focused on the highly replicated internal structure of psychometric tools developed over the previous century, whereas Jensen (1998) explicated how the central dimension of this hierarchy connects with important biosocial phenomena. Hunt's subsequent (2011) volume, *Human Intelligence*, deeply enriches these two. Collectively, this psychometric triptych provides a comprehensive depiction of the nature and real-world significance of intellectual abilities.

Essentially, general intelligence denotes individual differences in abstract/conceptual reasoning. This dimension accounts for around half of the common variance found in measures of intellectual functioning. Fifty-two experts (including Meehl) provided an excellent working definition: "[A] very general capacity 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).

Precisely because it is general, this dimension can be measured in multiple ways. For example, by "aptitude items" that require processing complex relationships, often, but not exclusively, across quantitative/numerical, spatial/mechanical, verbal/linguistic media, or, less efficiently, with varying and widely sampled "achievement items" of cultural content or knowledge (Lubinski & Humphreys, 1997; Roznowski, 1987). As Thurstone (1924, p. 247) pointed out, the former "type" of assessment concentrates on intelligence at work during the test (processing), the latter on the product of intelligence (knowledge). But often, when these assessments are broad, they engender equivalent correlates and are functionally interchangeable (Terman, 1925, pp. 289–306). In this vein, when introducing the "jangle fallacy," Kelley (1927) warned that attaching different labels to experimentally independent measures of the same attribute (e.g., academic aptitude, developmental level, fluid reasoning, general mental ability, general intelligence, *g*, IQ) does not mean that they measure different things.

> [C]ontaminating to clear thinking is the use of two separate words or expressions covering in fact the same basic situation, but sounding different, as though they were in truth different. The doing of this ... the writer would call the "jangle" fallacy. "Achievement" and "intelligence" ... We can mentally conceive of individuals differing in these two traits, and we can occasionally actually find such by using the best of our instruments of mental measurement, but to classify all members of a single school grade upon the basis of their difference in these two traits is sheer absurdity. (p. 64)[1]

Five decades later, an APA Task Force (Cleary et al., 1975) explicated the four dimensions involved in distinguishing "achievement" (specific knowledge) from "aptitude" (IQ) tests: breadth of sampling, recency of learning, the extent to which items are tied to an educational program, and purpose of assessment (current status versus potential for development). Achievement and aptitude tests do not differ in kind; they differ in degree. Cronbach (1976) echoed these considerations in responding to critics of psychological testing:

> *In public controversies about tests, disputants have failed to recognize that virtually every bit of evidence obtained with IQs would be approximately duplicated if the same study were carried out with a comprehensive measure of achievement.* (p. 211, italics original)

These highly replicated empirical generalizations are refreshing in the context of contemporary discourse on the "replication crisis" (Open Science Collaboration, 2015). It is critical to begin with and assimilate these well-established facts about the central parameter of intellectual functioning (Carroll, 1993; Hunt, 2011; Jensen, 1998) before we can evaluate any claim to have moved beyond them. An intellectual dimension provides value beyond general intelligence only if it truly gives us something more than general intelligence. As Messick noted (1992, p. 379),[2] "Because IQ is merely a way of scaling general intelligence [*g*], the burden of proof in claiming to move beyond IQ is to demonstrate empirically that ... test scores tap something more than or different from general intelligence by, for example, demonstrating differential correlates with other variables (which is the external aspect of construct validity)." Longitudinal studies of intellectually precocious children, as described in what follows, have done just that.

The Organization of Intellectual Abilities

Important intellectual dimensions beyond the general factor have been mapped in multiple ways and different labels applied (many with attendant "jangle"), yet they all possess differential value in the prediction of educational, occupational, and creative outcomes: fluid versus crystalized abilities (Cattell, 1971), verbal-educational-numerical versus mechanical-practical-spatial (Humphreys, 1962; Vernon, 1961), Wechsler's performance IQ versus verbal IQ (Matarazzo, 1972), and mathematical, spatial, and verbal reasoning (Corno, Cronbach et al., 2002; Gustafsson, 2002; Guttman, 1954; Snow et al., 1996). Because specific-ability measures focus on one particular type of content (e.g., verbal/linguistic, mathematical/quantitative, or spatial/pictorial), the individual differences they index constitute an amalgam of the general factor and the content-focused specific ability (Corno, Cronbach et al., 2002; Gustafsson, 2002). Conversely, when these indicators are systematically combined (Lubinski, 2004, p. 99), a distillate is formed that primarily indexes general intelligence (overall level of sophistication of the intellectual repertoire). Both levels of analysis – general and specific – are important (Wai et al., 2009). The radex model of intellectual functioning consists of a general dimension of abstract/symbolic processing or reasoning capability, surrounded by three specific abilities indexing degrees of competence with distinct symbolic systems: quantitative/numerical, spatial/figural, and verbal/linguistic (Wai et al., 2009, p. 821). The radex affords a global outline of the intellectual hierarchy (Lubinski & Dawis, 1992), and is as good as any framework for succinctly organizing the structure of human intelligence (Corno, Cronbach et al., 2002; Gustafsson, 2002; Guttman, 1954; Snow et al., 1996; Snow & Lohman, 1989).

Empirical Findings

That mathematical, spatial, and verbal reasoning abilities each add unique value to the prediction of important outcomes is well established for the general population and college-bound high school students (Humphreys, 1962; Humphreys et al., 1993; Kell & Lubinski, 2015; Lubinski, 2010, 2016; Wai et al., 2009). Following the editor's directive that authors focus here on their specific contributions to the field of intelligence, I will now describe how these intellective dimensions operate among intellectually precocious populations, specifically, the populations yielding empirical findings from the Study of Mathematically Precocious Youth (SMPY).

Study of Mathematically Precocious Youth (SMPY)

SMPY is a planned 50-year longitudinal study currently in its fourth decade (Clynes, 2016; Lubinski & Benbow, 2006). Launched by Julian C. Stanley in 1971, it was designed to identify mathematically precocious youth and uncover ways to facilitate their educational development. Shortly after its beginning, equal emphasis was placed on exceptional verbal ability. SMPY identified young adolescents ages 12 to 13 in the top 3% on conventional achievement tests routinely given in their schools, and gave them the opportunity to take college entrance exams, specifically, the SAT. These above-level assessments produce the same score distributions as they do for college-bound high school students. For decades (Assouline et al., 2015; Benbow & Stanley, 1996; Colangelo et al., 2004), young adolescents scoring at or above the mean for college-bound high school seniors have routinely enjoyed assimilating a full high school course in three weeks at summer residential programs for talented youth. Today, approximately 200,000 young adolescents are assessed annually with above-level instruments for such opportunities (Lubinski, 2016).

Currently co-directed by Camilla P. Benbow and David Lubinski at Vanderbilt University, SMPY is tracking five cohorts consisting of more than 5,000 intellectually talented participants identified in 1972–1997. Moreover, SMPY has evolved, from studying educational development to occupational and personal development as well as eminence and

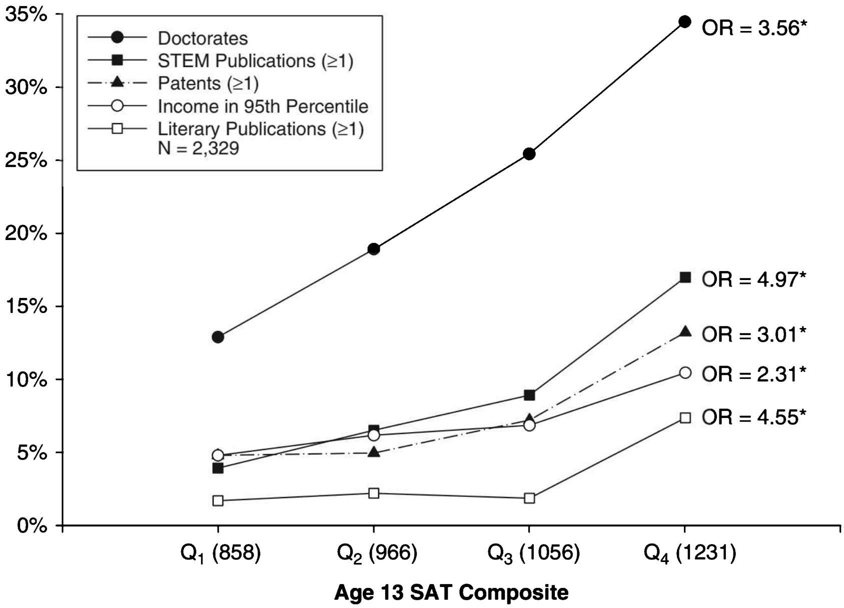

Figure 15.1 Participants are separated into quartiles based on their age 13 SAT-M + SAT-V Composite. The mean age 13 SAT composite scores for each quartile are displayed in parentheses along the x-axis. Odds ratios (ORs) comparing the likelihood of each outcome in the top (Q4) and bottom (Q1) SAT quartiles are displayed at the end of every respective criterion line. An asterisk indicates that the 95% confidence interval for the odds ratio did not include 1.0, meaning that the likelihood of the outcome in Q4 was significantly greater than in Q1. These SAT assessments by age 13 were conducted before the re-centering of the SAT in the mid-1990s (i.e., during the 1970s and early 1980s); at that time, cutting scores for the top 1 in 200 were SAT-M ≥ 500, SAT-V ≥ 430; for the top 1 in 10,000, cutting scores were SAT-M ≥ 700, SAT-V ≥ 630 by age 13.
Adapted from Lubinski (2009).

leadership. For present purposes, SMPY's unique empirical contributions highlight the psychological and social implications of assessing individual differences *within* the top 1% of ability.

Ability Level

Figure 15.1 contains data from 2,329 SMPY participants (Lubinski, 2009). By age 13, all met the top 1% cut score on either the SAT-Math or SAT-Verbal for their age group. Frey and Detterman (2004) documented that the SAT-M plus SAT-V composite constitutes an excellent measure of general intelligence (for above-average populations). First, their age-13 SAT composite (M + V) was divided into quartiles. Then, longitudinal criteria secured 25 years later were regressed onto the four quartiles. These criteria reflect valued accomplishments in education, the world of work, and creative expression (e.g., securing a patent, publishing a novel or major literary work, or publishing a refereed scientific article). Finally, odds ratios (ORs) were computed comparing the top and the bottom quartiles for each attainment. Figure 15.1 shows that individual differences within the top 1% of general intellectual ability, even when assessed at age 13, ultimately result in a set of achievement functions. More ability enhances the likelihood of many important accomplishments.

While the base rate for patents in the United States is 1% for the general population, the first quartile of this group achieves almost five times that. Further, the difference between the top and bottom quartiles, 13.2% versus 4.8%, respectively, is statistically and substantively significant. The same is true for the difference between the top and bottom quartiles in having an income at or above the 95th percentile (10.5% versus 4.8%). Note that these participants are in their mid-30s and such incomes are typically earned only much later in life. Thus, there is neither an ability threshold nor any sign of diminished returns within the top 1% of ability. But does the uniqueness of the specific abilities, each focused on a distinct symbolic modality, have additional psychological significance for intellectually talented youth?

Ability Pattern

Park and colleagues (2007) analyzed a group of 2,409 SMPY participants tracked for more than 25 years. Figure 15.2 organizes their findings into four Tukey plots: specifically, participants' SAT composites were plotted on the y-axis and their SAT-M minus SAT-V scores were plotted on the x-axis. These plots result in two independent dimensions, concurrently assessing overall ability level (i.e., the common variance these two measures share – "*g*", on the y-axis), versus ability-pattern (i.e., the unique psychological import of each measure's specific ability – on the x-axis). For the latter, positive scores on the x-axis denote greater mathematical relative to verbal reasoning ability (M > V), whereas the opposite is true for scores to the left (M < V). Finally, bivariate means for educational, occupational, and creative attainments were plotted. These were then surrounded by ellipses, defined by +/- one standard deviation on x and y, respectively, for members in each group.

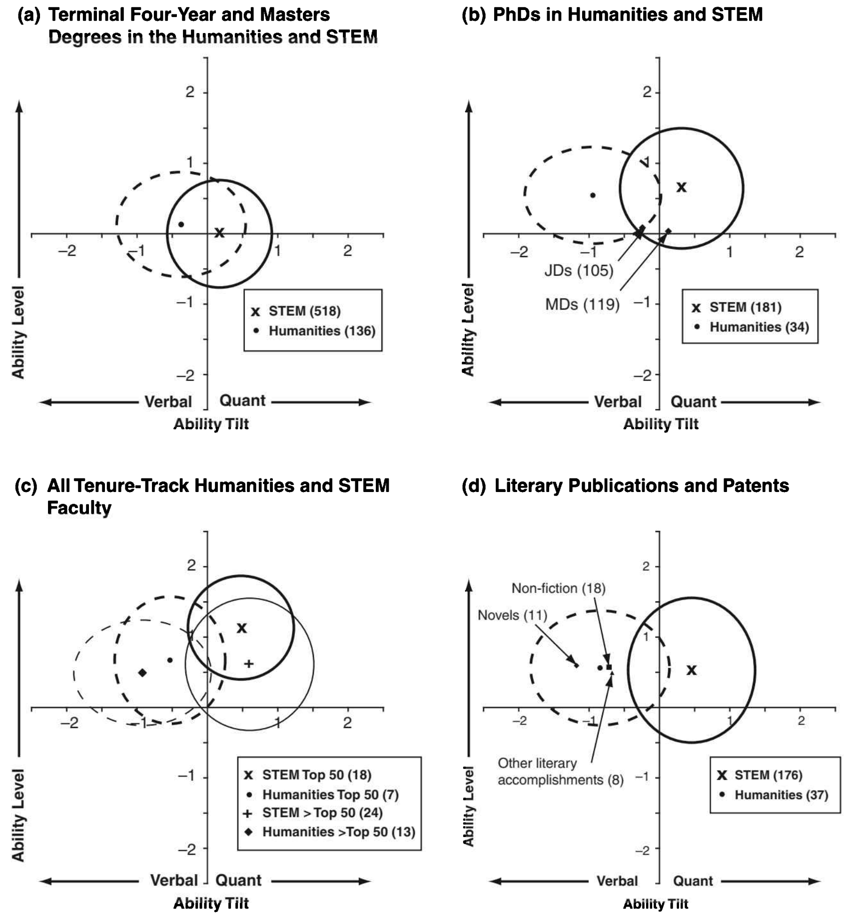

Figure 15.2 Participants' achievements as a function of ability tilt (SAT-Math score minus SAT-Verbal score) and ability level (sum of both SAT scores), in standard deviation units. Achievement categories were (a) completing a terminal four-year or master's degree, (b) completing a Ph.D. (means for MDs and JDs are also shown), (c) securing a tenure-track faculty position, and (d) publishing a literary work or securing a patent. In each graph, bivariate means are shown for achievements in humanities and in science, technology, engineering, and mathematics (STEM), respectively; the ellipse surrounding each mean indicates the space within one standard deviation on each dimension. The *n* for each group is indicated in parentheses. Mean SAT-Math and SAT-V scores, respectively, for each criterion group were: four-year and master's STEM degree – 575, 450; four-year and master's humanities degree – 551, 497; STEM Ph.D. – 642, 499; humanities Ph.D. – 553, 572; tenure-track STEM position in a top-50 university – 697, 534; tenure-track humanities position in a top-50 university – 591, 557; tenure track STEM position in a non-top-50 university – 659, 478; tenure-track humanities position in a non-top-50 university – 550, 566; patents (i.e., STEM creative achievements) – 626, 471; and publications (i.e., humanities creative achievements) – 561, 567.
From Park et al. (2007).

In all four panels, outcomes in the humanities and STEM were featured because they had the largest sample sizes to justify statistically stable results. However, bivariate points for other outcomes (e.g., MDs, JDs, novelists, and nonfiction writers) are also plotted to provide an even wider picture. Moving from four-year and master's degrees (panel A) to doctorates (panel B), we see increases in ability level (y-axis), as well as ability pattern (x-axis) becoming more distinctive. Tenured faculty at major universities in the humanities versus STEM (panel C) are distinct, as are those who secured refereed publications and patents (panel D). Participants achieving these qualitatively different attainments occupy different regions of the intellectual space defined by these dimensions. Importantly, these differences are detectable during early adolescence. However, they routinely pass unnoticed because of the ceiling problem. The vast majority of these participants will earn close to top possible scores on conventional college entrance examinations well before graduating from high school (when SAT assessments are typically conducted). At that point, for this population, such assessments are no longer capable of distinguishing the exceptionally able from the able. They are insensitive to their individuality, and especially so among the profoundly gifted.

Profoundly Gifted

The differential attainments observed earlier continue to be found at ever-higher points on these ability dimensions. Two scatter plots in Figure 15.3 illustrate the breadth of intellectual diversity typically unseen due to measurement limitations but routinely uncovered through above-level assessments. The bottom plot is based on a group of 320 SMPY participants scoring in the top 1 in 10,000 in either mathematical or verbal reasoning ability (Kell et al., 2013a); the top plot consists of 259 equally able participants identified by Duke University's Talent Identification Program (TIP), used for replication (Makel et al., 2016). Both groups were identified by age 13 and tracked for 25 years. As the diagonal line on each scatter plot reveals, a large majority in each group had estimated IQs > 160, yet the psychological diversity displayed by these profoundly gifted participants is stunning: some participants who scored in the top 1 in 10,000 for mathematical reasoning ability have verbal reasoning abilities that are more impressive than their mathematical prowess, while the verbal reasoning ability of others is "merely" around the cutting score for the top 1% (an age 13 SAT-V score just under 400). The same breadth of differential talent is observed among those scoring in the top 1 in 10,000 in verbal reasoning

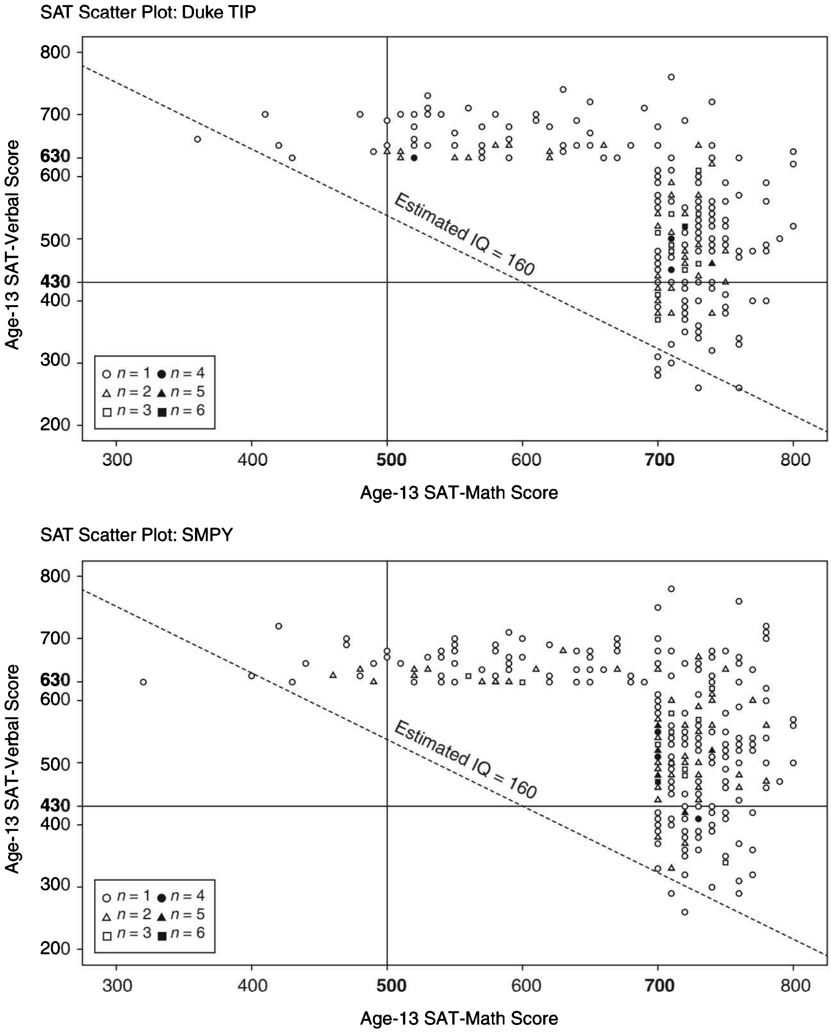

Figure 15.3 Scatterplot of age-13 SAT-Math (X) and SAT-Verbal (Y) scores for Duke TIP participants (top panel) and SMPY participants (bottom panel). Circles, triangles, and squares are used to denote bivariate points with more than one participant. The diagonal line in each scatterplot denotes where estimated IQs of 160 fall; bivariate values above these diagonals correspond to estimated IQs above 160. On the axes, the boldface numbers on the x-axis (**500, 700**) and the y-axis (**430, 630**) indicate cutoffs for the top 1 in 200 and the top 1 in 10,000 for this age group. TIP = Talent Identification Program; SMPY = Study of Mathematically Precocious Youth.
From Makel et al. (2016).

ability. High-ceiling assessments such as these are needed to capture the differential potentialities of profound intellectual talent. To validate the psychological significance of these assessments compellingly, however, data are needed on criterion outcomes such as their ultimate educational, career, and creative attainments as well as other longitudinally remote indices of their occupational stature.

Figure 15.4 presents a sampling of the creative outcomes of these two groups as a function of their ability pattern. Critically, all participants possess more mathematical and verbal reasoning ability than the typical PhD in any discipline, yet they tend to invest in those pursuits that draw on their greater strength. Participants whose intellectual profile was more distinguished by verbal relative to mathematical reasoning generally focused on the humanities and literary pursuits (the northwest quadrant of this graph), whereas participants whose mathematical acumen was more impressive than their verbal reasoning ability concentrated more on STEM pursuits (the southeast quadrant). The same patterns of investments were found at earlier stages in their educational-occupational development (Makel et al., 2016).

The preceding analysis characterizes the *nature* of accomplishment among profoundly gifted youth. Tables 15.1 and 15.2 assess its *magnitude*. Table 15.1 organizes a sampling of accomplishments prior to age 40 for the TIP and SMPY groups, which may be benchmarked normatively (e.g., the base rate for earning a doctorate in the United States is just under 2%). Table 15.2 lists some individual accomplishments (each listing representing a unique individual), which affords an idiographic qualitative appraisal of their consequential accomplishments. While any one of these individual accomplishments, if viewed in isolation, might be dismissed as a noteworthy anecdote, taken together, and replicated across both samples, the data aggregate to tell a compelling, systematic story. These normative and idiographic findings reveal, quantitatively and qualitatively, the magnitude of human capital predictable from above-level assessments prior to age 13. There appears to be nothing categorically different regarding the profoundly gifted. Rather, the data document a continuous gradation of extraordinary capability and its accompanying accomplishments.

Just as qualitatively different outcomes are observed as a function of contrasting ability patterns among college students (Humphreys et al., 1993; Lubinski, 2010; Wai et al., 2009), the gifted (Park et al., 2007), and the profoundly gifted (Kell et al., 2013a, Makel et al., 2016), so too does the magnitude of accomplishment vary across ability-levels of three, four, and

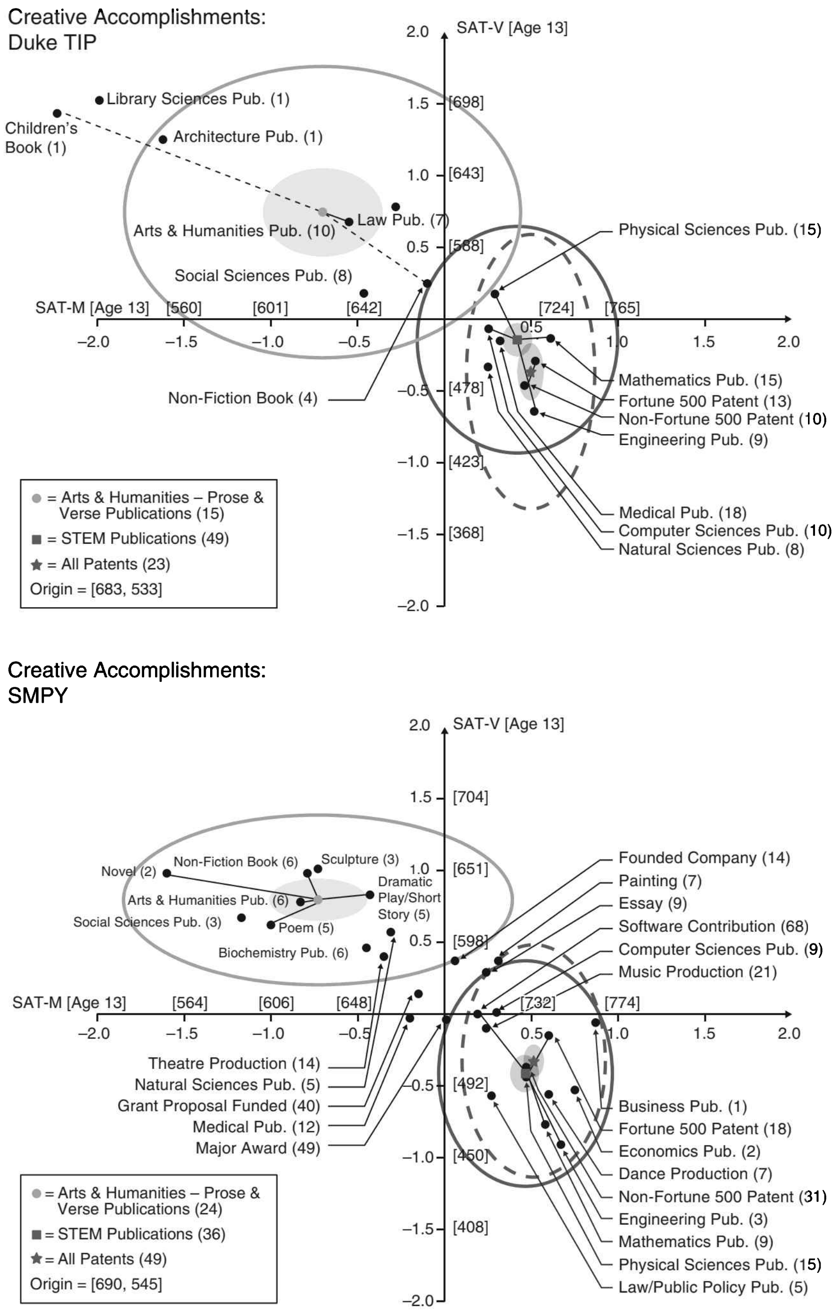

Figure 15.4 Bivariate means for age-13 SAT-Math (SAT-M; *x*) and SAT-Verbal (SAT-V; *y*) scores within categories of creative accomplishments for Duke University's

Table 15.1 *Selected Educational, Occupational, and Creative Accomplishments of the Talent Identification Program (TIP) and the Study of Mathematically Precocious Youth (SMPY) Participants*

Accomplishment	TIP	SMPY
Doctoral degree	37%	44%
Doctoral degree from top 10 university[a]	16.3%	22.5%
Tenure at the college level	7.5%	11.3%
Tenure at research-intensive university[b]	4.3%	7.5%
Peer-reviewed publication (≥ 1)	39%	24%
Patent (≥ 1)	9%	15%
Fortune 500 patent (≥ 1)	5%	6%
Book (≥ 1)	2%	3%
NSF grant (≥ 1)	4% (mean award = $63,700)	6% (mean award = $91,600)
NIH grant (≥ 1)	1% (mean award = $10,700)	3% (mean award = $18,900)

Note: Standard errors for the percentages reported in this table are as follows: 1% for percentages < 9%; 2% for percentages from 9% through 25%; and 3% for percentages greater than 25%. The one exception is that the standard error for the percentage of tenured professors among TIP participants is 2%. NIH = National Institutes of Health; NSF = National Science Foundation.

[a] Identification of the top 10 doctoral programs was based on the National Research Council's (1995) ratings. [b]Universities were classified as research-intensive by the Carnegie Foundation (2010) if they were deemed to have "very high research productivity."

Taken from Makel et al. (2016).

Figure 15.4 (*cont.*)

Talent Identification Program (TIP) participants (top panel) and the Study of Mathematically Precocious Youth (SMPY) participants (bottom panel). Bivariate means for individual categories are represented by black circles; the sample sizes for these categories are in parentheses. Three rationally derived outcome clusters are highlighted in this two-dimensional space: Arts & Humanities (NW quadrant in green) and two STEM outcomes (SE quadrant in purple): solid line = STEM publications, dotted line = patents. The dashed lines emanating from the centroids denote the constituents of those clusters. Each centroid is surrounded by two elliptical tiers: an inner ellipse defined by the standard errors of the SAT-M and SAT-V means for individuals within that centroid (i.e., width and height = ±1 *SEM* for SAT-M and SAT-V, respectively) and an outer ellipse formed by the standard deviations of the SAT scores for these individuals (i.e., width and height = ±1 *SD* for SAT-M and SAT-V, respectively). Along the axes, un-bracketed values are SAT-M and SAT-V scores in *z*-score units, and bracketed values are raw SAT scores.

Adapted from Makel et al. (2016).

Table 15.2 *Outlying Accomplishments of the Talent Identification Program (TIP) and the Study of Mathematically Precocious Youth (SMPY) Participants*

TIP	SMPY
Named as one of "America's Top Physicians" (Consumers' Research Council of America)	Co-director of hospital organ-transplant center serving more than 3 million people
Holder of 43 patents	Produced 100 software contributions
President of chamber of commerce of one of the 100 richest cities in the United States, by per capita income	Raised more than $65 million in private equity investment to fund own company
Associate chief counsel for a U.S. federal agency	Vice president of Fortune 500 company
Member of the Council on Foreign Relations	Deputy assistant to a president of the United States (national policy adviser)
Deputy director of the Office of the Assistant Secretary for a U.S. federal agency	Founder of three companies
Argued more than 10 cases before the U.S. Supreme Court	Producer of 500 musical productions
Professional poker player with annual earnings > $100,000	Marshall Scholar
Rhodes Scholar	Recipient of eight grants from the National Science Foundation (total funding > $5.5 million)
Recipient of nine grants from the National Science Foundation (total funding > $6.5 million)	Recipient of six grants from the National Institutes of Health (total funding > $1.6 million)
Recipient of six grants from the National Institutes of Health (total funding > $1.4 million)	

Note: The accomplishments listed in this table are non-overlapping, and each refers to the achievement of a single individual.
Taken from Makel et al. (2016).

five standard deviations above the normative mean (see Figure 15.1). There is a continuous progression in real-world accomplishment, impact, and creativity within the top 1% of ability (over one-third of ability range). In addition, the relationship between occupational and creative output and individual differences within the top 1% of ability continues to be meaningful even after advanced educational credentials and the caliber of the university attended for graduate study are controlled (Park et al., 2008).

Assessing individual differences within the top 1% of ability has even further implications. For decades, empirical evidence has revealed that college entrance examinations in the United States are suboptimal for reasons beyond their ceiling limitation. They are also suboptimal qualitatively (Humphreys et al., 1993; Wai et al., 2009). Intellectual dimensions beyond general-, mathematical-, and verbal-reasoning ability add important value for the gifted and the profoundly gifted, just as they do for typical college students.

Spatial Ability: The "Orphan Ability"

Spatial ability has been called the "orphan ability." Relative to general, mathematical, and verbal abilities (cf. Gohm et al., 1998; Humphreys et al., 1993; Kell et al., 2013b; Wai et al., 2009), spatial ability has been sorely neglected. Years ago, arguably the leading authority on the educational and occupational significance of spatial ability remarked,

> There is good evidence that [visual-spatial reasoning] relates to specialized achievements in fields such as architecture, dentistry, engineering, and medicine ... Given this plus the longstanding anecdotal evidence on the role of visualization in scientific discovery, ... it is incredible that there has been so little programmatic research on admissions testing in this domain. (Snow, 1999, p. 136)

Two years later, Shea and colleagues (2001) published educational and occupational outcomes for 563 SMPY participants recorded at ages 18 (after high school), 23 (after college), and 33 (early career). The three-dimensional plots in Figure 15.5 graph outcomes over a 20-year period for favorite and least favorite high school class, four-year college degree, and occupation. In standard deviation units, mathematical reasoning ability is scaled on the x-axis, verbal reasoning ability on the y-axis; the base of each arrow marks the location of these two abilities on the x- and y-axes. Spatial ability was also assessed during early adolescence and scaled here in standard deviation units using arrows: arrows to the right represent positive values; to the left, negative values. Now, imagine that the (right-pointing) positive arrows have rotated upward from the plane of the page, and the (left-pointing) negative arrows downward, so as to form 90-degree angles with the x- and y-axes. The arrowheads will then mark the locations in three-dimensional space of the trivariate points occupied by each labeled group. It is apparent that at all three lifetime stages, each of the abilities add independent predictive value for understanding the various life choices and preferences representing the outcomes.

Thus, for this gifted sample, those who find the humanities to be their favorite high school courses tend to have an intellectual repertoire dominated by verbal ability relative to mathematical and spatial ability, whereas the inverse is true for students who prefer STEM domains. This is not only true for preferences in learning environments, but also for work environments. A different specific ability configuration anticipates affinity for and accomplishments in STEM: salient mathematical and spatial abilities, relative to verbal ability. Dotted rectangles are used in each or the four panels of Figure 15.5 to isolate the location of the STEM outcomes. Neglecting any one of these specific abilities misses a critical component. None of the three specific abilities can be ignored without compromising our understanding of the outcomes.

This conclusion was reinforced 15 years later, when the creative accomplishments of the Shea and colleagues (2001) participants were followed up at age 48 by Kell and colleagues (2013b). For purposes of analysis, the creative criteria were placed in four mutually exclusive and exhaustive content groups, consisting of three types of refereed publications, Art-Humanities-Law-Social-Sciences (n = 27), Biology-Medicine (n = 35), STEM (n = 65), and fourth, patents (n = 33). Individuals who both held patents and published were retained in the relevant publication category, as that was considered more informative. Hence, the 33 in the patent category had no publications by age 48.

A discriminant function analysis employed the age 13 mathematical, spatial, and verbal ability assessments to predict the four types of creative outcomes described previously 35 years later. Mathematical and verbal ability scores jointly accounted for 10.5% of the variance in creative group outcomes. The inclusion of spatial ability – the "orphan ability" – added another 7.5% to that variance.

Although it was known for years that the level and pattern of mathematical and verbal ability are important in forecasting both the likelihood and nature of creative life outcomes among intellectually precocious youth (Lubinski, 2016; Park et al., 2007), Kell and colleagues' (2013b) was the first demonstration that spatial ability adds substantially to such predictions.

Figure 15.6 displays three different rotations of these findings when plotted in three mathematical, spatial, and verbal dimensions. Each trivariate point is surrounded by the orthogonal orbits of the three standard errors of each ability to form ellipsoids, which reveals their distinctiveness. It is clear that the creative outcomes under analysis are supported by different configurations of intellectual talent. For example, among participants who secure patents, their spatial ability is commensurate

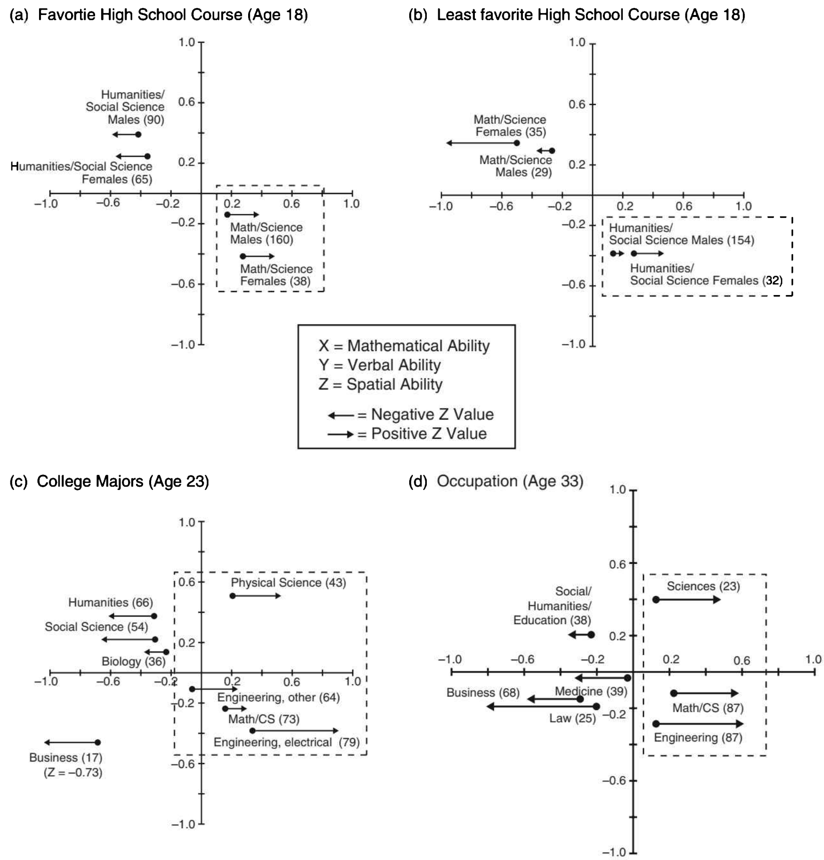

Figure 15.5 Shown are trivariate (X/Y/Z = Mathematical/Verbal/Spatial) means for (Panel A) favorite and (B) least favorite high school course at age 18, (C) college majors at age 23, and (D) occupation at age 33. Mathematical, verbal, and spatial ability are on the x-, y-, and z-axes, respectively (arrows to the right indicate a positive z value; arrows to the left indicate a negative z value). Panels A and B are standardized within sex; Panels C and D are standardized across sexes. For Business in Panel C, note that the length of the arrow is actually z = 0.73. Dotted rectangles surround the STEM preferences, degrees, and occupations to underscore that they occupy similar intellectual spaces at different time points.
Adapted from Shea et al. (2001). CS = computer science.

with those who publish in STEM, but the latter are more impressive in mathematical and verbal reasoning. Participants who publish in Art-Humanities-Law-Social Sciences are the lowest in spatial ability of all four groups. This informative graph maps the intellectual design

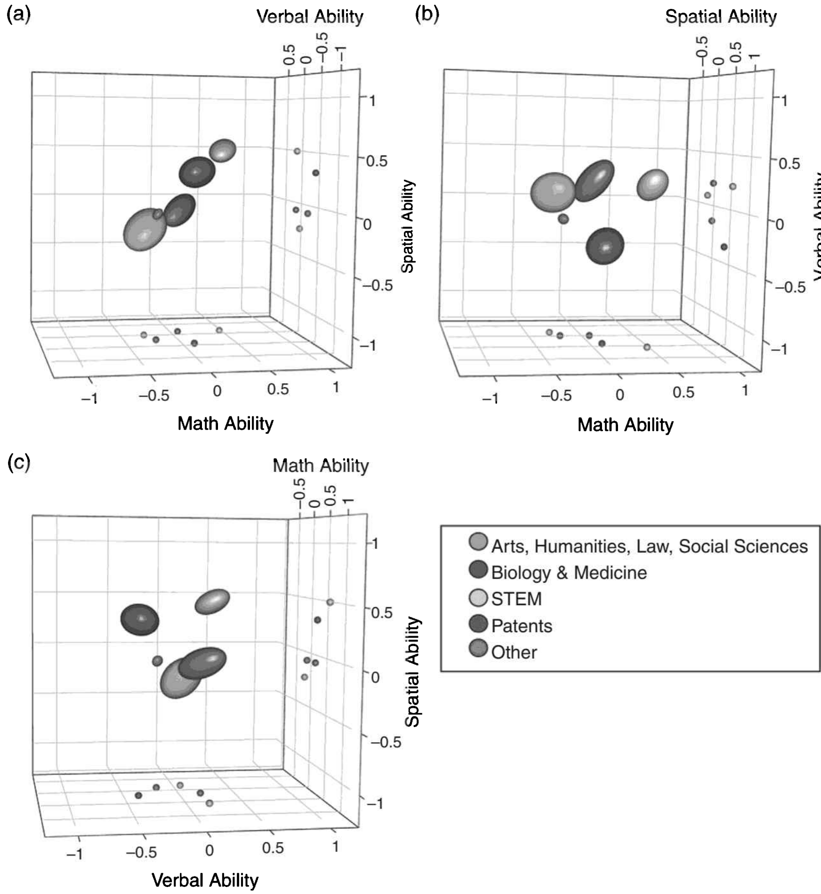

Figure 15.6 Confidence ellipsoids showing the locations of the four criterion groups in the three-dimensional space defined by scores for mathematical, verbal, and spatial reasoning ability. The data are rotated such that the graph in (a) shows mathematical ability on the x-axis, spatial ability on the y-axis, and verbal ability on the z-axis; the graph in (b) shows mathematical ability on the x-axis, verbal ability on the y-axis, and spatial ability on the z-axis; and the graph in (c) shows verbal ability on the x-axis, spatial ability on the y-axis, and mathematical ability on the z-axis. The ellipsoids are scaled so that each semi-principal axis is approximately equal in length to the standard error of the corresponding principal component. Each ellipsoid is centered on the trivariate mean (centroid), and bivariate means are plotted on the bordering grids. The criterion groups were defined as participants with a refereed publication in the arts, humanities, law, or social sciences; a refereed publication in biology or medicine; a refereed publication in science, technology, engineering, or mathematics (STEM); or a patent. In addition, an ellipsoid is shown for participants with none of these creative accomplishments ("other"). From Kell et al. (2013b).

space of much of what is considered important creative thought in modern cultures, especially the two subcultures that C. P. Snow (1967) famously labeled "science intellectuals" and "literary intellectuals."

Discussion

Decades of longitudinal research have documented that the hierarchical organization of human intellectual abilities has scientific significance. When researchers use developmentally appropriate measures and collect rare and highly valued outcome criteria from sufficiently large samples over protracted intervals, differential developmental trajectories of exceptional intellectual talent are consistently revealed.[3]

An important new insight comes from the configural relationships involving spatial ability. *They demonstrate that key intellectual attributes operate in learning and work settings whether or not participants consider them, practitioners or theorists assess them, or selection occurs on them*. The intellectually talented young adolescents in the studies reviewed here understood the importance of doing well on mathematical and verbal reasoning tests for their eventual college placement. However, the significance of spatial ability was never considered, nor was it ever used in selecting them for educational or occupational opportunities. Nonetheless, spatial ability played a critical role in structuring their educational, occupational, and creative pursuits and ultimate accomplishments. Abilities affect outcomes, like all natural causes, whether recognized or unrecognized.

Unfortunately, approximately half of young adolescents in the top 1% in spatial ability are missed by modern talent searches restricted exclusively to mathematical and verbal reasoning ability (Wai et al., 2009; Wai & Worrell, 2016). This omission not only neglects an underserved population – and a critical source of human capital for technical professions – it also constitutes a lost opportunity for the kind of refinements seen in Figures 15.5 and 15.6 for all individuals. Individuals may be highly similar on any two specific abilities (mathematical/spatial/verbal), but if they differ markedly on the third, differential development can be anticipated. They will differentially select contrasting opportunities, and they will experience markedly different degrees of satisfaction and display different degrees of competence across these areas. The challenge for educators and career counselors is to find the optimal niche for each student, so that he or she can maximize the positive aspects of his or her individuality (Lubinski, 1996, 2016; Lubinski & Benbow, 2000). This is best done by knowing and treating each student as an individual.

Nurturing Exceptional Talent

Ninety-five years ago, Carl Emil Seashore (1922) pointed out that among a random sample of college freshmen, the top 5% can learn five times more academic material than the bottom 5% (per unit time), and that there are successive gradations in between these levels. An analysis of level and pattern of general and specific abilities underscores the environmental diversity needed to optimally meet the needs of each student. Both the rate at which each student learns abstract/complex material and the nature and pace of the curriculum need to be aligned with students' specific level and pattern of ability (Assouline et al., 2015; Benbow & Stanley, 1996; Colangelo et al., 2004; Stanley, 2000). Young adolescents scoring in the top 1 in 10,000 have different educational needs relative to those scoring in the top 1 in 200, and both of these groups have different educational needs from typically developing students (Lubinski, 2016).

Once basic fundamental needs are met (e.g., health, nourishment, safety), the best way to develop intelligence is to draw on the salient positive features of each person's individuality (Lubinski & Benbow, 2000). Just as there are unique strengths and relative weaknesses in each person's intellectual profile, there are huge individual differences in each person's aversions and passions for contrasting opportunities. There are also huge differences in how much each individual is willing to invest in his or her intellectual development (Ferriman et al., 2009; Lubinski et al., 2014). Taking a multidimensional view of the personal attributes each person brings to learning and work settings is critical. That has always been a central feature of applied and theoretical research in the study of individual differences because that tradition eschews "truncated appraisals of human individuality" (Lubinski, 1996, 2010). When opportunity is available, abilities, commitment, energy, interests, and personality all matter. Drawing on the psychological fabric upon which interventions and opportunities act maximizes the motivation for sustaining positive development.

Benbow and Stanley (1996) entitled their compelling analysis "Inequity in equity: How 'equity' can lead to inequity for high-potential students" because one size will never fit all. This is readily accepted for students with developmental delays and, thankfully, in the United States, important legislation ensures that appropriate accommodations are made for students with special needs (Lubinski, 2016). Intellectually precocious students have special needs as well.[4] For that very reason, Stanley (2000) developed an instructional philosophy for intellectually precocious students that is generalizable to all students: "teach students only what they don't already know." Managing the vast differences in student readiness for learning and the knowledge they possess, which is routinely observed even among siblings reared in the same home (Murray, 1998, 2002; Waller, 1971), is sometimes challenging but imperative for achieving optimal learning for each child. This challenge is likely to intensify – there is evidence that it already has (Tyre, 2016) – as increased opportunities become available for students to self-select their learning environments and personally manage their rate of growth (e.g., receiving instruction over the Internet, selecting like-minded peers with similar interests and competence, and taking college courses in high school, among others).

Horizontal and Vertical Levels of Analysis

Just as McNemar (1964) and Schmidt and Hunter (1998) showed that for certain performances in school and work environments, respectively, general intelligence is sufficient to account for the criterion variance that the hierarchical organization of intellectual abilities offers, this chapter shows that for other outcomes, specific abilities do add value to general intellectual appraisals. Depending on the purpose of assessment, predictor sets and criterion outcomes can and should vary. When assessments of the quantitative and qualitative scope of intellectual abilities are conducted at exceptional levels of talent, meaningful research designs require commensurate measurement of qualitatively different and rare criterion outcomes to validate assessment procedures.

Finally, Meehl (2006) was correct that what remains "is to find out what microanatomic or biochemical features of the brain are involved" (p. 435). Undoubtedly, such advances will extend beyond general intellectual functioning (Asbury & Plomin, 2014). The patterns of intellectual talent found in Figures 15.3 through 15.6 offer distinct phenotypes for behavioral genetics and neuroscience inquiry. Examining the biological phenomena underpinning general intellectual ability has produced meaningful findings (and more remains to be learned), but additional clarity is likely if specific abilities are examined using biologically based procedures (Lubinski, 2016; Rimfeld et al., 2017). Just as additional insight into lifespan development is achieved by assessing ability level and pattern in its full scope, so too is it likely to occur for underlying biological phenomena.

Conclusion

More than 60 years ago, Lewis Terman (1954) reflected on his multiple-decade longitudinal study by affirming the importance of initially using general intelligence to identify participants when the gifted field was young and his groundbreaking work had just begun. Nevertheless, he then added: "[s]uch tests do not, however, enable us to predict what direction the achievement will take, … both interest patterns and special aptitudes play important roles in the making of a gifted scientist, mathematician, mechanic, artist, poet, or musical composer, …" (p. 224). Clear and consistent empirical findings reveal the wisdom of his remarks. Modern empirical findings have established the unique psychological significance of mathematical, spatial, and verbal abilities. Other studies have shown the added value of educational/occupational interests, personality, and the huge range of lifestyle preferences displayed when each individual has the opportunity to choose freely (Ferriman et al., 2009; Lubinski, 2016; Lubinski et al., 2014). Individuals embrace opportunities for development with different degrees of enthusiasm. Future studies of intellectual development and human accomplishment need to take into account personal attributes beyond individual differences in rates of learning and the extent to which a person can efficiently develop expertise. Individual differences in mathematical, spatial, and verbal reasoning ability, however, will always be part of the story. Their psychological significance can be seen most clearly when measured simultaneously and in their full scope.

Acknowledgment

Support for this chapter was provided by a research and training grant from the Templeton Foundation (Grant 55996) and by the Vanderbilt Kennedy Center for Research on Human Development. Invaluable suggestions for this article were provided by Brian O. Bernstein, Robert A. Gordon, Kira O. McCabe, Frank Miele, and Leslie J. Yonce.

Notes

1 As Kelley (1927) observes, under some circumstances, tools that focus on abstract reasoning versus specific content acquired in schools can be differentially informative. Assessments too tied to an educational curriculum rather than abstract problem solving can particularly disadvantage children who have experienced poor schooling. The early focus on the SAT was on reasoning, rather than knowledge per se, to facilitate uncovering exceptional intellectual talent in rare places.

2 It has been repeatedly shown that the predictive validity of innovative measures of competence such as "health literacy," "moral reasoning," and many others is largely driven by the general intelligence dimension that cuts across all measures of cognitive functioning (e.g., Gottfredson, 2002; Messick, 1992;

Sanders et al., 1995). When novel measures are purported to assess broad forms of competence in specific areas, the importance of determining whether they add any incremental validity to general intelligence has long been emphasized by measurement experts (Corno, Cronbach et al., 2002; Humphreys, 1962; McNemar, 1964), but their advice repeatedly goes unheeded (cf. Judge et al., 2007; Lubinski, 2004, 2010) as researchers strive for innovative originality.

3 The Graduate Record Examination (GRE), with which applicants for advanced degrees are routinely assessed in the United States, provides an interesting illustration of the extent to which upper ranges of intellectual talent may be undervalued. Scores on the verbal (V) and quantitative (Q) subtests of this instrument are reported on a scale with 600 points of range, from 200 to 800. A mid-range score of 500 on GRE-V denotes the 59th percentile, whereas 500 on GRE-Q represents only the 18th percentile! Thus, half of the score range on GRE-Q is expended on the bottom 18% of the distribution. GRE-Q scores of 700 or more, falling in only a sixth of the range, are obtained by 40% of test takers. A perfect score of 800 lies only at the 92nd percentile. See www.ets.org/s/gre/pdf/concordance_information.pdf. Contrast this with selection procedures used by Bill Gates in developing Research Institute-Beijing or at the Indian Institute of Technology. These two cross-cultural examples reflect procedures corresponding to selecting within the top 1 in 10,000 in ability (Kell et al., 2013a, p. 648).

4 Intellectual dimensions of central relevance for intellectually precocious youth may be viewed as reflections or mirror images of dimensions of central importance for meeting the learning needs of students with developmental delays. "Interventions designed to facilitate learning in students with developmental delays essentially reduce to delays in either general abstract reasoning and/or those concerning numerical/quantitative, spatial/pictorial, or verbal/linguistic media" (Lubinski, 2016, footnote 3, p. 935).

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