COMMENTARY

Understanding educational, occupational, and creative outcomes requires assessing intraindividual differences in abilities and interests

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Stoet and Geary (1) report important cross-cultural findings on how the advantage of females in reading proficiencies relative to males combined with more equitable educational opportunities have contributed to the recent overrepresentation of women in tertiary education. Developed nations vary in the extent to which males are underrepresented as a function of these two determinants, yet that they jointly contribute to a clear cross-cultural trend is undeniable. Hence, it is critical to assess personal proficiencies and the environmental contexts within which they operate to understand individual and gender differences in educational outcomes.

Further refinements in how far students progress in educational systems, why group disparities exist, and which specific disciplines students pursue are provided by examining other aspects of their individuality more holistically and simultaneously. This commentary places the assessment of human individuality into a broader (multidimensional) context. Major reviews of psychological research show that individual differences in both level and pattern of cognitive abilities and educational/occupational interests are critical for understanding educational, occupational, and creative outcomes across the lifespan (2–4). Incorporating cognitive abilities and interests into longitudinal research demonstrates how these two categories of psychological attributes give rise to different real-world accomplishments. That information allows us to understand each student's individuality, their learning needs, and develop policies for best practices. This commentary is to give readers a better understanding of why both inter- and intraindividual differences in abilities and interests must be considered when conceptualizing individual and group differences in real-life learning and work outcomes.

Cognitive Abilities

To enrich the perspective of Stoet and Geary's findings (1), two additional cognitive abilities, mathematical/quantitative and spatial/mechanical, are examined in the context of reading/verbal ability. These three constitute the central pillars of the hierarchical organization of cognitive abilities (5). The central dimension of this hierarchy constitutes general intelligence (that is, what all three abilities share). However, each specific ability also has a unique and psychologically operative component that drives differential development. Results from an extensive longitudinal study on tertiary degrees and occupational outcomes demonstrate the role each ability plays in determining why students approach some learning settings while avoiding or departing from others. They also reveal learning and work environments that capitalize on individual strengths and minimize relative weaknesses.

Fig. 1 presents longitudinal data from the ~400,000 high school students in Project TALENT (6)—a stratified random sample of US high school students assessed in 1960 and followed up 11 y later. This pattern has been subsequently replicated over several decades (7–10). In *z*-score units, mathematical/quantitative ability is shown on the *x* axis and reading/verbal ability on the *y* axis; dots at the base of each arrow represent the bivariate math/verbal mean for each group. The length of each arrow represents the spatial/mechanical ability mean for each group; blue arrows to the right indicate positive *z*-scores for spatial/mechanical ability and red arrows to the left, negative *z*-scores. When the blue arrows are rotated up from the page at a 90° angle from the *x* and *y* axes and the red arrows are rotated 90° downward from *x* and *y*, the arrowheads represent the trivariate *z*-score mean for each group in three-dimensional space. Thus, the arrowheads expressly reveal how far removed these educational/occupational groups are from each other psychologically as a joint function of their respective mathematical/spatial/verbal abilities.

Fig. 1 illustrates the importance of relative strengths in ability pattern. Individuals with conferred degrees in the humanities excel in reading/verbal ability, whereas those in STEM (science, technology, engineering, and mathematics) disciplines excel in spatial/mechanical

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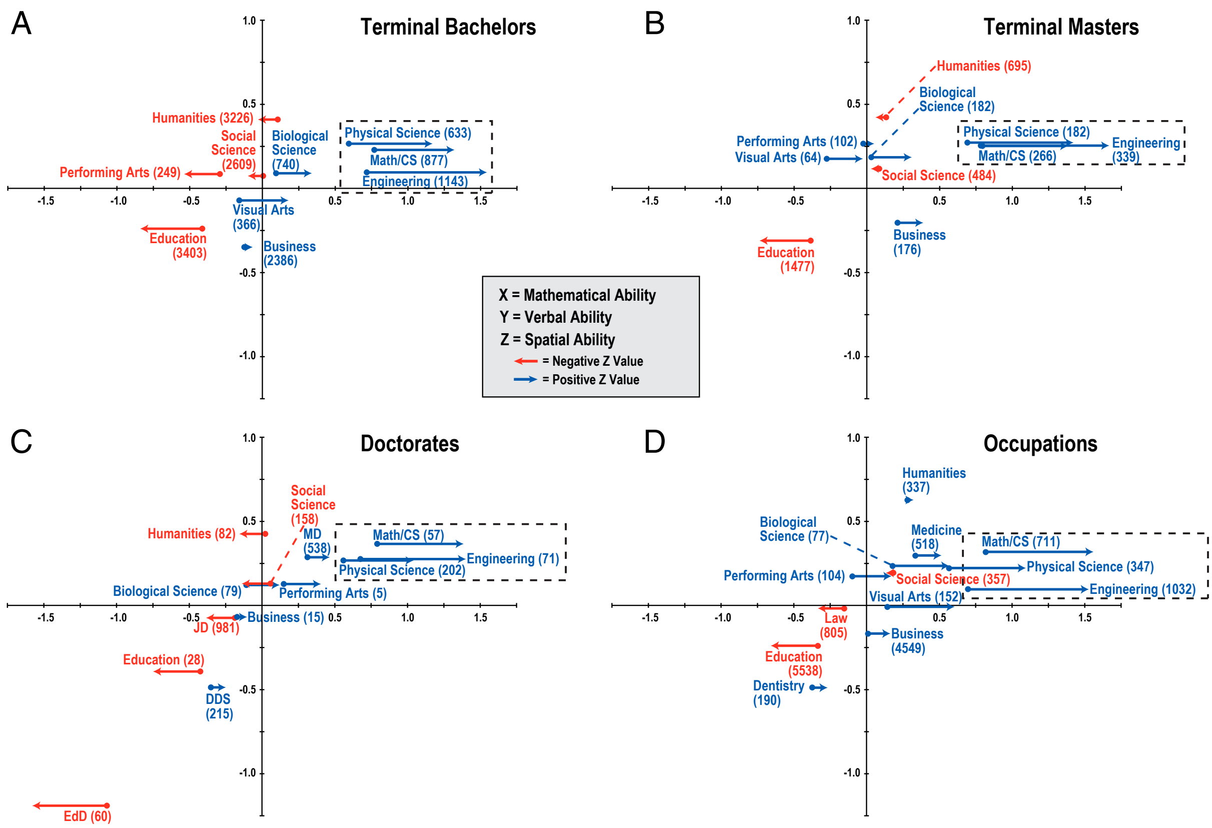

Fig. 1. **Trivariate (mathematical/verbal/spatial ability) *z*-score means for individuals with (*A*) terminal bachelor's degrees, (*B*) terminal master's degrees, (*C*) doctorates, and (*D*) occupations 11 y following high school graduation. *N*s are in parentheses. Mathematical ability is on the *x* axis, verbal ability is on the *y* axis, and spatial ability is scaled on a third dimension represented by arrows. For a benchmark, because all of the plotted means in the four panels are based on individuals with at least a 4-y degree (and *z*-scores were standardized within each panel), the general ability level of all of the above groups is >0.5 SDs above the normative population mean. Dashed rectangles indicate STEM disciplines. Reproduced with permission from ref. 6.**

ability. Regardless of how similar students are on any two abilities, their educational/occupational development will vary markedly to the extent that they differ on the third. Since the ability patterns among the ninth graders were just as informative as were those of high school seniors in predicting these outcomes, within-grade *z*-scores for grades 9 through 12 were averaged to create Fig. 1. This illustrates how stable cognitive abilities, assessed in early adolescence, collectively play out over time. However, they are frequently underappreciated because any one, especially spatial/mechanical ability, is seldom assessed in the context of the others. US students have long realized the importance of mathematical/quantitative and reading/verbal ability assessments in gaining admission to select universities. Seldom, however, do they think about spatial/mechanical ability and rarely, if ever, are they selected on it. Yet, these data reveal how individual differences in spatial/mechanical abilities structure development.

These findings are also generalizable to intellectually precocious 13-y-olds in the top 1% of ability (6). Above-level assessment (i.e., administering college entrance examinations and spatial/mechanical reasoning measures designed for high school seniors to young adolescents) is required to obtain a sufficiently high measurement ceiling to capture the full scope of their abilities. Based on 35 y of longitudinal research with precocious 13-y-olds, the ability patterns observed in Fig. 1 have been replicated across real-world educational (age 23 y) → occupational (age 33 y) → creative (age 50 y) outcomes (11). Conventional assessment tools for selecting undergraduate and graduate students are severely constrained for highly able students (3, 12). By late adolescence, all their scores tend to cluster at the top; hence, such ability differences are undetectable.

Interests

Educational/occupational interests are among the most powerful predictors of learning and work outcomes (2, 4, 5, 8). They add value to ability assessments (6, 7, 12). One well-known dimension of interests is learning about and working with people versus things (13), or, more precisely, an interest in working with organic versus inorganic material. For decades, gender differences of ~1 SD have been observed on this broad dimension, with males favoring inorganic subject matter and females favoring organic pursuits. This has been replicated repeatedly in intellectually gifted young adolescents as well (3, 14). When these gender differences are combined with gender differences in relative strengths of specific abilities—reading/verbal ability > spatial ability for females, and the inverse for males, reading/verbal ability < spatial ability—gender differences in some outcomes become more understandable. For years, women in the United States have been awarded more doctorates than men; however, the genders differentially populate various disciplines arrayed along the inorganic–organic dimension (15, 16).

Implications

Comprehensive assessments of abilities and interests illuminate differential individual and group developmental trajectories of learning and work outcomes (2, 4, 17–19). Group differences are simply aggregated individual differences. When individual differences contribute to outcome differences, aggregated individual differences (reflecting group differences) do so for demographic categories. It is not just a matter of whether students like something and are proficient at it. What they like the most and what they are best at also matters (2, 4, 17–21). The literature cited details several implications; some are detailed below.

There are clusters formed by the covariance between specific abilities and interests (19). These ability/interest amalgams are termed "aptitude complexes" in education (5) and "taxons" in the world of work (2, 7). For example, interests in people versus things covary positively with reading/verbal ability but negatively with spatial/mechanical ability. This is one reason some have characterized individuals with exceptional spatial/mechanical ability as being "extroverted for things," supporting Stoet and Geary's (1) remark that such students are often turned off by the typical educational curriculum. Perhaps such students could be given opportunities in English courses to read, rather than William Shakespeare, Charles Dickens, or Jane Austen, biographies of Marie Curie, Thomas Edison, or Henry Ford. This might enhance their appreciation of literature by resonating with their personal perspective or with the salient features of their individuality. This, in turn, could enhance their reading proficiency.

There are also several essential occupations that all modern societies require and for which outsourcing is not possible. Master carpenters, electricians, mechanics, and plumbers, among others, are needed to maintain and build complex infrastructures. Therefore, tertiary educational opportunities need to be conceptualized more broadly. Many with talent in spatial/mechanical ability possess ability/interest patterns that are ideally suited to these occupations. For educational and training programs to be optimally effective, they must be tailored to students' varying and even contrasting constellations of psychological attributes (2, 4, 18). The diversity of educational opportunities should reflect the psychological diversity of the students (2, 3, 5, 8). Therefore, criteria for evaluating successful educational opportunities should be similarly diverse.

Even among elite STEM graduate students trained at the best universities in the world, the small subset who go on to achieve eminence in STEM do not possess a unique quality (14, 18). Rather, they possess more of known qualities: They enter graduate school with more focused STEM interests and fewer competing interests and dedicate more time to the pursuit of STEM excellence. There is much attention devoted to more equal representation in the STEM pipeline (22–24) and the proportion of women opting out. Yet, women are not underrepresented in advanced educational credentials (15, 16), and evidence suggests that they are pleased with their choices (17). For example, women receive around 68% of the doctorates in education, over 70% in health and medical sciences, and over 75% in public administration/services. If mathematically gifted women are more likely to secure JDs or PhDs in epidemiology as opposed to an inorganic science, relative to their male counterparts, is this problematic? If a mathematically gifted woman with expertise in environmental law rescues some precious land in Alaska from polluting exploitation, is that less of a contribution than a male counterpart who advances knowledge of the physical universe?

Conclusion

For complex societies to operate effectively they need to identify and nurture many different constellations of human individuality. Meeting the challenges posed by climate change, cybersecurity, and global pandemics requires different sets of personal attributes for the development of sophisticated expertise needed. Understanding the multidimensionality of human individuality is critical for developing human potential, scientifically based educational–occupational practices, and policy formation. It also has potential for insight into social climate change, which ensues as a function of an inordinate number of individuals with a particular point of view populating a specific niche, as the technology industry has done for Seattle. Perhaps, more idealistically, widespread knowledge of human psychological diversity will contribute to increased cross-cultural empathy.

1 G. Stoet, D. C. Geary, Gender differences in the pathways to higher education. *Proc. Natl. Acad. Sci. U.S.A.* **117**, 14073–14076 (2020).
2 R. V. Dawis, The individual differences tradition in counseling psychology. *J. Couns. Psychol.* **39**, 7–19 (1992).
3 D. Lubinski, From Terman to today: A century of findings on intellectual precocity. *Rev. Educ. Res.* **86**, 900–944 (2016).
4 P. R. Sackett, F. Lievens, C. H. Van Iddekinge, N. R. Kuncel, Individual differences and their measurement: A review of 100 years of research. *J. Appl. Psychol.* **102**, 254–273 (2017).
5 L. Corno *et al.*, *Remaking the Concept of Aptitude* (Erlbaum, Mahwah, NJ, 2002).
6 J. Wai, D. Lubinski, C. P. Benbow, Spatial ability for STEM domains: Aligning over fifty years of cumulative psychological knowledge solidifies its importance. *J. Educ. Psychol.* **101**, 817–835 (2009).
7 J. T. Austin, K. A. Hanisch, Occupational attainment as a function of abilities and interests: A longitudinal analysis using Project TALENT data. *J. Appl. Psychol.* **75**, 77–86 (1990).
8 D. Lubinski, Neglected aspects and truncated appraisals in vocational counseling: Interpreting the interest–efficacy association from a broader perspective: Comment on Armstrong and Vogel (2009). *J. Couns. Psychol.* **57**, 226–238 (2010).
9 D. Lubinski, C. P. Benbow, Study of Mathematically Precocious Youth after 35 years: Uncovering antecedents for the development of math-science expertise. *Perspect. Psychol. Sci.* **1**, 316–345 (2006).
10 D. E. Super, P. B. Bachrach, *Scientific Careers and Vocational Development Theory: A Review, a Critique and Some Recommendations* (Teachers College, Columbia University, New York, 1957).
11 H. J. Kell, D. Lubinski, C. P. Benbow, J. H. Steiger, Creativity and technical innovation: Spatial ability's unique role. *Psychol. Sci.* **24**, 1831–1836 (2013).
12 M. C. Makel, H. J. Kell, D. Lubinski, M. Putallaz, C. P. Benbow, When lightning strikes twice: Profoundly gifted, profoundly accomplished. *Psychol. Sci.* **27**, 1004–1018 (2016).
13 R. Su, J. Rounds, P. I. Armstrong, Men and things, women and people: A meta-analysis of sex differences in interests. *Psychol. Bull.* **135**, 859–884 (2009).
14 B. O. Bernstein, D. Lubinski, C. P. Benbow, Psychological constellations assessed at age 13 predict distinct forms of eminence 35 years later. *Psychol. Sci.* **30**, 444–454 (2019).
15 H. Okahana, E. Zhou, *Graduate Enrollment and Degrees: 2007 to 2017* (Council of Graduate Schools, Washington, DC, 2018).
16 T. D. Snyder, C. de Brey, S. A. Dillow, *Digest of Education Statistics 2017* (NCES 2018-070, National Center for Education Statistics, Washington, DC, 2019).
17 D. Lubinski, C. P. Benbow, H. J. Kell, Life paths and accomplishments of mathematically precocious males and females four decades later. *Psychol. Sci.* **25**, 2217–2232 (2014).
18 K. O. McCabe, D. Lubinski, C. P. Benbow, Who shines most among the brightest?: A 25-year longitudinal study of elite STEM graduate students. *J. Pers. Soc. Psychol.*, 10.1037/pspp0000239 (2019).
19 S. von Stumm, P. L. Ackerman, Investment and intellect: A review and meta-analysis. *Psychol. Bull.* **139**, 841–869 (2013).
20 G. Stoet, D. C. Geary, Sex differences in academic achievement are not related to political, economic, or social equality. *Intel* **48**, 137–151 (2015).
21 G. Stoet, D. C. Geary, The gender-equality paradox in science, technology, engineering, and mathematics education. *Psychol. Sci.* **29**, 581–593 (2018).
22 S. J. Ceci, D. K. Ginther, S. Kahn, W. M. Williams, Women in academic science: A changing landscape. *Psychol. Sci. Public Interest* **15**, 75–141 (2014).
23 S. J. Ceci, W. M. Williams, Understanding current causes of women's underrepresentation in science. *Proc. Natl. Acad. Sci. U.S.A.* **108**, 3157–3162 (2011).
24 F. Gino, C. A. Wilmuth, A. W. Brooks, Compared to men, women view professional advancement as equally attainable, but less desirable. *Proc. Natl. Acad. Sci. U.S.A.* **112**, 12354–12359 (2015).