CHAPTER 17

EXPERTISE: INDIVIDUAL DIFFERENCES, HUMAN ABILITIES, AND NONABILITY TRAITS

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It is often easy to identify experts in a variety of domains; they are often recognized by their professions, by widespread recognition, and by their records of accomplishments, whether it be as a top doctor in the medical field, a master builder in the construction industry, or a Nobel Laureate in one of many scientific and other fields. However, an expert need not have a local, national, or world-class reputation. Expertise can be found in less visible or glamorous areas (e.g., taxicab drivers, travel agents, salespeople, landscapers, psychotherapists, school teachers, etc.).

Unfortunately, little or no comprehensive data are available that provide counts of experts in particular fields. Rather, expertise is often implied by awards or certifications received or recognitions by peers, customers, or clients. In areas where expertise can be quantified in terms of productivity, it is frequently defined somewhat arbitrarily, such as an individual who performs in the top 10% of a group of peers, mainly because the distribution of productivity across individuals is continuous—that is, experts in such domains may not necessarily "stand out," from a quantitative perspective, but they do stand out from a qualitative perspective. It is important to note that, in some occupations, a "winner-take-all society" (Frank & Cook, 1995) operates to make the differences between the top performers appear to be much larger than they are in terms of actual performance differences. For example, although a small number of professional golfers typically end up winning major tournaments every year, the differences in overall performance between the highest performer and the 20th highest performer are minuscule, when compared with the differences between the 20th highest performer and the average golfer. The same can be said about other professions, from medicine to music and beyond.

The treatment of expertise in this chapter is to consider expertise as a continuous variable, along which individuals differ to a greater or lesser degree, rather than a highly-selected group that represents only the "best," in any particular domain. From this perspective, what makes an individual an expert is that he or she has a deep knowledge of a particular domain and the skills to express that knowledge. An extra capability for some experts is the ability to incorporate new information into the expert's domain knowledge.

There are two critical questions to be addressed in this chapter: What characteristics of an individual determine whether he or she will develop expertise? And how do these characteristics operate to enable the development of expertise? The first part of this chapter reviews some of the theories and empirical research on key traits (i.e., relatively stable and broad characteristics) related to the development of expertise. The second part of the chapter discusses some of the current ideas about how these traits combine with an individual's direction and intensity of effort to yield expertise. The final section of the chapter considers the questions that are yet to be answered and strategies for shedding light on these enduring issues.

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HISTORICAL AND CONTEMPORARY PERSPECTIVES

Expertise represents a relatively unusual place in the consideration of giftedness and talent. On one hand, debates have raged across the decades about the role of genes, environment, and the role of various aspects of intelligence in the identification and demonstration of giftedness, especially in young children and adolescents (e.g., see Simonton, 1999). Reasoned arguments and empirical data have clearly established that giftedness and talent result from combinations of nature and nurture (e.g., Anastasi, 1958), though there is an endless supply of arguments about the respective proportions of variance accounted for by genes and environment, as if it would be theoretically or practically possible to separate the two. On the other hand, there is little controversy that expertise is clearly a product of talent (i.e., abilities) and experience (i.e., education, work experience, etc.). One simply cannot become an expert in any area, whether it be science, engineering, medicine, law, music, psychology, carpentry or plumbing, without a substantial foundation of domain knowledge and skill. Of course, there is controversy about the magnitude of respective influences of talent and experience in determining individual differences in expertise—it is just that the extreme nature/nurture positions are more clearly untenable for expertise than they are for more abstract constructs like intelligence (e.g., see Ackerman, 2014).

Predicting the Development of Expertise

Expertise often represents the pinnacle of vocational and avocational (e.g., hobbies) achievement. Experts typically perform their tasks more effectively, and for tasks where speed is important, experts usually perform tasks more quickly than nonexperts. Although many individuals strive for expertise, others do not. The reasons for success or failure in developing expertise are complex and sometimes idiosyncratic. Yet, the field of differential psychology (i.e., the study of individual and group differences) provides many clues for understanding and predicting the development of expertise. These clues, in turn, are important for making sure that various stakeholders (e.g., teachers, guidance counselors, parents, students) are provided with essential information to optimize opportunities for the development of individuals toward reaching their respective potentials. Failure to do so can result in societal costs (e.g., inefficient use of resources) and personal costs (poor person–job fit).

One goal for researchers and practitioners is to identify the domain or domains where students are most likely to maximize their potential for expertise. Another goal is to determine the likelihood that students are indeed likely to develop expertise, given available educational and experiential resources. The first goal is the classic *classification task*: find the optimal match between students' cognitive and noncognitive characteristics and a particular domain (e.g., science, humanities, mechanical areas, entrepreneurial occupations). The second goal is known as the *selection task*: predict individual differences in future performance given existing educational/instructional/experiential resources and opportunities (see Chapter 11, this handbook).

Methods for Studying Development of Expertise

From a scientific research perspective, it would be ideal to take a group of young children, assess them on key traits and other measures of interest, randomly assign them to particular educational and occupational programs, and then evaluate which children developed high or low levels of expertise in each of the domains to which they were assigned. Of course, such a program of research is not possible in any society where individuals are allowed choice in their educational or occupational pursuits, or where professional research ethics preclude using draconian procedures that could be expected to result in frustrations and failures among numerous research participants. Nonetheless, in the absence of true randomized treatment studies, it is necessary to use procedures that are suboptimal to evaluate the important questions of the determinants of individual differences.

There are two main approaches to the study of individual differences in the development and expression of expertise. The first is the *prospective approach*, which includes performing a (typically large) survey of children or adolescents, assessing them on measures thought to relate to later expertise, and then waiting to follow-up and determine which individuals have achieved expertise. From these data, one can examine the measures collected at the initial survey and determine whether any of the measures are related to the final expertise criterion measures. These studies, using a longitudinal design, are fraught with logistical and theoretical shortcomings. The main logistical difficulties relate to the substantial time and effort expenditures associated with running a study over years, or even decades before the key data are available for evaluation. Additional difficulties arise in terms of locating and eliciting cooperation from study participants years after the initial survey, and in terms of interpreting results from the sample that may be significantly reduced from the initial survey.

For studies of expertise (in contrast to studies of general intelligence or personality traits), this kind of design is further compromised by the fact that the number of different occupations likely to be represented in the sample is very large, and there are likely to be insufficient numbers of individuals within broad occupational types, rendering within-occupation study difficult. Comparing expertise across domains is perhaps even more problematic, given the inherent differences in educational and vocational requirements for developing expertise. It seems unlikely that sufficient communality will be obtained when lumping together master carpenters, concert violinists, and expert realtors, biologists, engineers, and so on, simply on the basis of where they stand with respect to others in each occupation. Theoretical limitations are perhaps less problematic, as they mainly pertain to the fact that in the years that intervene between the initial survey and the follow-up assessments of expertise, the measures obtained at the initial survey may no longer be "in vogue" or thought to capture essential constructs.

The second approach is a *retrospective approach*. In these investigations, researchers typically limit their samples to a single occupation or a small number of occupations. They survey a group of individuals in the occupations, determine individual differences in the expression of expertise, and then attempt to discover, retrospectively, the nature of the early traits and experiences of the individuals that may be related to the differentiation of those who achieved eminence or expertise, and those who did not. Although the retrospective approach is not subject to the logistical or theoretical difficulties of the prospective approach, there are other fundamental pitfalls associated it. First, these studies fail to take account of individuals who may have started a career in a particular domain, but for one reason or another, are no longer in the occupation of interest. For a study where the researcher wants to examine the antecedents of expertise, a retrospective study will ordinarily exclude all but the most resilient of individuals who are mediocre or poor at their jobs, and may also miss others who developed high levels of expertise, but nonetheless have quit or were fired from their jobs.

Finally, another major shortcoming of the retrospective approach is that the investigator may focus on "current" assessments of key variables (e.g., ability, personality, interests) and project back in time what the likely scores would have been for their sample. The investigator may also attempt to collect from archival sources any data on the variables that were collected when the individuals were children or adolescents. The typically sparse availability and the heterogeneity of available archival data other than common assessments (e.g., college entrance exam scores, grades, teacher reports), make such investigations similarly problematic. Therefore, the most frequent approach to collecting historical information, especially educational and experiential data, is to ask the individuals about their recollections, which may be faulty, or may be influenced/biased to some degree by the individual's current situation or attempts to frame their personal histories in a positive or negative light.

Evaluating Expertise

The other difficulty in studying individual differences in expertise is that, for reasons of feasibility, it is generally not possible to evaluate the breadth and depth of knowledge across multiple areas of knowledge and skill. For example, if one identified a particular field of expertise (e.g., cardiac surgery), it is relatively straightforward to assess individual differences in level of expertise for that domain.

A researcher could enlist peers to judge the efficiency and effectiveness of surgeons while they perform bypass operations. The researcher could administer an examination (such as that for board certification) to a group of surgeons, or the researcher could even do archival research on the surgical records of the physicians. Each of these techniques could converge on an evaluation of individual differences in the depth of knowledge and skill in cardiac surgery. The key problem relates to evaluating the breadth of knowledge for surgeons, in medicine and also in all of the other areas of knowledge that a surgeon might have, whether in related occupational fields (e.g., biology, chemistry, genetics), less-related occupational fields (e.g., engineering, math, business, carpentry, auto mechanics), or other areas (e.g., literature, art, philosophy, music, business, law). As Cattell (1987) noted, to assess the full breadth of knowledge and skills of adults, a researcher would need as many tests as there are areas of knowledge. Moreover, to assess the depth of knowledge for each of these areas, each test would have to survey general surface-level knowledge (e.g., "Who was Beethoven?") and specialized knowledge (e.g., "How do the late symphonies of Beethoven differ from his early symphonies?"). To develop such assessments would be a task far beyond the resources of any empirical researcher.

RELEVANT THEORY AND PRINCIPLES

Because of the impossibility of conducting an ideal experiment to determine who develops expertise (e.g., random assignment of individuals to educational/occupational/training programs), a number of competing theories have arisen regarding the development of expertise that can only be subjected to indirect tests for evaluation. Two prominent controversies in this field relate to extreme positions that more or less pertain to nature/nurture arguments.

Performance Over Practice: Individuals Get More Similar Versus Individuals Get More Different

Thorndike (1908) originally posed the question of whether individuals would get more similar or more different in performance as they practiced a skill. The reasoning went something like this: If nurture (experience) was the primary determinant of performance and learners were given extensive practice/experience on a task, there should be a convergence of performance levels at a postpractice assessment when compared with performance levels at the initial assessment. If nature (genes) was the primary determinant of performance, then providing extensive practice and experience would reduce the influence of nurture. Under those circumstances, there should be an increase in the spread of individual differences in performance. Several decades of arguments resulted in inconclusive results, which were mainly resolved when different tasks were categorized by the information processing demands imposed on the individual performers (Ackerman, 1987). For example, in a novel task, there is often a wide range of performance differences when the task is first performed—dependent on prior experience, transfer of training from similar tasks/procedures, abilities to understand instructions, to develop task strategies, and so on. When tasks have consistent information processing demands—meaning that the appropriate responses to particular stimuli do not change from one occasion to the next—there is typically a steep average learning curve. In fact, with increasing task practice, many individuals who perform relatively poorly at initial task exposure eventually acquire skills equal to, or nearly equal to, those of the individuals who start off performing well, resulting in a convergence of individual differences in performance.

For tasks that lack this inherent consistency, and those that are so complex that a significant number of learners never acquire a fundamental understanding, there is often a lack of convergence across individual performers with practice. In addition, there are domains of knowledge/skill that, although consistent overall, require learners to develop new (and more difficult) skills to attain an acceptable level of expertise. The field of mathematics provides an excellent example of this kind of domain. Instruction and experience with math typically starts with the four basic functions (addition, subtraction, multiplication, and division), each of which has consistent information processing demands. Children, when given extensive practice on such tasks, generally converge in performance (e.g., reciting multiplication tables). Once these basic functions are learned, students are confronted with new and more complex mathematical tasks to learn (e.g., algebra, geometry, trigonometry, calculus). Although each of these tasks is inherently consistent in terms of information processing demands, many learners "drop out" of attaining expertise when confronted with the next higher level of math to acquire. By adulthood, the magnitude of individual differences in mathematics expertise increases far beyond what was seen in students in first or second grade. In the final analysis, though, these results provide little evidence on the nature/nurture controversy.

Individual Differences in Expertise: Deliberate Practice Versus Talent

A second, but related, controversy has occurred much more recently, and is the focus of scholarly debate and popular press discussions: The proposition is that engagement in immense practice (when motivated and deliberate) is the main determinant of expert performance, and individual differences in abilities have little or nothing to do with the development of expertise (e.g., see Ericsson, Krampe, & Tesch-Römer, 1993). This proposition has carried over to the popular press by authors such as Gladwell (2008) and Shenk (2010; for a contrasting view, see Epstein, 2013). Gladwell, in particular has suggested that to achieve expertise, one must complete 10,000 hours of practice on a task (e.g., sports, playing a musical instrument, chess). The research that has gone into these propositions is almost entirely based on retrospective studies, the limitations of which were discussed earlier in this chapter. Recent discussions (e.g., see Detterman, 2014), and meta-analyses (e.g., Macnamara, Hambrick, & Oswald, 2014) have suggested that the proposition that expert performance is entirely dependent on extensive practice vastly overstates the influence of practice. Macnamara et al. (2014), for example, have estimated that 26% or less of the individual differences variance in expert performance is attributable to differences in the amount of task practice. Furthermore, the "practice is everything" proposition fatally ignores evidence of the effects of talent (e.g., abilities and related nonability traits) on the development and expression of expertise (for discussion, see Ackerman, 2014).

RESEARCH REVIEW

There are three major sources of research reviewed here. The first source concerns the study of differences between novices and experts. The second source pertains to direct studies of aging and the development of adult intellect. The third source includes investigations of theories of intellectual development that are based on investment of cognitive resources in acquisition of knowledge and skills.

Expert–Novice Differences

Studies of expert–novice differences do not directly address questions of individual differences in the development and expression of expertise, because they take experts and novices "as is," rather than randomly assigning novices to particular instructional/occupational experiences and examine which novices eventually develop expertise. Nonetheless, expert–novice studies can illuminate some of the variables of interest in the role of expertise development. For example, perhaps a sample of expert auto mechanics differs from novice auto mechanics on particular abilities or personality traits (which are generally stable throughout most of young and middle adulthood). If that is the case, a reasonable hypothesis to pursue in direct studies would be that there may be specific ability or personality correlates in the development of expertise that, in turn, would relate to differential attrition during training or on-the-job work that results in experts having the particular profile of these traits.

Several investigations, most notably an extensive series of studies of physics experts (e.g., physics professors) and novices (e.g., undergraduate physics majors) by Chi, Glaser, and Rees (1982) indicated that these groups did not markedly differ in terms of intellectual abilities, given that all participants were highly selected on intelligence prior to participation. Instead, the main difference between these groups was the breadth and depth of their domain knowledge, which was keenly associated with experience. Such a result suggests a couple of different possibilities. First, it suggests that experts are not necessarily more intelligent than nonexperts (at least to some degree—keeping in mind that in the case of physics expertise, the "novices" were highly selected university students). Second, it might follow that nonability traits (e.g., personality, motivation, interests), which relate to the direction and level of effort and the total investment of time and effort in acquiring expertise are fundamentally important determinants of which individuals achieve different levels of expertise in a particular field.

Aging and Adult Intellect

Studies of aging and adult intellect vis à vis expertise also provide indirect evidence regarding the nature of individual differences in expertise. The history of research and theory on aging and intelligence is beyond the scope of this chapter (see Ackerman, 2008). However, since the early 1920s, it has been evident to researchers and theorists that expressions of adult intellect are fundamentally different from that of children and adolescents. On one hand, middle-age adults tend to perform more poorly than adolescents and young adults on many tests that appear on traditional IQ measures (e.g., short-term and working memory, abstract reasoning). On the other hand, older adults perform well on tests of knowledge. In fact, middle-age adults often perform better than young adults on tests of knowledge (e.g., factual knowledge about health, literature and other humanities, social sciences, business, and law; e.g., see Baltes, Smith, & Staudinger, 1991; for a review, see Cornelius, 1990).

Hebb (1942), in particular, reported that in older adults who had experienced brain injuries, there would often be substantial impairments on such IQ-type measures, but that these same individuals had largely retained their previously learned skills and knowledge. Hebb described adult intelligence as made up of two components: Intelligence A represents the process aspects of intelligence that are critical to new learning and Intelligence B represents previously acquired knowledge and skill components of intelligence. Henmon (1921) best summarized the view that "intelligence . . . involves two factors—the capacity for knowledge and knowledge possessed" (p. 195).

The implication is that in normal adult aging, there may be marked declines in the components of intelligence most associated with short-term and working memory, and with abstract reasoning, but expertise—once developed—is largely preserved well into middle age and beyond. In reference to individual differences in expertise, there appears to be a critical period for acquiring domain knowledge and skills, but once acquired, expert knowledge and skills (which are just specific domains of crystallized intelligence) are robust to many of the vicissitudes of aging.

Investment Theories

Cattell's investment theory. Several theories and research findings ultimately converged to suggest that individual differences in expert occupational and avocational knowledge are the result of an interplay of ability and nonability traits, especially during late adolescence and early-to-middle adulthood. Cattell (1987) developed his own bifurcation of the two major components of intelligence, similar to Hebb's (1942) Intelligence A and Intelligence B, which he referred to as *fluid intelligence* (Gf) and *crystallized intelligence* (Gc). Cattell articulated an extensive "investment theory" of intellectual development that included Gf and nonability traits that together interacted to result in individual differences in the breadth and depth of domain knowledge (which is the essence of Gc). The fundamental ideas behind this theory were based on earlier work by McDougall (1933), who asserted that there was an interaction of ability traits and motivational traits that determined the development of individual differences in knowledge, and by Hayes (1962), who proposed that genetic and acquired motivational drives influence which individuals approach learning experiences and which individuals avoid them. Such variations in learning experiences lead, in turn, to different trajectories of acquired knowledge and skills for different individuals (e.g., different domains of expertise and different levels of expertise/knowledge within the particular areas of interest). Cattell's investment theory, although it does not make precise predictions of which individuals will acquire expertise, includes consideration of motivational traits, personality, and interests as important variables in determining the direction of effort and the amount of effort devoted to acquiring Gc knowledge and skills. Although the theory has useful heuristic value, little attention was given to this perspective until the 1990s, when two developments provided an additional foundation for current empirical research on individual differences in domain knowledge. The first development was an explication of *trait complexes* and the second was a more explicit framework for adult intellectual development, referred to as PPIK (intelligence-as-Process, Personality, Interests, and intelligence as Knowledge; Ackerman, 1996).

Trait complexes. Historically, there have been three major obstacles to integrating consideration of nonability traits (e.g., personality, interests, motivation, self-concept) in the context of other constructs, especially intelligence. The first obstacle is the proliferation of multiple trait constructs over the last century. The literature has evidenced a huge number of nonability traits, making it difficult to determine which particular traits might be related to the development of expertise. Moreover, until recent meta-analysis, it has not been clear whether these traits are independent or have varying degrees of overlap with one another. Also, theories of nonability traits, with few exceptions, have largely developed independently of theories of abilities and intellectual development. Many extant personality and interest-trait measures, for example, are often carefully constructed to be relatively uncorrelated with intellectual abilities, in that the goal is to develop measures that are independent of individual differences in cognitive functioning. This approach stands in stark contrast to the historical development of intellectual ability measures, which are typically validated against educational and occupational success criteria.

If one draws on extant research where personality and interest measures were correlated with measures of intellectual abilities, and uses meta-analysis to estimate their respective relations, it turns out that there are some key communalities among these different constructs. Ackerman and Heggestad (1997), in an analysis of nearly 200 studies, found that it is possible to reduce the number of traits considered to a relatively small number of trait complexes. These trait complexes represent families of traits across ability, personality, and interest domains that are significantly, and often substantially positively correlated with one another. Four trait complexes in particular were identified: intellectual/cultural, science/math, clerical/conventional, and social. Subsequent empirical investigations have supported these and other trait complexes (e.g., Armstrong, Day, McVay, & Rounds, 2008; Staggs, Larson, & Borgen, 2007; Sullivan & Hansen, 2004). The most important aspect of this research, especially for the study of individual differences in the development of expertise, is that the trait complex findings suggest that researchers do not need to address dozens of different traits but can focus on a small number of trait complexes, which capture cognitive, personality, and interest domains and can be synergistic determinants of the depth and breadth of intellect and expertise development.

PPIK. The PPIK framework, first proposed by Ackerman (1996; see also Ackerman, Bowen, Beier, & Kanfer, 2001), builds on and integrates the prior work of McDougall (1933), Hayes (1962), Hebb (1942), Cattell (1987), Vernon (1950) with the foundation of trait complexes from the meta-analytic review of ability, personality, and interest trait relations by Ackerman and Heggestad (1997). This framework specifies how investment of intelligence-as-process (e.g., Cattell's Gf, Hebb's Intelligence A) leads to development of intelligence-as-knowledge (e.g., domain knowledge or expertise) with the intensity and direction of investment determined by individual differences in trait complexes that are either facilitative or impeding of the acquisition of knowledge in particular domains. There are four general propositions from this framework:

1. Intelligence-as-process represents the potential (or as Henmon, 1921, put it, "the capacity for knowledge" [p. 195]).
2. Facilitative trait complexes (e.g., intellectual/cultural, science/math) orient individuals toward development in knowledge in educational and particular occupational domains (e.g., physical sciences, technology, engineering, math, humanities, social sciences). Impeding trait complexes (e.g., clerical/conventional) either lead individuals away from specialized knowledge through higher education and perhaps more

toward traditional "blue-collar" domains, or (in the case of the social trait complex) toward development of interpersonal aspects of expertise (e.g., sales, management).

3. The intensity of investment is partly determined by an individual's standing on intelligence-as-process (which represents the efficiency of the cognitive system in acquiring new knowledge), partly determined by the individual's standing on particular trait complexes, and more generally associated with the amount of time and effort the individual devotes to acquiring expertise. That is, this is a partly compensatory model, in which, to achieve a level of expertise equal to a dedicated high-ability individual, an individual who is average or slightly above average in intelligence-as-process must allocate more time and effort to acquiring expertise.
4. The outcome of the investment of intelligence-as-process, oriented through the trait complexes, is a range of individual differences in the breadth and depth of domain knowledge and skills (i.e., intelligence-as-knowledge; see Figure 17.1).

Empirical support for the PPIK framework. Several studies of adolescent and adult intellect-as-knowledge have provided support for some of the basic tenets of the PPIK framework. Initial studies involved

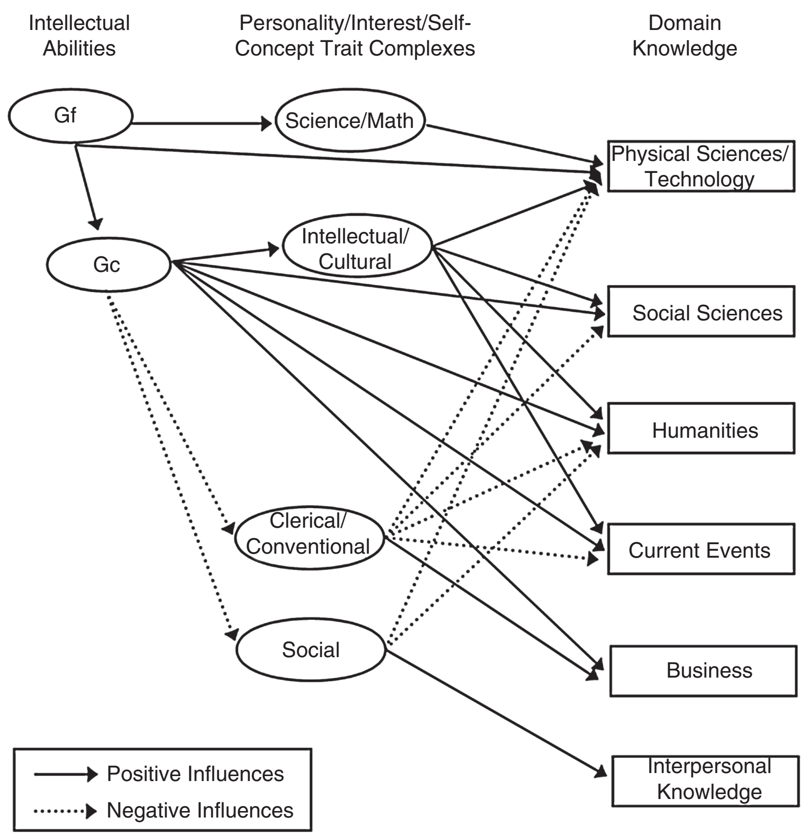

FIGURE 17.1. Illustration of constructs and influences in the PPIK (intelligence-as-Process, Personality, Interests, and intelligence as Knowledge) theory (Ackerman, 1996; Ackerman & Heggestad, 1997). Gf = fluid intelligence or "intelligence-as-process"; Gc = crystallized intelligence; positive influences = higher levels of one construct (e.g., Gc) lead to higher levels of the other construct (e.g., Clerical/Conventional trait complex); negative influences = lower levels of one construct lead to higher levels of the other construct. From "A Theory of Adult Intellectual Development: Process, Personality, Interests, and Knowledge," by P. L. Ackerman, 1996, *Intelligence, 22,* p. 238. Copyright 1996 by Elsevier Science. Reprinted with permission.

assessments of process abilities, "historical" Gc (i.e., the kinds of general knowledge one acquires in primary and secondary education and from wider exposure through mass media and in the home), and breadth/depth of knowledge up to a college-level survey course in 20 different domains representing a sample of physical and social sciences, humanities, business, and law. In cross-sectional investigations, where samples of young and middle-age adults were assessed (e.g., see Ackerman, 2000; Ackerman & Rolfhus, 1999), it was found that middle-age adults, on average, had greater breadth and depth of domain knowledge in most areas, except for math and the physical sciences. Moreover, facilitative trait complexes were positively associated with higher levels of academic domain knowledge, and impeding trait complexes were either unrelated or negatively related to academic domain knowledge. These findings were later extended into investigations of current-events knowledge (Beier & Ackerman, 2001) and health-related knowledge (Beier & Ackerman, 2003).

Other supporting evidence was obtained in short-term learning studies, where research participants were required to learn about new technology, financial planning, or acquire knowledge about health-related topics, such as cardiovascular disease (Ackerman & Beier, 2006; Beier & Ackerman, 2005). The general patterns of results from these studies supported the importance of all four components of the PPIK model (i.e., intelligence-as-process, personality, interests, leading to individual differences in intelligence-as-knowledge) in the acquisition of new domain knowledge. Whereas initial studies concentrated on contrasts between young and middle-age adults, more recent studies have focused on adolescent intellectual development. These investigations have also shown support for the proposition that development of domain-specific knowledge (as indexed by enrollment and subsequent performance on elective advanced placement [AP] courses), is largely an interaction between the investment of intelligence-as-process, previously developed Gc, and personality/interest/self-concept trait complexes.

It is important to note that although these studies are consistent with the PPIK framework for predicting/understanding the development and expression of expert domain knowledge, they too are "indirect" sources of evidence, rather than critical experiments, because with the exception of the short-term learning studies, individuals are not randomly assigned to courses of study and experience; rather, they are the result of self-selection. Therefore, other factors may be responsible for these patterns of results. It also remains a question as to whether the same individuals who develop expertise in one domain would be just as likely to develop expertise in other domains, if they were assigned to courses and experiences in other domains.

PRACTICE AND POLICY ISSUES

Primary schooling, at least in the developed world, tends to focus on development of basic skills, because these are considered to be the building blocks for later development of specialized occupational knowledge (e.g., see Porter, McMaken, Hwang, & Yang, 2011). Until middle-school, students have few, if any, choices about the educational curriculum to which they are exposed (with the exception of art, music, and languages, to some degree). Even well into secondary school, there are required courses (e.g., math, science, language) that make up a core curriculum, so that students are expected to have a working knowledge and skills about many different areas of knowledge. Programs for gifted and talented young children usually focus on these main curricular areas, but as children reach adolescence, there are opportunities to obtain specialized instruction in areas outside the core curriculum in addition to simple advancement (taking regular courses above grade level). In this sense, it is when the child is *allowed* to obtain advanced courses or specialized courses in a particular area, a focus on the development of expertise can be seen. At the postsecondary level and beyond, whether in vocational training, college/university study, or on the job, we expect individuals to develop expertise in one or more domains. This approach to education is not the only one possible. For example, earlier specialized vocational training was popular 100 years ago in the United States, and in some countries, such specialization into direct vocational training or specific preparation for postsecondary education is the norm rather than the exception.

There are two fundamental issues that must be addressed to maximize the development of expertise across a wide range of individual talents and interests. If a zero-sum basis for the amount of instructional time spent in school is accepted, then there is a clear tradeoff between general education at the secondary-school level and specialized training opportunities. The first issue is that if policy makers wish to maximize expertise development in areas that do not require higher (postsecondary) education, then there needs to be a reassessment of the proper balance between general education and specialized training. This is also true, but to a lesser extent, for specialized curricula in domains that require education beyond high school (e.g., should a budding physicist be required to complete courses in history or geography, when he/she could be taking advanced mathematics or physics courses?). In many ways, modern colleges and universities have been moving in this direction for the last several decades, such as the removal of requirements for foreign language and similar courses for a bachelor's degree, but high schools largely maintain the general curriculum approach that has been in existence since the mid-20th century (e.g., see Aiken, 1942).

The second, and perhaps the larger issue, is that we need a better set of procedures for determining the optimal career direction for individual students, especially during the adolescent years. Today's high school guidance counselors have pretty much the same tools that were available 50 or 60 years ago. These tools include omnibus intelligence tests (e.g., IQ tests), specialized ability tests (e.g., multiability batteries), achievement tests, broad vocational interests measures, and the students' course transcripts. Moreover, these tools do not provide any sense of integrated information—the guidance counselor must look at each set of measures and make his/her own judgement about how a particular pattern of ability strengths and weaknesses and the student's interests map on to broad categories of occupations or particular careers. The student's patterns of grades might further illuminate the likelihood of success in particular educational/vocational programs, but again the counselor must draw such inferences on the basis of prior experiences rather than having any empirically derived foundation for making such projections.

The experience of AP course enrollments and subsequent performance on AP exams is illuminating. AP programs, where students have an opportunity to complete college-level courses in high school, and in turn, receive college credit on successful completion of an exam, have seen explosive growth, especially in the last two decades. In 1993, nearly 640,000 AP exams were completed, but in 2013, there were nearly 4,000,000 exams completed. Nonetheless, of those exams, 41% of the scores were below a level that typically receives college credit (College Board, 2014), suggesting that at least to some degree, there is a substantial inefficiency in matching students to these academic courses. Currently, there are no universal procedures for determining which students enroll in particular AP courses. Some schools have rigid rules about prior grade requirements for placement, some depend on teacher ratings, whereas still others allow students (and/or their parents) to make decisions about which courses, if any, in which to enroll. There are a few tools available for predictions to be made about the likelihood of individual student success in these exams, but these tools are mainly dependent on the student's ability tests scores—they take few, if any, nonability traits into account.

In 1904, Charles Spearman introduced the concept of "g" or general intelligence, which was envisioned to be a "mental engine" that was fixed early in life, and was instrumental in determining individual differences in performance on all intellectually demanding activities (albeit to differing degrees, depending on the "g saturation" of the tasks; Spearman, 1927). Although this turned out to be a substantial oversimplification of the nature of intelligence (especially in contrast to Binet's approach to intelligence assessment; Binet & Simon, 1905/1961), there is an important kernel of validity in Spearman's position (see Chapter 10, this handbook). In childhood and early adolescence, a combination of individual differences in general intellectual abilities and a relatively universal core school curriculum, results in differences in broad potentials for the later development of expertise. These factors, in turn, set the stage for interactions between nonability traits and the investment of attention and effort toward or away from accumulating Gc/domain knowledge, which ultimately leads to individual differences in expertise.

As noted earlier, unlike general intelligence, where there have been heated debates regarding nature and nurture, no credible researcher will claim that expertise is substantially inherited. It must be learned through diligent effort and practice over extended periods of time (e.g., see Simonton, 1988; see also Chapter 18, this handbook). How much effort an individual puts into developing expertise, and how long that effort is maintained, is a function of the individual's Gf/intelligence-as-process, personality and motivational traits, educational/occupational opportunities, successes and failures, and transfer of training/knowledge from relevant/supporting Gc/intelligence-as-knowledge. Moreover, some domains of expertise typically require much more foundational knowledge than others (e.g., the differences between the educational foundation and extent of knowledge required to become a master carpenter vs. an expert neurosurgeon). Such differences in requirements to acquire expertise impose some limitations on the individuals who could be expected to succeed in the laborious efforts required. In the case of neurosurgeons, for example, these requirements include highly successful secondary and postsecondary school achievements, in addition to a rigorous selection process to medical school, internships, residency/fellowship, and beyond.

Furthermore, predicting which individuals will attain world-class levels of expertise is essentially a "fool's errand," because the base rates for such attainments are extremely rare. For example, assuming that 1 of 100 individuals reach world-class expertise, researchers might design a battery of assessments for adolescents that presumably included the ability and nonability traits that are instrumental to the development of expertise, with a validity of $r = .40$ (which would be a quite respectable correlation between test scores administered at age 11 and a criterion of expertise in a profession at age 40). With such a battery, it would be possible to identify 70% of the world-class experts, but the actual probability of attaining world-class expertise, given a positive test score would only be .023, that is, about 2 in 100. If world-class experts are even more rare than 1 in 100, which is entirely likely for many domains of expertise, the probability of identifying them becomes even more difficult (for a more extensive discussion, see Ackerman, 2014). Predicting expertise at a level that is not world class, but rather relative excellence among peers, is a much more feasible task, and one that represents a reasonable goal for researchers and applied psychologists.

FUTURE CONSIDERATIONS AND DIRECTIONS

Returning to Henmon's (1921) definition of intelligence as "the capacity for knowledge and knowledge possessed" (p. 195), we can accept that expertise is the result of the level of intellectual ability in childhood and adolescence (mostly made up of Gf at young ages) and the investment of intellectual resources toward acquisition of knowledge and skills, in terms of time and effort. The key task for researchers is to develop and validate tools that can assess an individual's current standing on abilities, along with the nonability traits of motivation, personality, self-concept, and other related constructs, which, in turn, determine the best fit for the individual to one or more possible domains for development of expertise. One must, of course, keep in mind that some individuals do not aspire to develop expertise in any area, but others may need guidance to help them find the domains for which they are best suited, and those where they are most likely to be satisfied. Multiability batteries provide data for the first consideration, and vocational interest measures provide one source of data for the second consideration. Additional measures, such as assessment of the trait complexes described earlier, may provide additional data from which differential diagnostic predictions can be effectively implemented.

The importance of talent identification from this perspective can hardly be overestimated. Mismatches of individuals to courses of study or educational programs are clearly seen in the numbers of students in college who change majors during their college careers. Even more stark are the data on students who drop out from college entirely.

Recent estimates put this number in the neighborhood of 30% in the U.S. students (National Center for Educational Statistics, 2014), though many of these students drop-out for reasons other than, or in addition to, a mismatch between their ability and nonability traits and the educational requirements. Nonetheless, nearly 40% of all students who enter graduate programs fail to complete the degree—much of this is clearly a waste of student time/effort and institutional resources (Institute of Education Sciences, 2007). Improving predictions of success and optimizing the match between individual characteristics and educational/occupational requirements can be expected to have substantial benefits to the individuals (who can better use their time and effort in pursuing activities for which they are better suited) and institutions (that can make better selection decisions, to maximize success of the programs and students).

The identification of individual optimal paths for development of expertise, and more generally person–job fit, will probably require a reconsideration of the degree to which schools and counselors approach the identification of gifted and talented students in two ways. First, rather than mainly focusing on the top of the distribution of students, in terms of intellectual abilities, the focus would be expanded to encompass a much larger portion of the population of students (keeping in mind that attainment of expertise is a joint function of the "capacity for knowledge" and the time and effort the individual is willing to invest in the acquisition of knowledge). Individuals with average or above average intellectual abilities, but who also have the compensating influence of a high degree of motivation for investing a greater portion of their abilities to acquire knowledge, may benefit from new opportunities that allow them to engage topics with more depth than the standard curriculum, even if such courses are not as challenging as the traditional gifted and talented courses in the same domains. This would initially require much greater attention to assessment of nonability traits (motivation, personality, interests) than currently exists in the typical school system. Second, the range of educational/vocational training opportunities would need to be expanded or even individualized, especially at the secondary school level, to accommodate a higher level of specialization that better aligns with the individual's optimal direction of knowledge/skill acquisition.

SUMMARY AND CONCLUSIONS

Thomas Edison famously said that: "Genius is one percent inspiration and ninety-nine percent perspiration." He may have had his percentages off by quite a bit, but he captured the essence of the argument. Experts, like geniuses are not born as experts. Expertise is the product of abilities, nonability traits, and a substantial investment of time and effort in acquiring domain knowledge and skills. Although some intelligence theorists still concentrate on general intelligence of children as the single most important cognitive trait predictor of later development of expertise, it is clear that many different traits—including ability and nonability traits, interact to determine the individual's direction and level of investment in acquiring domain knowledge and skills that make up the foundation of an expert's competencies.

Identification of the myriad traits (especially the nonability traits) that influence the development of expertise represents an area of research that is in its infancy. Several nonability constructs have been proposed as instrumental in developing expertise in general and within specific areas. The collection of empirical data that will aid in evaluation of these predictions will be a long and laborious process, requiring at a minimum that individuals be followed over long periods of time, as they transition from secondary school well into their professions. Such efforts can be expected to have significant payoffs. Identification of talent for expertise in specific domains may substantially improve the efficiency of educational/occupational systems, but perhaps more important, improve career success and satisfaction, by better aligning individuals' talents and other characteristics with careers for which they are well suited.

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