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Trait Complexes, Cognitive Investment, and Domain Knowledge

Philip Ackerman and Margaret E. Beier

The study of expertise has a long and varied history across over one hundred years of modern psychology. Along the way, various approaches and perspectives have been applied to examination of two central questions: "Who becomes an expert?" and "How does one become an expert?" Traditional experimental psychology researchers have focused on describing the processes involved in acquisition of expert performance (for example, Bryan and Harter, 1899), or on specifying the methods one should adopt for successfully acquiring expert performance (for example, James, 1890/1950). In contrast, traditional differential psychology researchers have focused on differentiating individuals from some specified group (for example, novices) who will acquire expertise during the course of training or job tenure from those who will fail to acquire expertise, given the same exposure. Researchers from a third perspective, which is best characterized as an "interactionist" approach, have attempted to build representations that consider both trait differences and childhood and adulthood experiences as spurs to the development of expertise (for example, Snow, 1996).

The focus of our discussion in this chapter is mainly on the differential and interactionist approaches. That is, we seek to understand the development of expertise as an interaction between individual characteristics (abilities, personality, interests, self-concept, and so forth) and the environment, as jointly influencing which persons develop expertise and which persons do not. In addition, we concern ourselves with the *direction* of investment of cognitive resources, which in turn determines the domains of expertise that are developed. The "environment" in this context can be highly constrained, as in elementary school and secondary school, or much less constrained, as post-secondary education and the world of work.

This chapter will first review some central issues of our perspective, such as the distinction between typical and maximal performance and the concept of aptitude complexes or trait complexes. Next, we describe a theoretical approach that encompasses the interactions between trait complexes and knowledge acquisition, followed by a brief review of empirical evidence associated with the theory. The current theoretical perspective will be placed in the context of other theories of abilities and expertise. We close with a discussion of some implications of this approach for science, for education, and for society.

TYPICAL BEHAVIOR VERSUS MAXIMAL PERFORMANCE

By the mid-1900s, researchers concerned with individual-differences theories and assessment procedures had split into essentially non-overlapping groups. Cronbach (1957) identified the field of correlational (differential) psychology as "sort of a Holy Roman Empire whose citizens identify mainly with their own principalities" (p. 671). For example, ability theorists and practitioners had little contact or communication with personality theorists and practitioners. As Cronbach (1949) earlier pointed out, abilities (in terms of both theory and assessment practices) were associated with "maximal performance." That is, when individuals were administered intelligence, aptitude, or achievement tests, they were exhorted to "do your best." The goal of the assessments was explicitly to measure the performance of an individual at his/her level of maximum cognitive effort. Individuals who did not try hard on such assessments effectively invalidated the inferences that could be made on the basis of the resulting test scores. In contrast, according to Cronbach (1949), personality theory and assessments were not concerned with maximal performance. Instead, they focused exclusively on how the individual "typically" behaved or focused on what were the individual's typical likes and dislikes. Operationally, personality assessment measures asked, for example, "Do you like to attend parties?" to obtain an estimate of the individual's underlying level of introversion-extroversion. Although Cronbach (1957) initially argued for the integration of experimental and differential approaches to behavior, subsequent investigators have attempted to better integrate the disparate streams *within* differential psychologies of cognition (abilities), conation (motives and volition), and affect (personality). Such approaches were advocated by Snow (1963), Cronbach (1975), and others (see Ackerman, 1997, for a review).

When it comes to expertise, the traditional concept of ability-as-maximal-performance leaves a lot to be desired. The contrasting contexts for ability assessment and achievement assessment make this point in a salient fashion. On the one hand, ability tests (such as standard omnibus intelligence tests) generally attempt to *remove* the benefits of specific expertise on overall performance, by (a) sampling very broadly (maximizing the heterogeneity of test content), and (b) specifically selecting content that is not associated with expertise (for example, neither the Stanford-Binet nor the Weschler Adult Intelligence Scales require that the examinee know how to read). Thus, the expert chef and the expert chemist are confronted with little test content that could benefit from their respective fields of expert knowledge. On the other hand, achievement tests (especially specialized domain-knowledge tests, such as professional certification tests) attempt to focus only on the specialized knowledge domain in question. For example, the Graduate Records Examination (GRE) Subject test in Chemistry can be expected to effectively discriminate between the chemist and the cook in a way that demonstrates the differences between their respective cumulative knowledge about chemistry. (It should be noted, though, that such tests have their limitations, such as the potential confound of individual differences in reading comprehension abilities that might influence performance on a time-limited domain-knowledge test. For a discussion of this issue, see Carroll, 1982.)

Looking at so-called intelligence and achievement tests through the perspective of maximal effort and typical behavior, it becomes clear in theory (though not entirely certain in practice) that without the application of directed cognitive effort toward domain-knowledge acquisition over extended time, performance on specific achievement tests will suffer. In contrast, tests of maximal effort, especially when presented in decontextualized formats (such as working-memory tests with letters and numbers as stimuli), are likely to be less influenced by cognitive investment toward developing expertise *in any specific domain*, though the cumulative effects of investment across domains can be expected to influence performance somewhat. Such considerations suggest that tests of general intelligence (as measures of maximal effort) are likely to have diminished associations with individual differences in the development of expert knowledge when compared with measures that are more appropriate to the assessment of typical levels of cognitive investment over extended periods of time.

APTITUDE COMPLEXES AND TRAIT COMPLEXES

In a seminal study of learning in post-secondary physics that considered interactions among abilities, attitudes, personality variables, and prior knowledge, Snow (1963) asked whether there are "combinations of levels of some variables which are particularly appropriate or inappropriate for efficient learning?" (p. 120). The concept of these kinds of combinations of traits was ultimately described by Snow as "aptitude complexes," in the same kind of framework as Cronbach's (1957) generic usage of "aptitude" as any individual-differences construct. Over the course of the subsequent three decades, Snow and his students (for example, Peterson, 1976; Porteus, 1976; for reviews see Snow, 1976, 1989) revealed the existence of several interesting personality-ability aptitude complexes that were related to the relative effectiveness of different instructional treatments (such as high structure/low structure class environments).

Although not directly resulting from an analysis of learning outcomes, Ackerman and Heggestad (1997) performed a large-scale meta-analysis and review of the literature associated with relations among ability, personality, and interest variables. They identified four broad sets of traits that shared significant and meaningful levels of common variance, which they called "trait complexes" after Snow's aptitude complex conceptualization (the term "traits" replaced "aptitude" in order to address the larger context of the overlapping characteristics across learning and other contexts). The four trait complexes were identified as (1) Social, (2) Clerical/Conventional, (3) Science/Math, and (4) Intellectual/Cultural, and the component traits are shown in Figure 1.1. These complexes have elements in common with Snow's aptitude complexes, but are, in fact, derived outside of the educational context. These trait complexes are posited to coalesce during child and adolescent development. Moreover, they represent combinations of traits that will, in turn, affect both academic and vocational orientations. Trait complexes affect the direction and intensity of the investment of cognitive effort and ultimately lead to differentiation between individuals in the breadth and depth of knowledge/expertise acquired during adulthood. Initial indications suggested that many sources of domain knowledge were

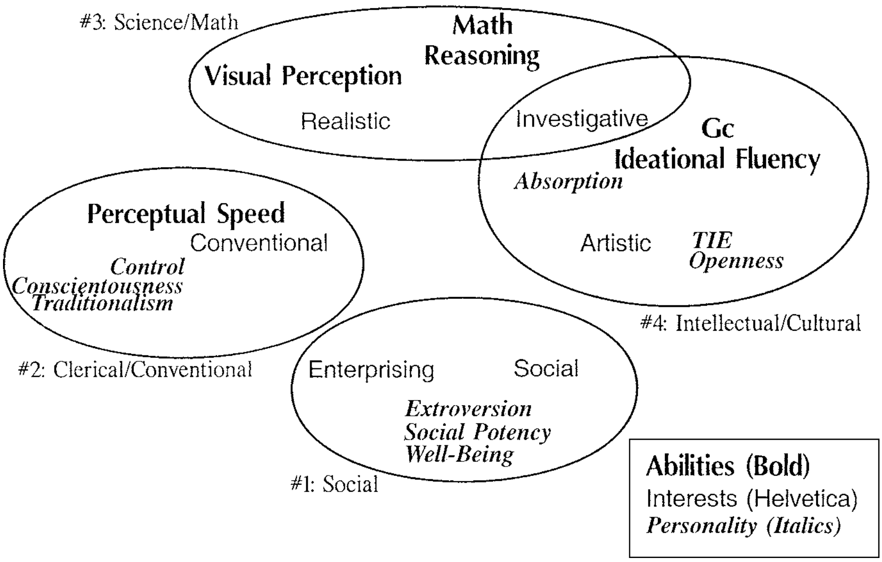

FIGURE 1.1. Trait complexes, including abilities, interests, and personality traits showing positive commonalities. Shown are (1) Social, (2) Clerical/Conventional, (3) Science/Math, and (4) Intellectual/Cultural trait complexes. Ability traits = bold; Interests = Roman font; Personality traits = Italic font. (Figure 7 on p. 239 of Ackerman and Heggestad, 1997, "Intelligence, personality, and interests: Evidence for overlapping traits." *Psychological Bulletin*, *121*, 219–45. Copyright American Psychological Association. Reprinted by permission.)

positively associated with high levels of Science/Math and Intellectual/Cultural trait complexes, and were associated with lower levels of Social and Clerical/Conventional trait complexes. Some of the subsequent empirical research on this topic will be discussed in a later section, but first we review a theoretical perspective that puts many of these constructs into a single theoretical framework, called PPIK.

PPIK

By integrating the concepts of typical versus maximal performance together with considerations of commonality among cognitive, affective, and conative traits, Ackerman (1996) has proposed a representation of the development of intellect across much of the adult lifespan. The approach is called PPIK for the four major components of the framework: intelligence-as-Process, Personality, Interests, and intelligence-as-Knowledge. Figure 1.2 provides a general description of these components, within a developmental framework. The PPIK approach draws

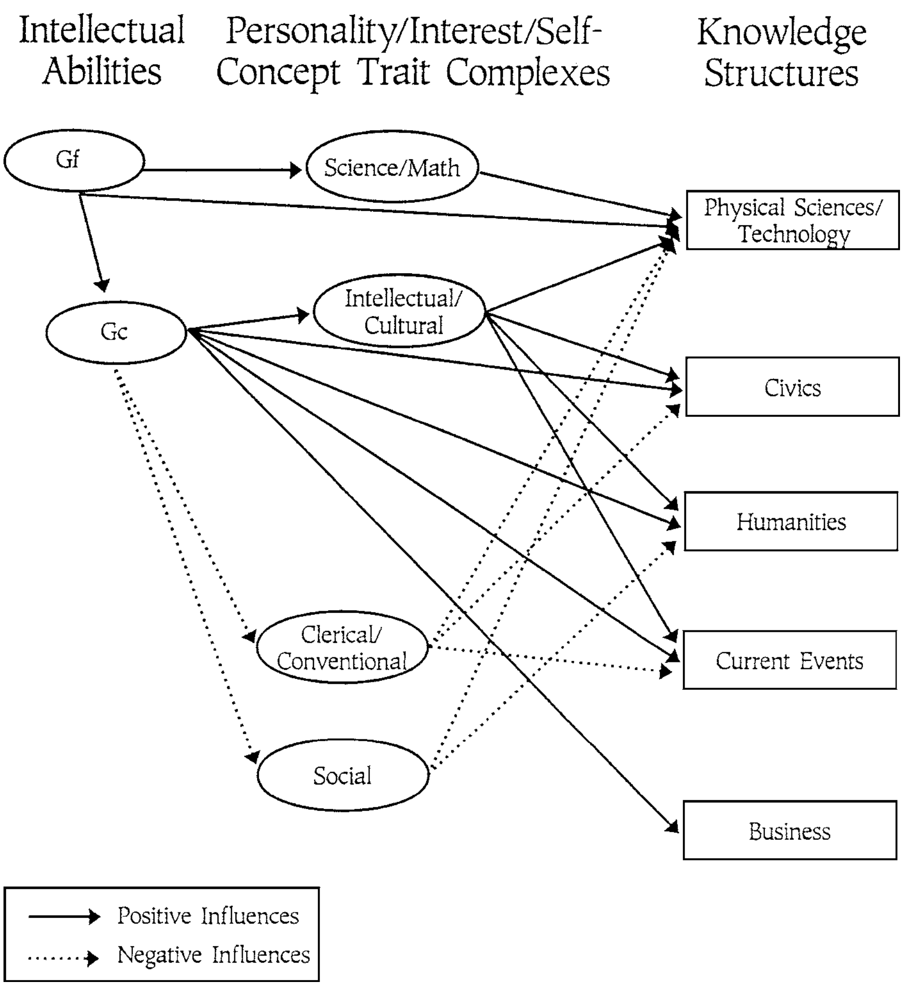

FIGURE 1.2. Illustration of constructs and influences in the PPIK theory (Ackerman, 1996). Gf (fluid intelligence) represents “intelligence-as-process”; Gc = crystallized intelligence. “Negative influences” mean that lower levels of one construct (for example, Gc) lead to higher levels of the other construct (for example, Clerical/Conventional trait complex). (Phillip L. Ackerman, Kristy R. Bowen, Margaret E. Beier, and Ruth Kanfer (2001). Determinants of Individual Differences and Gender Differences in Knowledge. *Journal of Educational Psychology*, 93, Number 4. Copyright American Psychological Association. Reprinted by permission.)

on the conceptualizations of Cattell and Horn (Cattell, 1943, 1971/1987; Horn and Cattell, 1966), the concepts of trait complexes (Ackerman and Heggestad, 1997), and Cattell's Investment Hypothesis (Cattell, 1957). Individuals start with differing levels of intelligence-as-process, which is similar to Cattell's fluid intelligence (Gf), but is limited to abilities that are based on substantially decontextualized processes (for example, working memory, abstract reasoning). Through interactions between intelligence-as-process and the development of key personality and interest variables (such as the trait complexes discussed earlier), individuals devote greater or lesser amounts of cognitive effort to the acquisition of domain-specific knowledge. These variables have mutually supporting or mutually impeding influences. For example, initial success in performing math problems may lead to an increment in math interests and supportive personality traits, which in turn may lead to increments in cognitive investment toward acquiring new knowledge in the mathematics domain (see Holland, 1959, 1973). In contrast, initial failures in performing math problems may lead to a decrement in associated interests and personality traits and in turn may lead to a decrement in cognitive investment toward acquiring new knowledge in the mathematics domain.

Across child and adolescent development, as the individual invests greater or lesser amounts of cognitive effort across different knowledge domains, coherent patterns of supportive and impeding traits are expected to coalesce into trait complexes. As individuals move from experiencing a common curriculum (for example, in elementary school) to increasingly differentiated experiences (both in secondary and postsecondary educational situations and in occupational and avocational activities), knowledge and expertise develop in increasingly differentiated repertoires. From the PPIK perspective, intelligence-as-knowledge is similar to Cattell's (1957) conceptualization of crystallized intelligence (Gc), but is much broader in operationalization than traditional measures of Gc (see, for example, Ackerman, 1996, for a discussion). In contrast to intelligence-as-process, intelligence-as-knowledge has an accumulative pattern across much of the adult lifespan (except for knowledge that is not regularly accessed and used, e.g., foreign language knowledge that is acquired in secondary school, but rarely used in subsequent years). Figure 1.3 illustrates the broad developmental patterns of intelligence-as-process, Gc (as traditionally assessed), and both occupational and avocational intelligence-as-knowledge. The figure indicates that, despite declines in intelligence-as-process during adulthood,

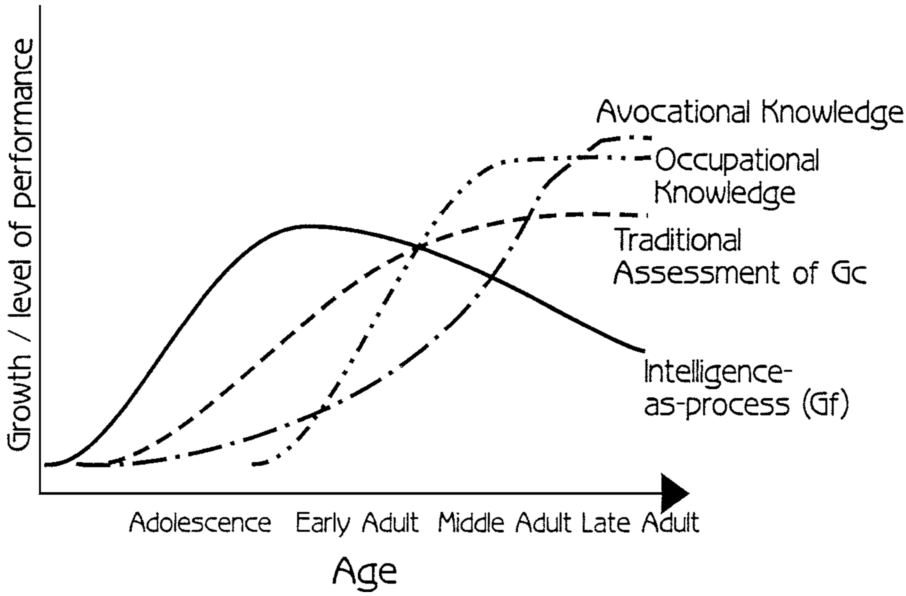

FIGURE 1.3. Hypothetical growth/level of performance curves across the adult lifespan, for intelligence-as-process, traditional measures of Gc (crystallized intelligence), occupational knowledge, and avocational knowledge. (Intelligence-as-process [Gf] and Gc modeled after Horn [1965].) (From Ackerman [1996].)

domain-specific knowledge and expertise tend to increase during the same period. Such increases, though, represent average standings – individual differences in trajectories are expected to be found, resulting from differential investment of cognitive effort toward or away from particular domains.[1]

EMPIRICAL FINDINGS RELATED TO THE PPIK THEORY

In a continuing series of studies over the past decade, we have investigated the relations among demographic variables of age and gender, intelligence-as-process, Gc, and several trait complexes in predicting individual differences in domain-specific knowledge. These studies are

[1] Note that the discussion of intelligence-as-process and intelligence-as-knowledge does not deny the potential influences of other abilities, either those traditionally defined empirically (for example, Carroll, 1993) or rationally (for example Gardner, 1999). The current approach focuses on what we consider the major sources of influence on intellectual performances, while remaining agnostic about the utility of other relevant cognitive traits.

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described in detail elsewhere (Ackerman, 2000; Ackerman and Rolfhus, 1999; Beier and Ackerman, 2001; and Rolfhus and Ackerman, 1996, 1999), but we provide a brief review of this work below.

Study 1

In our first major study, we administered twenty academic and technology-oriented tests to a sample of 135 adults between the ages of thirty and fifty-nine (Ackerman and Rolfhus, 1999), and compared their performance with a group of 141 younger college students between ages eighteen and twenty-seven (Rolfhus and Ackerman, 1999). The middle-aged adults were found, on average, to know a great deal more about nearly all the various knowledge domains. In addition, this investigation showed that individual differences in knowledge are partly predicted by general intelligence, but especially well predicted by verbal/crystallized abilities, independent of general intelligence. The results were generally supportive of the Ackerman (1996) PPIK theory. A factor analysis of personality, interest, and self-concept traits, illustrated in Table 1.1, provided support for three of the trait complexes proposed by Ackerman and Heggestad (1997). The patterns of correlations between these three

TABLE 1.1. *Factor Analysis (Varimax Rotation) Showing Trait Complexes*

	Intellectual/Cultural	Science/Math	Social
Openness to experience	**.803**	−.005	−.046
Typical intellectual engagement (TIE)	**.838**	.135	.109
Investigative interests	**.638**	.250	−.033
Artistic interests	**.670**	−.085	.040
Verbal self-concept	**.630**	−.070	.066
Verbal ability	**.608**	.152	−.373
Realistic interests	.320	**.390**	.112
Math self-concept	−.339	**.628**	.014
Mechanical self-concept	.216	**.653**	.066
Spatial self-concept	.211	**.688**	.141
Math ability	−.190	**.502**	−.263
Spatial ability	.034	**.616**	−.274
Extroversion	−.092	−.075	**.662**
Social interests	.234	.047	**.688**
Enterprising interests	−.067	.004	**.586**

Note: $N = 135$, from study reported in Ackerman & Rolfhus (1999).
Salient factor loadings shown in boldface.

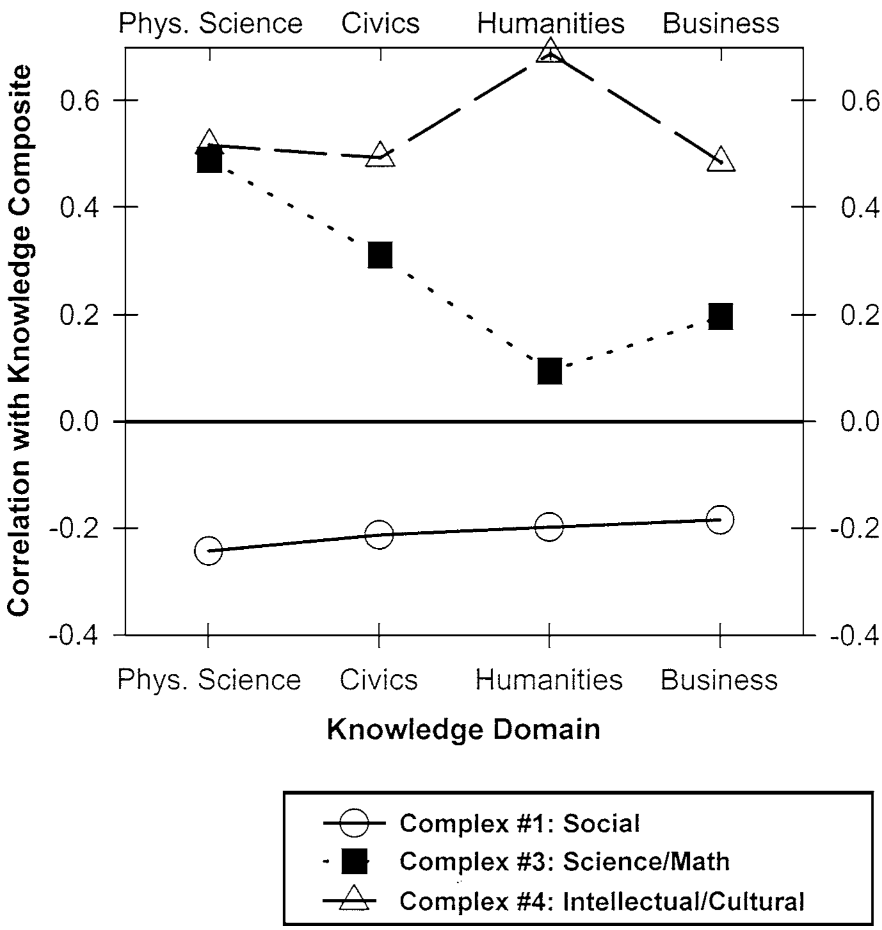

FIGURE 1.4. Correlations between trait complex scores and knowledge composites. $N = 276$ (Ages 18–59).

trait complexes (Social, Science/Math, and Intellectual/Cultural) and domain knowledge were consistent with the PPIK theory. Specifically, as shown in Figure 1.4, individuals with higher Intellectual/Cultural trait complex scores were more knowledgeable about all assessed knowledge domains than those with lower scores on the trait complex. The highest correlations between Intellectual/Cultural trait complex scores were found for knowledge in the humanities domain (for example, literature, music, art). Individuals with high Science/Math trait complex scores were broadly more knowledgeable than those with low scores, but especially more knowledgeable in physical sciences knowledge (for