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# Knowledge Structures and Adult Intellectual Development

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The College Board
Educational Excellence for All Students

## *Acknowledgments*

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# Abstract

This report reviews a theoretically inspired empirical investigation of individual differences in knowledge, abilities, and nonability traits as part of an ongoing effort to better understand adult intellectual development and to develop more accurate measures of adult intelligence.

Twenty Knowledge Scales were constructed, drawing on College-Level Examination Program® (CLEP) and Advanced Placement® Examinations (AP) provided by the College Board, and local development efforts. These Knowledge Scales were administered, along with an extensive battery of traditional ability tests, and measures of personality, interests, and self-concept, to two samples of adults, a "younger" adult group, age 18–27 (143 students in a college-level Introductory Psychology course), and an "older" adult group, age 30+ (139 adults who were either college or university students or college graduates).

Results indicted that, as predicted, although the older adult group had significantly lower mean scores on Mathematical/Numerical and Spatial Ability Tests, the older adults performed better than the younger adults on Verbal Ability Tests. The older adult group performed significantly better than the younger adult group on all of the knowledge tests but one (Chemistry), where there was no significant difference between younger and older groups. The older adults in this sample know a lot more than the younger adults across a broad range of domains, including those domains that are represented both inside and outside of standard college curricula.

In general, the older adult group showed a much higher degree of orientation toward things "intellectual" than the younger adult group, as indicated by scores on interest, personality, and self-concept scales. Among both the younger and older adult samples, general intelligence and verbal ability (even after general intelligence was partialled) were positively and consistently related to individual differences on the Knowledge Scales. No consistent pattern of correlations between spatial and mathematical abilities and Knowledge Scales was found, once general intelligence was partialled from these abilities. Much of the Knowledge Scale variance, though, was not predicted by traditional ability measures. In general, these results are consistent with theoretical predictions that the nature of adult intellect-as-knowledge is fundamentally distinct from intellect-as-process (such as abstract reasoning), and distinct from traditional assessments of crystallized intelligence.


# Introduction

Historically, assessment of adult aptitudes has taken one of two paths—assessment of abstract reasoning and processes (e.g., working memory), or assessment of knowledge and skills developed during the high school years (e.g., the SAT®, the general tests of the GRE). Such measures are generally quite good predictors of success in college and graduate school for traditional students (i.e., those that proceed to college directly from high school and to graduate school directly from college). However, increased development and use of knowledge-based tests may have three major positive influences for selection, counseling, and public policy purposes:

1. From several basic research and applied sources, theory and data suggest that as individuals proceed from high school to college and beyond, what they know (i.e., knowledge structures) may play a more important role, in comparison with standard aptitude measures, in predicting academic and occupational success. However, with the exception of the GRE advanced tests, knowledge tests have been generally underutilized for selection purposes. For example, Willingham (1974) noted that, at least in a couple of domains, the GRE advanced tests have higher validities than the GRE general tests in predicting success in graduate school and beyond.
2. A recent influx of and projected increases in nontraditional student enrollment in colleges (especially older adults) suggests that any diminished validity of standard aptitude tests for predicting academic performance may be overcome by use of knowledge-based tests. Knowledge tests may have higher validity for relevant criteria and are not expected to be as susceptible to the age-related declines that are found in aptitude measures but are not necessarily found in actual college- or graduate-school performance indexes.
3. Throughout this century, there have been numerous efforts to discredit the use of aptitude measures in predicting college performance, including, for example, objections related to gender and ethnic group differences. Knowledge-based examinations, such as CLEP and AP, are much less susceptible to such criticisms because they can be readily content-validated. To the degree that criterion-related validity can be improved by using knowledge-based tests, the concomitant decrease in criticism from outside the testing community may provide a "win-win" solution for prediction of academic performance.

## *A Theory of Adult Intellectual Development*[1]

It is possible to provide an integrative perspective of intelligence that takes account of the traditional process components, but also a wider array of knowledge components, along with personality and interest domains. Figure 1 shows one conceptualization, called PPIK—intelligence-as-process, personality, interests, and intelligence-as-knowledge. This conceptualization combines these four sources of individual-differences variance to yield individual differences in levels of academic and occupational knowledge (Ackerman, 1996a). This perspective not only identifies a developmental progression from process to knowledge, but also identifies potential cross-influences between personality and interests and knowledge acquisition. For adults, though, this perspective provides a means for linking traditional measures of intelligence with potential measures of intellectual knowledge and skills. That is, while traditional intelligence measures may partly predict adult knowledge, an adequate assessment of adult intellect requires assessment of adult knowledge. Some areas of knowledge can be adequately measured using existing scales of college-level achievement and occupational proficiency, but such scales only begin to identify adult intellect. Nonetheless, by using a combined assessment strategy that takes account of traditionally measured intelligence, personality, and interests, a more comprehensive evaluation of adult intellect may be possible. Moreover, one can also incorporate aspects of motivational skills into the developmental model, inasmuch as they influence the interface between interests and knowledge acquisition (Kanfer & Ackerman, 1996). Of course, a full understanding of adult development awaits longitudinal evaluation of the changes in knowledge structures that occur across the adult life span.

### Implications for Adult Learning and Education

There are three specific applications of intellectual assessment for adult educational purposes, namely: selection, classification, and instruction. The PPIK approach adopted here suggests several promising applications across these three fields of application.

### Selection

First of all, the PPIK approach to adult intellect suggests that prediction of adult academic success will be improved (i.e., higher validity) when assessments are made of individual differences in relevant knowledge structures, rather than the traditional college entrance examinations. Subject to additional empirical validation (e.g., Willingham, 1974), it is expected that tests of knowledge structures will show higher validity for grades and degree progress, especially as students proceed along the course of knowledge acquisition. Such a result is entirely consistent with the repeated demonstrations showing that, although traditional measures of intelligence well predict first-semester college grades, the validity of these indexes declines as students progress through college (Humphreys & Taber, 1973). In contrast, when course material is novel for most students, knowledge tests may have low validity—but as students progress, the knowledge tests are expected to increase in validity. If the ultimate selection criterion is degree completion, higher overall prediction validity may be expected from knowledge tests. In addition, given the developmental progression of knowledge acquisition, middle-aged and older adults may be expected to perform better than younger adults on the knowledge tests—a result that is consistent with the fact that older adults tend to perform better in postsecondary courses than younger adults with equivalent scores on traditional college selection tests, such as the SAT or ACT (see, e.g., Sawyer, 1986).

### Classification

The task of finding an optimal field of study for adults returning to school is currently more of an art than a science. The counselor will try to integrate work experience information with traditional ability and interest measures. The PPIK approach provides a rationale for finding out, specifically, what it is that the adult learner knows. A profile of knowledge structures (along with an understanding of the knowledge demands of various curricular choices) for prospective adult learners could be used to choose a course of study that optimally builds on the knowledge of each learner. Because adults are likely to have lower levels of process-related intelligence, an assessment along these lines could provide for a scientifically determined "match" between field of study and the learner's strengths. Moreover, improving the match between adult learners and field of study will help ameliorate problems associated with emotion control, by placing the learner in familiar fields of inquiry.

### Instruction

Ideal instructional environments match the content and difficulty of instruction to the knowledge and process abilities of the individual learner. When it is impossible to provide one-on-one instruction, it is often possible to provide at least some tailoring of the educational experience to the particular attributes of the learner (e.g., see

[1]This following section is reprinted from Ackerman (1998).

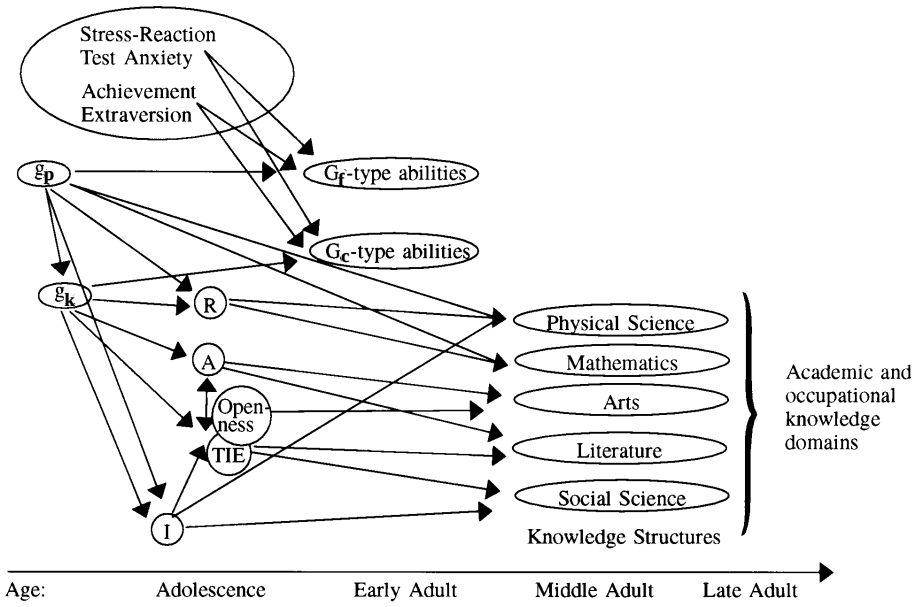


**Figure 1**. Illustration of Ackerman's PPIK theory, outlining the influences of intelligence-as-process, personality, interests, and intelligence-as-knowledge during adult development, covering academic and occupational knowledge. Arrows represent correlational influence. Adapted and expanded from Ackerman (1996a). $g_p$ = intelligence-as-process (fluid intelligence), $g_k$ = intelligence-as-knowledge (crystallized intelligence), $G_f$ = fluid intelligence, $G_c$ = crystallized intelligence, R = realistic interests, I = investigative interests, A = artistic interests, TIE = typical intellectual engagement. (From Ackerman, 1996, Figure 3, p. 238).

Snow, 1989). Numerous sources of interactions between individual-differences traits and optimal instructional methods have been documented over the past 30 years (e.g., see Cronbach & Snow, 1977; Snow & Yalow, 1982; Snow, Corno, & Jackson, 1996). For most learners, we can expect that taking account of trait complexes (that include intelligence, personality, and interests) can result in more effective instruction. In addition, instructional systems need to take account of the learner's emotion control skills and motivation control skills, because deficiencies in these skills may influence the likelihood that the learner will persist in a course of study when confronted with inevitable plateaus and failures that accompany any learning situation. Thus, remediation of these motivational skills might precede actual substantive instruction. However, for adult learners, it may be especially important to take account of age-related decreases in process-related intelligence and increases in knowledge-related intelligence. Particularly appropriate instructional changes would attempt to minimize, for example, rote learning of new facts (which requires process abilities), and maximize the degree to which new material is built upon preexisting knowledge structures. Changes to instructional methods might be as simple as increasing the use of analogy examples in the classroom, to exploration of "connections" between extant knowledge structures and new material. Regardless, the main theme is that with the accompanying changes to the structure of intelligence with adult development, instruction must be adapted away from the current process-based approach toward a knowledge-based approach. (End of reprinted material.)

## *Overview of Current Project*

The goal of the current research is to design a program of study that may transform the nature of adult educational and intellectual assessment from abstract reasoning and high school knowledge and aptitude measures to direct assessment of adult knowledge structures. Successful completion of this effort may provide a basis for a shift of focus in the adult educational testing industry, predicated partly on measures developed by the College Board and ETS for assessing adult knowledge such as the CLEP and AP Examinations. This work is expected to improve adult educational selection and counseling, as well as provide a much improved methodology for meeting the needs of nontraditional students who will be reentering the educational system in the next few decades (Ackerman, 1996a, 1997, 1998).

This study attempts to describe the relations among abilities, interests, personality, and motivational variables, and individual differences in depth and breadth

of knowledge. Future experiments will focus on evaluating whether assessments of individual differences in knowledge structures can be used to build predictive models of academic success. Specifically, we hope to determine how learner-characteristic information (including knowledge structures) can be optimally integrated with extant educational systems and less-structured learning situations (like those involved in learning from scientific texts or developing effective problem-solving skills). The critical learning situations for this approach, though, are likely to be those in which the topic to be learned is knowledge-rich (which probably represents much that is encountered in the real world and in postsecondary education) rather than domains in which the learner is likely to have no relevant background knowledge.

# Test Development and Description of Reference Trait Measures

## *Knowledge-Structure Test Development*

The following section briefly describes the strategy used for developing the 20 Knowledge-Structure tests and provides additional information about test content and item sources. Whenever possible, College Board examinations were used to form the backbone of the knowledge tests. However, the tests were required to discriminate in populations with less knowledge of these domains than the CLEP and AP Examination populations. Therefore easier items were developed to measure knowledge at levels less advanced than those tested in the CLEP and AP Examinations. In situations where relevant College Board examinations were not available, tests were developed locally. Local development of test items was coordinated by graduate and undergraduate research assistants and volunteer graduate students in specific departments (e.g., chemistry graduate students were recruited for the test on chemistry knowledge). Descriptions of individual tests are provided below, along with information about the proportion of items from CLEP and AP sources and from local sources. All these tests have gone through at least two development cycles (in which all items are administered to at least 100 examinees, the test is revised, and then the test is readministered to another 100-plus examinees), prior to final use in the study. For details on scale refinement and modifications, see Rolfhus (1998).

### American Government

This test covers the structure of American government, the functions of various government units, and the American political system. Typical questions might ask about the significance of the *Roe v. Wade* decision of 1973 or the nature of the president's veto power. Sixty percent of this test was derived from the CLEP American Government Examination; the remainder of the items was developed locally.

### American History

This test covers American history from pre-Revolutionary War times to the present. Fifty percent of this test was derived from two CLEP examinations, American History I: Early Colonization to 1877 and American History II: 1865 to the Present. Typical questions might address the effect of Martin Luther King, Jr. or America's policy of isolationism. Fifty percent of this test was developed locally.

### American Literature

This test covers a broad range of American writers, playwrights, and poets from Revolutionary War times to the present. Questions require identification of a variety of authors and works ranging from Walt Whitman to Kurt Vonnegut, and an understanding of literary styles and movements such as transcendentalism. This test was developed locally.

### Art

This test asks examinees to identify and interpret art and architecture from around the world from images displayed on a computer monitor. Items require identification of the work, the artist, and the artistic style and movement reflected. Typical items might require the examinee to identify the Taj Mahal or the movement that Salvador Dali's work reflects. This test was developed locally.

### Astronomy

This test covers broad areas of astronomy: observational tools and techniques, structure of the solar system, structure of the universe, and physical principles that govern astronomical observations. Typical items might require the examinee to identify the planet nearest the sun or techniques to estimate stellar distances. This test was developed locally.

### Biology

This test covers a broad range of biology at the cellular, organismal, and ecological levels. Typical questions

might require an understanding of food chains or the functions of meiosis and mitosis. Eighty percent of this test was adopted from the CLEP General Biology Examination. The remainder was developed locally.

### Chemistry

This test covers the content of a first-year college course in chemistry; from the structure of the atom to standard laboratory procedures. Eighty percent of this test was adopted from the CLEP General Chemistry Examination. The remainder was developed locally.

### Economics

This test covers both micro- and macroeconomics. Questions test knowledge ranging from the fundamental understanding of supply and demand to reasons underlying the Federal Reserve's monetary policy. Sixty percent of this test was adopted from two CLEP examinations: Principles of Microeconomics and Principles of Macroeconomics; the remainder was developed locally.

### Electronics

This test covers basic principles of electricity and their applications in electrical equipment and circuitry. Typical questions might ask the function of a transformer, the proper fuse size for residential light circuits, or techniques for testing voltage in a circuit. This test was developed locally.

### Geography

This test covers world geography; including the location of mountains, rivers, oceans, cities, nations, and biomes. Approximately one-half of the items are maps. A typical item might require matching a city to a letter on a map or identifying the name of a country shaded in red. This test was developed locally.

### Law

This test covers basic principles of law and more advanced criminal, civil, and business law. Items range from knowledge of basic constitutional rights to more complex contract and commercial law. Sixty percent of this test was adopted from the CLEP Introductory Business Law Examination; the remainder was developed locally.

### Business/Management

This test covers business-management principles and their application. A typical item might ask about job analysis or types of organizational structure. Seventy percent of this test was derived from the CLEP Principles of Management Examination; the remainder was developed locally.

### Music

This test covers basic music terminology and styles, instruments, and composers. Approximately one-third of the test involves identification of classical music pieces played over headphones. Items might range from identification of a woodwind instrument to selecting the composer of a particular piano sonata. This test was developed locally.

### Physics

This test covers basic physical principles and their applications. Items address both classical and quantum physics, thermodynamics, and atomic structure. Sixty percent of this test was adopted from the AP Physics Examination; the remainder of the test was developed locally.

### Psychology

This test covers the content of an introductory college course in psychology. Question topics range from personality theory, clinical assessment tools, and neuronal structure, to learning theory and behaviorism. This test was entirely derived from the CLEP Introductory Psychology Examination.

### Statistics

This test covers the content of a one-semester college course in basic inferential and descriptive statistics. Items range from measures of central tendency to basic regression and analysis of variance. This test was developed locally.

### Technology

This test assesses understanding of a wide range of modern technologies. Question topics range from how microwave ovens and televisions work to an understanding of superconductivity. This test was developed locally.

### Tools/Shop

This test covers both tool identification and use. Examinees are asked to match tools to related objects or identify correct tool use in the plumbing, building, or electrical trades. This test was developed locally.

### Western Civilization

This test covers major political, philosophical, and economic events in Europe from Ancient Greece to the Cold War. Typical items relate to the French Revolution or the genesis of World War II. Approximately 50 percent of this test was adopted from the CLEP Western Civilization II (1648-to the Present) Examination; the remainder was developed locally.

### World Literature

This test covers non-American literature and poetry, primarily classic Western literature. Items address ancient Greek plays and mythology through twentieth century authors such as George Orwell and D. H. Lawrence. This test was developed locally.

## *Other Measures*

Following are brief descriptions of other "reference" trait measures administered in the current study.

### Ability Battery

Ten tests were selected to assess the following abilities/factors:

#### *Verbal and Verbal Reasoning*

Three tests: (1) Verbal Analogies (from Ackerman & Kanfer, 1993), (2) Controlled Associations (from the ETS Kit, Ekstrom, French, Harman, & Dermen, 1976)), and (3) Extended Range Vocabulary Test (from the ETS Kit).

#### *Mathematical/Numerical Problem Solving*

Three tests: (1) Math Knowledge (from Ackerman & Kanfer, 1993), (2) Problem Solving (from Ackerman & Kanfer, 1993), and (3) Number Series (the PMA test, Thurstone, 1962).

#### *Spatial Abilities*

Three tests: (1) Paper Folding , (2) Verbal Test of Spatial Abilities, and (3) Spatial Orientation (all three tests from Ackerman & Kanfer, 1993).

#### *Mechanical Knowledge*

One test: Mechanical Knowledge from the Cognitive Ability Battery (Hakstian & Cattell, 1976).

### Personality

The NEO-FFI (FFI stands for five-factor inventory) was included to tap broad personality traits. This inventory is a short form of the NEO Personality Inventory (Costa & McCrae, 1992), and is composed of 60 items that measure 5 factors: Neuroticism, Extroversion, Openness, Conscientiousness, and Agreeableness. Participants respond to a five-point scale ranging from "strongly disagree" to "strongly agree." Additional measures of personality traits were used to supplement the NEO-FFI. The 59-item Goff and Ackerman (1992) Typical Intellectual Engagement (TIE) scale was administered. Sample items are "I prefer my life to be filled with puzzles I must solve" and "I read a great deal." A six-point response scale was used, ranging from "strongly disagree" to "strongly agree." Nineteen items from the Helmreich and Spence (1978) Work and Family Orientation (WOFO) Questionnaire were administered (to assess aspects of achievement motivation, such as "Work Orientation," "Mastery," and "Competitiveness"). The 20-item Spielberger State-Trait Anxiety Inventory (Spielberger, 1983) was administered, under "trait" instructions, i.e., how you generally feel. Additional scales were administered as part of a larger study and are not reported here.

### Interests

The 90-item Unisex American College Testing Interest Inventory (UNIACT) inventory (Lamb & Prediger, 1981) was used to provide an assessment of six interest themes identified by Holland (1959, 1973): Realistic, Investigative, Artistic, Social, Enterprising, and Conventional. The items (15 per scale) assess an individual's preference for specific job tasks like "studying biology" and "compose or arrange music." A six-point response scale was used, ranging from "strongly dislike" to "strongly like."

### Self-Concept

Self-concepts for competencies and aptitudes in several specific areas were assessed with a 30-item, self-report questionnaire. The areas assessed were self-concepts of mechanical, verbal, clerical, and spatial aptitude competencies, as well as self-concept of self-management skills and ability.

### Self-Estimates of Ability

For self-ratings of ability, a 21-item questionnaire was used. The items represent five scales of broadly described abilities, aptitudes, or skills, namely: verbal, mathematical, self-management, clerical, and mechanical. Participants were instructed to respond with a self-evaluation relative to other persons their age.

### Biographical Questionnaire

A take-home questionnaire contained basic biographical and demographic questions, along with questions about school experiences and avocational activities. The questionnaire was divided into six sections:

1. Demographic/Background information. Questions about age, gender, educational background, occupation, and employment background (22 items).
2. High school experiences. Questions about extracurricular activities (12 items) and course grades and course enjoyment (44 items).

3. College/University experiences. Questions about course grades and course enjoyment (44 items).
4. General experiences. Questions about avocational activities (12 items), attendance at cultural events (8 items), reading periodicals (14 items), reading books (18 items), radio and television habits (7 items).
5. Motivational traits. As part of another study (Heggestad & Kanfer, in preparation), 183 items regarding aspects of motivational traits were administered in this questionnaire.
6. Occupational/Work experiences. Ten (mostly open-ended) questions about job training and occupational goals.

# Method

## *Participants*

Two samples of participants were drawn for this study. One sample (called "younger") was selected from a large undergraduate Introductory Psychology course at the University of Minnesota. These participants received course credit for the first five hours of participation and $20 each for the remaining two hours of the study. Participants were required to have a native English-speaking background; be age 18 or over; and have normal (or corrected-to-normal) vision, hearing, and motor coordination. The second sample (called "older") was drawn from the larger University of Minnesota community. The participants were required to have a native English-speaking background; to be at least 30 years of age; to be either a university student or graduate; and to have normal (or corrected-to-normal) vision, hearing, and motor coordination. These participants received $80 each for participating in the study.

Data from three participants (two from the younger group and one from the older group) were discarded because the participants failed to follow the experiment's instructions. Data from one participant in the younger group were discarded because the participant reported an age of 30 years (which would have resulted in an overlap between the ages of the younger and older groups). The results reported below were based on data from 143 younger participants and 139 older participants.[2]

[2]Note that four of the older participants were over 60 years of age. Because of the small number of participants in this group, it was deemed prudent to exclude them from most analyses, except where noted.

The resulting sample characteristics for age, gender, and education are shown in Table 1. Similar proportions of participants in the two samples were females (66 percent in the younger group and 70 percent in the older group). In contrast, the younger group had a much lower level of educational achievement (all but one of the 143 participants had not yet attained a B.A./B.S. degree) in comparison with the older group (in which 76 percent of the participants had attained a B.A./B.S. degree). Of the latter, 26 percent had completed at least some postbaccalaureate education, including 7 participants who reported having attained a Ph.D.

## *Apparatus*

For the Knowledge-Structure tests, instructions, item presentation, and response collection were performed with DELL and IBM 90/100MHz Pentium computers with standard keyboards and high-resolution graphics display monitors (1152 pixels horizontal x 864 pixels vertical resolution). For the paper-and-pencil tests, instructions (and timed start-stop directions) were presented over a public address system, using prerecorded minidiscs. Participants were tested in groups of up to 15 at a time, in individual carrels (for the computer-based tests) and at tables (for the paper-and-pencil tests). For the Biographical Questionnaire, participants were given a paper booklet with instructions to fill in their responses at home and return the completed booklet to the laboratory.

## *Procedure*

The first three-hour session (Session 1) of the experiment began with completion of informed consent forms and then administration of the 10 ability tests (with one 5-minute break after an hour of testing). After the 10 tests (about 2 hours), participants had another break and then moved from the paper-and-pencil testing room to the computer testing room. During the remaining hour, participants completed the measures of personality, interests, self-concept, self-estimates of ability, the WOFO Questionnaire, and the State-Trait Anxiety Inventory. These measures were administered in a self-paced fashion. At the end of Session 1, participants were given the Biographical Questionnaire and instructed to return the completed instrument at the beginning of Session 2. The second session was devoted to computerized administration of the 20 Knowledge-Structure tests. Participants were given two five-minute breaks during the session. After completion of the 20 tests, those participants who had time remaining (within the 3-hour total session time) completed additional self-report questionnaire

TABLE 1

**Description of Participant Samples by Gender and Highest Degree Achieved**

| | *Age Group by Gender* | | | *Age Group by Highest Degree* | | |
|---|---|---|---|---|---|---|
| *Age Group* | *Male* | *Female* | *Total* | *Less than BA* | *BA* | *More than BA*** |
| 18–29 | 49 (34.3%) | 94 (65.7%) | 143 | 142 | 1 | 0 |
| 30–39 | 25 (35.7%) | 45 (64.3%) | 70 | 14 | 34 | 20 |
| 40–49 | 12 (23.1%) | 40 (76.9%) | 52 | 16 | 25 | 10 |
| 50–59 | 5 (38.5%) | 8 (61.5%) | 13 | 2 | 7 | 4 |
| 60+* | 2 (50.0%) | 2 (50.0%) | 4 | 3 | 1 | 0 |

*Because of the small number of participants over age 60, this group was excluded from most analyses in this report.
** Three participants failed to report highest degree.

items on the computer. Afterwards, participants were debriefed and compensated.

# Results

The analysis for this study was conducted in four stages:

Stage 1. This stage involves basic cohort/age-group comparisons of means and distributions on the various measures, including ability, personality, interest, and other traits, to provide a general description of the cross-sectional samples.

Stage 2. This stage focuses on the Knowledge Scales, for which there were two levels of analysis: age-group differences on the Knowledge Scales examined first, followed by within age-group comparisons.

Stage 3. This section involves joint intraindividual and interindividual comparisons, focusing on the structure of knowledge within and between individuals. The analysis starts with generation of a "knowledge-profile" of each participant (essentially a plot of his/her respective pattern of strengths and weaknesses), and example cases are presented for review. Future analyses will involve sortings of profiles on the basis of "similarity," and aggregate scaling of profile similarity will be conducted by subjecting the co-occurrence matrix to a nonmetric multidimensional scaling algorithm. Such procedures may allow us to determine latent dimensions of profile differences between participants and for a taxonomic categorization of "types" of individuals (e.g., scientific, artistic, social).

Stage 4. This section focuses on the interrelations between knowledge levels and other trait measures. The PPIK theory (Ackerman, 1996b) predicts that significant and substantial correlations are to be found between specific interest, personality, and cognitive ability measures and level of knowledge in specific domains (e.g., a correlation between investigative interests and knowledge about physical sciences, or a correlation between TIE and knowledge about arts and literature).

Results from each of the four stages of analysis are presented and discussed in turn below.

## *Stage 1. Basic Cohort/Age-Group Comparisons*

The first set of analyses is designed to provide an overview of the similarities and differences between the younger and older groups, and to some degree, within the older group across the age range. For each measure, means and standard deviations (*sd*) are presented for the younger and older groups, followed by the results of *t*-tests for the differences between means. Then a within-group (for the older examinees [between 30 and 59 years old]) correlation is presented between examinee age and scores on each measure. In this way, it is possible to look at broad differences between the younger/older samples (which admittedly come from two different populations—one sample of students from an Introductory Psychology course, and the other sample from the university community at large). In addition, within the older sample, it is possible to examine the relationship between age and performance (across the 29-year age range from youngest to oldest examinee in the older group).

### Abilities

The first set of analyses is a standard cross-sectional comparison between the older and younger groups, to evaluate the general representativeness of the samples. Based on the extant literature (e.g., Horn, 1965, 1968), *a priori* expectations were that the older group would show higher scores on the Verbal Ability Tests and equivalent or lower scores on the Mathematical/Numerical and Spatial Ability Tests. Two sets of comparisons were computed: mean differences between the age 18–27 and age 30–59 groups and within-group correla-

tions between test scores and chronological age for the age 30–59 participants. These results are shown in Table 2. In reviewing the means, standard deviations, and *t*-test results, it is clear that the older sample performed substantially better than the younger sample on the Verbal Ability Tests and the Mechanical Knowledge Test, less well on the Mathematical/Numerical Ability Tests (except for the word-problem test), and mixed on the Spatial Ability Tests. The table shows differences in raw scores, but if the ability tests had been standardized to the young examinees, the older group would have the following mean levels of performance, in *z*-score terms: Verbal Analogies = 1.0, Controlled Associations = .83, Vocabulary = 2.44, Paper Folding = -.45, Verbal Test of Spatial Ability = .14, Spatial Orientation = .00, Math Knowledge = -1.2, Problem Solving = .11, Number Series = -.49, Mechanical Knowledge = .48. With unit-weighted *z*-score composites for three major ability factors, the aggregate mean scores for the older group (again with the younger sample providing the standardization mean $z = 0$, $sd = 1$) were: Verbal Composite $z = 1.6$, Math Composite $z = -.67$, and Spatial Composite $z = -.13$. Such results are generally consistent with the available literature in that the older group showed lower mathematical ability and higher verbal ability than the younger group. However, in keeping with our strategy of sampling adults throughout the university community (many examinees were students in the Continuing Education and Extension Program), the older examinee group appears to have somewhat higher abilities than might otherwise be found in the population at large (this is also concordant with the fact that a higher proportion of examinees had completed the B.A. degree than would be found in the wider community).

The older examinee within-group correlation between age and performance provided further evidence in support of the general representativeness of the older adults in the sample, at least with respect to ability levels and age/cohort differences. The correlations between age and test score, shown in the last column of Table 2, indicated significant negative relations between age and ability for all three Spatial Ability Tests, for two of the Mathematical/Numerical Ability Tests (excluding Problem Solving, which contains mathematical-type word problems and has a substantial verbal component), and no significant correlations between age and ability on the Verbal Ability and Mechanical Knowledge Tests.

## Interests, Self-Concept, and Self-Estimates of Abilities

A series of analyses (parallel to the ability analyses) was conducted for some of the self-report measures and are

TABLE 2

**Reference Aptitude and Ability Tests: Means, Standard Deviations, *t*-Tests Between Younger and Older Groups, and Correlations With Age (for Older Group Only)**

| | *Younger 18–27* | | *Older 30–59* | | | *Older (only) 30–59* |
|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *t-Test* | *Correlation With age* |
| Verbal Ability | | | | | | |
| Verbal Analogies | 26.71 | 5.75 | 32.68 | 5.58 | 8.79*** | -.01 |
| Controlled Associations | 23.24 | 7.67 | 29.61 | 9.47 | 6.19*** | -.01 |
| Ext. Range Vocabulary | 15.19 | 6.72 | 31.62 | 7.58 | 19.15*** | .15 |
| Spatial Ability | | | | | | |
| Paper Folding | 12.39 | 5.06 | 10.09 | 4.87 | -3.84*** | -.28** |
| Verbal Test of Spatial Ablility | 11.49 | 4.34 | 12.08 | 4.90 | 1.06 | -.19* |
| Spatial Orientation | 7.18 | 3.91 | 7.21 | 3.83 | .05 | -.30** |
| Mathematical/Numerical Ability | | | | | | |
| Math Knowledge | 17.35 | 6.36 | 9.69 | 5.69 | -10.55*** | -.21* |
| Problem Solving | 4.30 | 2.29 | 4.56 | 2.19 | .99 | -.11 |
| Number Series | 10.22 | 2.84 | 8.81 | 3.21 | -3.88*** | -.18* |
| Mechanical Knowledge | | | | | | |
| Mechanical Knowledge | 6.96 | 3.95 | 8.87 | 3.83 | 4.10*** | .01 |

Note: $N = 143$ (younger) and 135 (older); *t*-test $df = 276$; for correlations $df = 133$.
*$p < .05$, ** $p < .01$, *** $p < .001$.

shown in Table 3. For interests, Table 3 shows that there were large differences favoring the older group on interests that have been identified (Ackerman & Heggestad, 1997) as integral to intellectual pursuits (namely, Realistic, Investigative, and Artistic), and virtually no differences between the two groups on nonintellectual interests (Social, Enterprising, and Conventional), suggesting either age/cohort differences or differences between the types of examinees in each group. (Given the current study design, it is impossible to know which cause is manifest, but this may be an important finding to investigate in later longitudinal and cross-sectional studies using stratified sampling procedures.)

Group differences on self-concept and self-estimates of ability generally parallel objective test performance—the older group showed higher levels of verbal skills and ability and lower levels of math ability—indicating some general concordance between mean levels of perceptions and mean levels of performance. Curiously, though, there were few concomitant correlational effects within the age 30–59 group (only clerical self-concept showed a small but significant negative correlation with age, and self-management self-concept showed a small but significant positive correlation with age). Such results suggest that it may be important to examine more closely the developmental period associated with school-to-work transitions (especially through the mid-20s and early-30s). This is a developmental period that may be critical for plasticity of adult self-concept and self-estimates of ability.

## Personality and Motivation

Seven personality scales were administered in this study: Neuroticism, Extroversion, Openness, Agreeableness, and Conscientiousness (from the NEO-FFI), Anxiety (from the Spielberger State-Trait Anxiety Inventory), and TIE (from Goff & Ackerman, 1992), along with three motivation-oriented scales from the Helmreich and Spence WOFO Questionnaire (Work Orientation, Mastery, and Competitiveness). Means, standard devia-

TABLE 3

**Interests, Self-Concept, and Self-Estimates of Abilities: Means, Standard Deviations, *t*-Tests Between Younger and Older Groups, and Correlations With Age (for Older Group Only)**

| | *Younger 18–27* | | *Older 30–59* | | | *Older (only) 30–59* |
|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | t-*Test* | *Correlation With age* |
| Interests | | | | | | |
| Realistic | 48.21 | 13.39 | 54.24 | 11.99 | 3.95*** | .03 |
| Investigative | 55.47 | 14.38 | 66.58 | 13.08 | 6.73*** | .04 |
| Artistic | 58.34 | 16.78 | 68.42 | 14.08 | 5.42*** | -.02 |
| Social | 70.62 | 10.24 | 70.10 | 10.52 | -.42 | -.07 |
| Enterprising | 59.45 | 13.68 | 57.81 | 13.38 | -1.01 | -.05 |
| Conventional | 46.47 | 18.08 | 44.64 | 15.66 | -.90 | .11 |
| Self-Concept | | | | | | |
| Mechanical Knowledge | 17.84 | 6.13 | 18.75 | 6.54 | 1.20 | .03 |
| Self-Management | 19.51 | 5.10 | 21.38 | 4.98 | 3.09** | .19* |
| Verbal | 22.64 | 5.37 | 26.10 | 3.61 | 6.27*** | -.10 |
| Clerical | 22.57 | 3.93 | 23.22 | 3.89 | 1.40 | -.19* |
| Math | 20.46 | 6.74 | 15.82 | 7.19 | -5.56*** | -.11 |
| Spatial | 20.67 | 4.82 | 20.18 | 5.38 | -.79 | -.09 |
| Self-Estimates of Abilities/Skills | | | | | | |
| Verbal Ability | 19.57 | 4.45 | 23.18 | 3.47 | 7.50*** | -.08 |
| Math Ability | 17.80 | 4.14 | 15.06 | 4.87 | -5.06*** | -.08 |
| Self-Management Skills | 26.28 | 4.29 | 26.29 | 4.49 | .02 | .02 |
| Clerical Ability | 9.46 | 2.04 | 9.80 | 2.72 | 1.18 | -.12 |
| Mechanical Skills | 8.28 | 2.23 | 8.32 | 2.36 | .14 | .01 |

Note: $N$ = 143 (younger) and 135 (older); $t$-test $df$ = 276; for correlations $df$ = 133.
*$p$ < .05, ** $p$ < .01, *** $p$ < .001.

tions, *t*-tests, and age correlations are presented in Table 4. Significant differences between the younger and older groups were found on many of these measures. Specifically, in comparison with the younger group, the older group had significantly lower scores on Extroversion and Competitiveness, and significantly higher scores on Openness, Agreeableness, Conscientiousness, and on the measure of TIE. Again, it is not clear what the source of these differences is; only Competitiveness showed a significant correlation (negative) with age in the older group of participants.

## Trait Measures: Summary and Observations

The picture that emerges from the intergroup comparisons of the younger and older groups (and the within-group correlations for the older group) is one that is generally concordant with normal age/cohort differences from younger adulthood to middle age (e.g., with respect to verbal, mathematical, and spatial abilities). For nonability traits, the older sample consistently appears to have a higher level of orientation toward things "verbal/intellectual" than the younger sample. Older adults have higher levels of verbal ability and verbal self-concept and higher levels of interest in activities and occupations that appear to be associated with intellectual demands (Realistic, Investigative, and Artistic interests). In contrast, the older adults are less sanguine about their mathematical abilities—they have a lower mathematical self-concept and lower self-estimates of their mathematical abilities. Such perceptions are generally accurate, in the sense that the pattern of mean differences in the self-report measures parallels the mean differences in objective ability tests (shown in Table 2).

Nonetheless, aside from the cognitive ability correlations with age, surprisingly few nonability measures showed within-group age correlations for the older adults. This may be because of the smaller number of items for each of the self-report measures in comparison with the ability tests (and thus a lower reliability), but it may be, in contrast, that the older adult group has a more optimistic view of the effects of aging on their abilities than was borne out by the objective test performance data. On the whole, though, the older group appears to have higher scores on nonability traits that are usually considered to be reflective of good adjustment (e.g., higher levels of Openness, Agreeableness, Conscientiousness, and TIE), and lower levels of Competitiveness.

The significantly lower scores for the older group on Extroversion stand out as a puzzle from our theoretical view, in that a meta-analysis (Ackerman & Heggestad, 1997) indicated that higher levels of Extroversion tend to be associated with higher levels of cognitive/intellectual abilities. In contrast, for both the younger and older groups, Extroversion as measured by the NEO-FFI showed consistently negative correlations with abilities (for the younger group $r$ = -.23, -.32, and -.24 for

TABLE 4

**Personality and Motivation Scales: Means, Standard Deviations, *t*-Tests Between Younger and Older Groups, and Correlations With Age (for Older Group Only)**

| | *Younger 18–27* | | *Older 30–59* | | | *Older (only) 30–59* |
|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | t-*Test* | *Correlation With Age* |
| Personality | | | | | | |
| Neuroticism | 33.94 | 8.26 | 32.61 | 8.92 | -1.28 | -.06 |
| Extroversion | 44.37 | 7.00 | 41.04 | 7.02 | -3.96*** | -.09 |
| Openness | 41.13 | 6.49 | 46.32 | 5.66 | 7.09*** | -.04 |
| Agreeableness | 43.80 | 6.42 | 45.78 | 5.66 | 2.72** | .14 |
| Conscientiousness | 43.40 | 6.90 | 45.56 | 6.58 | 2.67** | .00 |
| TIE | 233.26 | 35.77 | 264.09 | 31.39 | 7.62*** | -.14 |
| Anxiety (trait) | 39.54 | 8.39 | 37.82 | 8.81 | 1.67 | -.13 |
| Work/Motivation (WOFO) | | | | | | |
| Work Orientation | 20.12 | 2.71 | 20.76 | 2.81 | 1.94 | -.01 |
| Mastery | 20.62 | 5.01 | 20.54 | 4.34 | -.14 | -.12 |
| Competitiveness | 13.96 | 3.57 | 10.81 | 3.93 | -7.00*** | -.19* |

Note: $N$ =143 (younger) and 135 (older); *t*-test $df$ = 276; for correlations $df$ = 133.
*$p$ < .05, ** $p$ < .01, *** $p$ < .001.

verbal, mathematical, and spatial ability composites, respectively; for the older group $r$ = -.32, -.17, and -.17 for verbal, mathematical, and spatial ability composites). It is possible that there is something unusual about the NEO-FFI estimate of Extroversion, or there may be some important moderators of the extroversion-intelligence associations. Perhaps Cattell (1945) was, after all, correct in his prediction that higher-ability persons would more likely be introverts who "prefer the company of books to other persons."

## *Stage 2. Knowledge Scales*

The first analyses addressed age-group differences on the Knowledge Scales, and, for the older group, correlations between knowledge and age. A set of analyses was conducted for the Knowledge Scales that paralleled the earlier analysis of traits, (see Table 5). In reviewing these results, note that it is important to refer back to Table 2, which shows that the older group, while performing better than the younger group on verbal abilities, performed worse on mathematical/numerical abilities, as would be expected. However, in all but one of the 20 tested knowledge domains shown in Table 5 (Chemistry), the age 30–59 group performed significantly better than the age 18–27 group. In addition, only one of the tests showed a significant correlation with age for the older group (Tools/Shop showed an increase with age).

Although the older adults performed better overall

TABLE 5

**Knowledge Scales (Number Correct): Means, Standard Deviations, *t*-Tests Between Younger and Older Groups, and Correlations With Age (for Older Group Only)**

| | *Younger 18–27* | | *Older 30–59* | | | *Older (only) 30–59* |
|---|---|---|---|---|---|---|
| | ***M*** | ***SD*** | ***M*** | ***SD*** | ***t*-Test** | ***Correlation With Age*** |
| Natural and Physical Sciences and Statistics | | | | | | |
| Astronomy | 16.34 | 10.11 | 19.69 | 12.73 | 2.23* | .17 |
| Biology | 16.22 | 10.83 | 23.31 | 12.27 | 4.98*** | -.09 |
| Chemistry | 15.93 | 8.86 | 15.88 | 9.41 | -.05 | -.12 |
| Physics | 12.82 | 6.46 | 15.91 | 5.84 | 4.13*** | -.06 |
| Statistics | 7.44 | 4.55 | 8.78 | 5.50 | 2.10* | -.13 |
| Social Sciences, Law, and Business | | | | | | |
| Business/Management | 13.20 | 7.65 | 23.67 | 9.26 | 10.27*** | .00 |
| Economics | 17.97 | 13.44 | 27.99 | 14.02 | 6.01*** | -.11 |
| Geography | 20.81 | 12.20 | 29.52 | 13.35 | 5.27*** | -.06 |
| Law | 17.76 | 10.40 | 30.95 | 10.14 | 10.62*** | -.06 |
| Psychology | 13.94 | 7.56 | 19.71 | 7.98 | 6.18*** | .01 |
| History and Western and American Civilization | | | | | | |
| American Government | 24.14 | 13.63 | 39.66 | 13.24 | 9.47*** | -.03 |
| American History | 38.88 | 20.30 | 61.80 | 20.63 | 8.51*** | .03 |
| Western Civilization | 22.82 | 12.62 | 34.94 | 15.49 | 6.90*** | .04 |
| Arts and Literature | | | | | | |
| American Literature | 33.90 | 14.61 | 55.83 | 16.49 | 11.70*** | .11 |
| Art | 12.13 | 6.03 | 19.41 | 4.74 | 9.82*** | -.09 |
| Music | 19.88 | 10.15 | 33.44 | 10.25 | 10.34*** | .13 |
| World Literature | 30.79 | 14.18 | 53.80 | 18.74 | 11.55*** | .05 |
| Technology and Tools | | | | | | |
| Electronics | 10.52 | 5.92 | 18.16 | 7.56 | 8.70*** | .14 |
| Technology | 18.82 | 11.07 | 30.68 | 12.58 | 7.52*** | -.03 |
| Tools/Shop | 16.11 | 6.29 | 20.98 | 7.40 | 5.72*** | .19* |

Note: $N$ varies (because of incomplete data) MAX = 143 (younger) and 135 (older); $t$-test $df$ = 276; for correlations max $df$ = 133.
*$p$ < .05, ** $p$ < .01, *** $p$ < .001.

on the Knowledge Scales, the older adults' scores were not equally as high throughout the broad range of tests. With the taxonomic categorization of knowledge domains, knowledge-domain *z*-score composites can be formed to provide a broader-brush representation of the younger and older group differences. As with the ability scales, the Knowledge-Scale scores were standardized on the younger group, and then mean *z*-scores were computed for the older adult group. Group differences, are shown with the areas of greatest advantage to the older group, in descending order:

| | | | |
|---|---|---|---|
| 1.Arts and Literature | Mean *z*-score difference | = | 1.42 *sd* units |
| 2.Technology and Tools | Mean *z*-score difference | = | 1.04 *sd* units |
| 3. History and Western and American Civilization | Mean *z*-score difference | = | .99 *sd* units |
| 4.Social Sciences, Law and Business | Mean *z*-score difference | = | .97 *sd* units |
| 5.Natural and Physical Sciences and Statistics | Mean *z*-score difference | = | .35 *sd* units |

These results provide additional support for the sense that the older adult group had higher mean performance in all of the knowledge categories that were assessed in this study—though the largest differences between older and younger groups were found in the Arts and Literature domain, and the smallest differences in knowledge were on the Natural and Physical Sciences. One potential interpretation here, is that the older adult sample excelled in domains that are traditionally "electives" in postsecondary curricula, and that the younger sample came closest to holding even with the older adults on the Physical Science topics (such as chemistry and physics) that are more traditionally "required" high school and college courses. (Informal reflection would further support this point by suggesting that many fewer continuing-education students take courses in chemistry or physics than take courses in art or literature—however, such a point would need to be verified by examining course enrollment statistics or evening/weekend course offerings by post-secondary institutions.)

## *Stage 3*

The formal analysis of within- and between-group differences in knowledge profiles has not yet been completed. In the interim, though, it is possible to provide some descriptive information that shows the richness of the data obtained from this study. Below is a description of six cases from the older group. The older group is used because more extensive education and occupational information exists for these participants (mainly because participants from the older group were far more likely to have completed a college degree and to have full-time occupational experience, in contrast to the younger group, where many of the participants listed "undecided" on the question about college major field). The Appendix (pages 23–25) provides graphic representations of each of the six listed cases. Each graph shows the *z*-transformed scores (across the combined younger and older samples) for the three ability composites (verbal, mathematical/numerical, and spatial), and then for each of the 20 Knowledge Scales, separated into the five thematic categories (Natural/Physical Sciences, Social Sciences/Law/Business, History/Civilization, Arts and Literature, Technology and Tools). Note that a few Knowledge-Scale scores are missing for some participants. This is because some of the participants did not finish the scales in the allotted time. To further illustrate the cases, a brief description of them is provided.

### Case 1

This case is a woman between 30 and 39 years old. She had completed postgraduate study (at the Ph.D. level), with a major in history and law. She currently has an occupation in education. Her Artistic and Social Interests are relatively low (from the UNIACT), but she has relatively high levels of interest in the Enterprising domain. The profile shows above average scores in the three ability composites, and a knowledge profile that has the highest levels in the Social Sciences/Law/Business area and History/Civilization area. (In fact, the two highest Knowledge-Scale scores corresponded to this person's college major fields—law and history). This person scored at an average level on the measure on TIE.

### Case 2

This case is a man between 30 and 39 years old. He has completed postgraduate study (at the M.A. level) in sociology, and is currently a graduate student. Scores on the ability composites indicate substantially superior performance on the math and spatial abilities, and above-average performance on verbal ability. This participant appeared to have scored higher on the largest number of Knowledge Scales than anyone else in the study. All Knowledge-Scale scores were positive, with the highest scores in the various sciences. His dominant interest scores were opposite those of Case 1, in that the highest scores were in the Artistic domain, and the lowest scores were in the Enterprising domain. This participant had the second highest score on the TIE measure ($z = 1.94$) across the combined younger and older samples.

### Case 3

This case is a man between 30 and 39 years old. He is currently a certified nursing assistant. His ability scores were average for verbal and math abilities, and above-average for spatial abilities. This knowledge profile is

decidedly more distinct, in terms of peaks and valleys. The peaks correspond to the Natural/Physical Sciences and Technology and Tools, and the valleys are found in the areas of Arts and Literature and Business. Such scores correspond to similar low levels of interests in Enterprising and Conventional domains. This case's TIE score was at the average level.

### Case 4

This case is a woman between 40 and 49 years old. She completed some postsecondary education (at the associate-degree level), with a concentration in psychology and sociology. This case's abilities are highly differentiated, with substantially above average verbal ability and substantially below average scores on math and spatial abilities. The Knowledge-Scale profile appears to be generally consistent with the ability pattern, in that this person's knowledge strengths are in Arts and Literature, History/Civilization, and Technology and Tools. She scored relatively high on TIE (92nd percentile), which is interesting because of the concentration of knowledge in fewer domains—a deep, rather than broad intellectual orientation.

### Case 5

This case is a woman between 40 and 49 years old. She completed postsecondary education (at the B.A./B.S. level), with multiple specializations in art, anthropology, and history. Currently, she has an occupational position in a museum. Scores on verbal- and spatial-ability composites were above average, while performance on the mathematical ability composite was below average. This case also demonstrated substantial peaks and valleys, with the peaks in Arts and Literature, and the valleys in the Natural/Physical Sciences. Her dominant interest themes were in Realistic, Conventional, and Artistic themes (suggesting broad interests), and she showed an above average TIE score.

### Case 6

The last case is a man between 50 and 59 years old. He completed postsecondary education (at the B.A./B.S. level), with a major in mechanical engineering (though he last attended college in the 1960s). He scored above average on the verbal- and mathematical- ability composites, and scored very high on the spatial-ability composite. His dominant interest theme was Realistic, with very low levels of interests of Artistic interests. Similarly, he had a below-average score on TIE. The Knowledge-Scale profile appears to match the dominant Realistic interest theme, with the highest scores in Natural/Physical Sciences and Technology and Tools.

The profiles suggest that the approach taken here is coherent, and is consistent with the specifications of the PPIK theory. However, these cases were selected partly because they represent the various salient features of ability and knowledge-structure profiles. The more difficult part of future analyses will be formal sorting and cluster analysis of profiles.

## *Stage 4*

This section focuses on the interrelations between knowledge levels and other trait measures, in the context of the PPIK theory of adult intellectual development (Ackerman, 1996b), and the corpus of data that addresses communalities of individual differences across trait families (e.g., see Ackerman, 1997; Ackerman & Heggestad, 1997; Rolfhus & Ackerman, 1996). The section is divided into four parts, each considering a separate family of traits as possible correlates with individual differences in Knowledge Scale performance. The families of traits are (1) Ability, (2) Self-Concept/Self-Estimates of Ability; (3) Interests, and (4) Personality and Motivational traits. Each of these families of traits are considered in turn below.

### Ability-Knowledge Correlations

To many researchers interested in adult intelligence, the most important results of this investigation will be captured in the associations between traditional ability factors and Knowledge-Scale performance. While a review of individual ability-knowledge correlations is illuminating, an attempt has been made to summarize the noteworthy associations between the battery of ability tests and the battery of Knowledge Scales. There are many statistical techniques that can be used to describe the communality between these two sets of scales, such as interbattery factor analysis and canonical correlation analysis. The first pass through these data is less complicated (and arguably less sophisticated), but it is a method that is easy to understand (at least conceptually). The method adopted here starts with a hierarchical factor analysis of the ability tests (using the procedure described by Schmid & Leiman, 1957), so that an oblique first-order factor solution can be re-cast as an orthogonalized factor matrix of two orders (in this case, a general ability factor [*g*] that has substantial loadings across all three major ability factors [verbal, spatial, mathematical]. With an estimation of the factors underlying the ability tests, factor loadings of the Knowledge Scales are estimated by use of the Dwyer extension procedure.[3]

[3]The Dwyer (1937) extension analysis procedure allows extending a factor solution to determine correlations between "new" variables (in this case, the Knowledge-Scale scores), and

Because significant differences in many of the ability measures were found between the younger and older groups, the ability-test factor analyses and the Dwyer extension analyses were conducted separately for the two groups. The hierarchical factor solutions and extended factor loadings for the Knowledge Scales are shown in Table 6 for the younger group and Table 7 for the older group, respectively.

Comparison across Table 6 and Table 7 show more similarities than differences. A similar pattern of factor loadings was expected for the two groups—indeed it would have been problematic if first-order verbal, spatial, mathematical ability factors and a second-order general (*g*) ability factor had not been found for both groups. The only marginally interesting deviations between the two solutions were the loadings of Problem Solving and Math Knowledge tests. For the younger sample (which outperformed the older group in mean performance level), Math Knowledge had a smaller loading on *g* (.385), and the older group had a larger loading on *g* (.612). In contrast, performance of the younger group on the Problem Solving test (a test of mathematical word problems) was related to the verbal ability factor (.296), but performance was unrelated to verbal ability for the older group (.005). Such results suggest that either ceiling or floor effects may have partially influenced the factor solutions, or possibly that persons in the two age groups were using different strategies for performing at least some of the Mathematical tests (see, e.g., strategy and ability discussion by Kyllonen, Lohman, & Woltz, 1984). Regardless, the solutions are sufficiently similar to allow for a rough comparison across groups on the extended loadings to the Knowledge Scales.

The Dwyer extension results for both groups show that, first of all, after accounting for a general ability factor (*g*), very little common variance remained between mathematical or spatial ability factors and Knowledge Scales. In the younger group, only Astronomy and Chemistry had marginally salient loadings on the first-order mathematical ability factor. In the older group, Art, Electronics, and Tools/Shop had salient loadings on the spatial ability factor, and only Art had a salient loading (negative) on the mathematical ability factor. In contrast, many of the Knowledge-Scales showed substantial positive loadings on the first-order verbal ability (which is the closest that traditional ability assessment methods come to assessing intelligence-as-knowledge in adults), as predicted by the PPIK theory. Some differences between younger and older groups are found in these comparisons, but the largest loadings on the verbal ability factor in both age groups come from Knowledge Scales in Arts and Literature, and to a somewhat lesser extent History and Western and American Civilization and Social Sciences, Law and Business. Biology and

[3 (cont.)] the previously determined factor solution (the ability factors), given knowledge of the correlations between these "new" variables and the "old" variables used to derive the factor solution. Using extension analysis to determine the loadings of the "new" variables on the predetermined for solution allows one to derive the original factors independently of the variables hypothesized to relate to them and avoids the psychometric problems inherent in factor scores. See Fruchter, 1954 and Gorsuch, 1983, for in-depth discussions of the method.

TABLE 6

**Younger Sample: Orthogonalized Hierarchical Factor Analysis Solution for Ability Tests, With Loadings of Knowledge Scales on Ability Factors by Dwyer Extension Procedure**

| | g | *Verbal* | *Spatial* | *Math* |
|---|---|---|---|---|
| Verbal Ability | | | | |
| Verbal Analogies | **.629** | **.547** | .043 | .015 |
| Controlled Associations | **.484** | **.410** | .011 | .039 |
| Ext. Range Vocabulary | **.473** | **.555** | -.045 | -.060 |
| Spatial Ability | | | | |
| Paper Folding | **.620** | .013 | **.443** | .189 |
| Verbal Test of Spatial | **.632** | .203 | **.421** | .045 |
| Spatial Orientation | **.388** | -.005 | **.502** | -.039 |
| Mathematical/Numerical Ability | | | | |
| Math Knowledge | **.385** | .002 | -.042 | **.363** |
| Problem Solving | **.552** | .296 | -.010 | .216 |
| Number Series | **.445** | .006 | .057 | **.336** |
| Extension Analysis—Knowledge Scales | | | | |
| Astronomy | **.509** | .178 | .035 | **.251** |
| Biology | **.454** | **.530** | -.115 | .001 |
| Chemistry | **.478** | .222 | -.106 | **.292** |
| Physics | **.461** | **.333** | .045 | .062 |
| Statistics | **.300** | .156 | -.036 | .146 |
| Business/Management | **.337** | **.421** | -.056 | .048 |
| Economics | **.441** | .236 | -.052 | .206 |
| Geography | **.495** | **.305** | .069 | .099 |
| Law | **.335** | **.299** | .109 | .064 |
| Psychology | **.431** | **.382** | -.064 | .074 |
| American Government | **.475** | **.308** | -.161 | .253 |
| American History | **.500** | **.339** | .037 | .097 |
| Western Civilization | **.394** | **.417** | -.063 | .009 |
| American Literature | **.384** | **.457** | -.100 | .007 |
| Art | **.298** | **.398** | -.072 | -.049 |
| Music | **.362** | **.406** | .059 | -.100 |
| World Literature | **.394** | **.613** | .004 | -.218 |
| Electronics | **.371** | .277 | -.014 | .080 |
| Technology | **.491** | **.326** | .164 | .004 |
| Tools/Shop | **.291** | .021 | .127 | .136 |

Note: Boldface indicates salient loadings.

TABLE 7

**Older Sample: Orthogonalized Hierarchical Factor Analysis Solution for Ability Tests With Loadings of Knowledge Scales on Ability Factors by Dwyer Extension Procedure**

| | g | *Verbal* | *Spatial* | *Math* |
|---|---|---|---|---|
| Verbal Ability | | | | |
| Verbal Analogies | **.659** | **.595** | .005 | .157 |
| Controlled Associations | **.363** | **.450** | -.023 | .056 |
| Ext. Range Vocabulary | **.393** | **.676** | .021 | -.024 |
| Spatial Ability | | | | |
| Paper Folding | **.434** | .030 | **.517** | .001 |
| Verbal Test of Spatial | **.598** | .027 | **.481** | .108 |
| Spatial Orientation | **.367** | -.082 | **.519** | .002 |
| Mathematical/Numerical Ability | | | | |
| Math Knowledge | **.612** | .098 | .170 | .228 |
| Problem Solving | **.578** | .005 | .244 | .208 |
| Number Series | **.638** | -.055 | .011 | **.364** |
| Extension Analysis—Knowledge Scales | | | | |
| Astronomy | **.370** | **.341** | .137 | .027 |
| Biology | **.455** | **.431** | .238 | -.001 |
| Chemistry | **.580** | .216 | .150 | .179 |
| Physics | **.559** | **.353** | .244 | .080 |
| Statistics | **.433** | .208 | .119 | .115 |
| Business/Management | .283 | **.357** | .182 | -.046 |
| Economics | **.430** | .128 | .132 | .135 |
| Geography | **.421** | .139 | .190 | .100 |
| Law | **.377** | **.295** | .213 | .013 |
| Psychology | .255 | **.449** | .096 | -.055 |
| American Government | **.468** | **.290** | .132 | .100 |
| American History | **.381** | **.418** | .078 | .033 |
| Western Civilization | **.333** | **.507** | .037 | -.006 |
| American Literature | .166 | **.618** | .003 | -.120 |
| Art | .203 | **.550** | **.378** | **-.241** |
| Music | **.282** | **.499** | -.034 | -.000 |
| World Literature | .235 | **.634** | .074 | -.119 |
| Electronics | **.432** | .178 | **.346** | .025 |
| Technology | **.521** | **.508** | .196 | .028 |
| Tools/Shop | **.357** | .191 | **.461** | -.071 |

Note: Boldface indicates salient loadings.

Physics Knowledge Scales had substantial positive loadings on the verbal ability factor, even taking note of the fact that all common ability variance is first accounted for in the *g* factor loadings. Finally, the second-order *g* factor was significantly and positively associated with all of the Knowledge-Scale scores in the younger sample, and was positively associated with all of the Knowledge-Scale scores in the older sample (though some of the loadings were much smaller, e.g., Art [.203], American Literature [.166], World Literature [.235]).

In summary, both factor solutions for the younger and older participant groups and the respective extension analyses indicated that an underlying verbal ability factor showed substantial common variance with many of the Knowledge Scales, even in addition to the variance in common between verbal ability and *g*. In contrast, mathematical and spatial abilities (which figure prominently in traditional measures of intelligence) appear to have substantially less common variance with knowledge in the domains under consideration, once their common variance associated with general intelligence is partialled out. As such, the PPIK-inspired hypotheses are supported. That is, verbal and crystallized abilities are more highly associated with what adults "know" across a wide variety of topics, in contrast to the communality between abilities that are more associated with intelligence-as-process (i.e., spatial and mathematical abilities) and what adults "know."

The ability-knowledge association demonstration is but the first step in validating the PPIK theory, and putting the theory to use in educational and occupational applications. The next steps for the research are to take account of other trait correlates of individual differences in knowledge, and to determine how traits may interact during adult development to determine individual differences in the depth and breadth of knowledge. The remaining analyses reported below represent an attempt to further validate the nonability portions of the PPIK theory, but also to further sift the trait universe so as to later concentrate on the traits that are most likely to have involvement in determining the paths of adult-intellectual development.

For reporting of the remaining correlational analysis, the younger and older samples have been combined. Review of the individual group analyses suggests that the patterns of correlations are generally similar. The combined sample analyses allow for the major relationships among traits and knowledge scales to be discussed, without distractions by smaller differences found between the two age groups.

## Self-Concept/Self-Estimates of Ability-Knowledge Correlations

Correlations between self-report measures of Self-Concept and Self-Estimates of Ability with the Knowledge Scales are reported in Table 8. Consistent with earlier investigations that correlated self-concept scales and abilities, self-report knowledge, and other traits (e.g., see Ackerman, 1997; Ackerman, Kanfer, & Goff, 1995), there is thematic correspondence between Self-Concept, Self-Estimates of Abilities, and objective data (e.g., objective aptitude measures). In this case, spatial ability/skill self-concept, mechanical ability/skill self-

TABLE 8

**Correlations Between Self-Concept and Self-Estimates of Ability and Knowledge-Scale Scores (Whole Sample)**

| | *Self-Concept* | | | | | | *Self-Estimates of Ability* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Knowledge Scale* | *Mechanical* | *Self-Management* | *Verbal* | *Clerical* | *Math* | *Spatial* | *Verbal* | *Math* | *Self-Management* | *Clerical* | *Mechanical Knowledge* |
| Astronomy | **.251**** | .166* | .110 | .146* | **.148*** | **.255**** | .139* | **.207**** | -.080 | -.049 | **.226**** |
| Biology | **.233**** | .176** | .333** | .194** | .022 | **.202**** | .366** | .130* | .000 | .081 | **.150*** |
| Chemistry | **.362**** | .076 | .066 | .058 | **.363**** | **.279**** | .077 | **.446**** | -.107 | -.135* | **.210**** |
| Physics | **.390**** | .133* | .185** | .109 | **.137*** | **.193**** | .205** | **.237**** | -.121* | -.062 | **.304**** |
| Statistics | .109 | -.006 | .126* | .094 | .063 | .075 | .165** | .140* | -.067 | .115 | .093 |
| Business/Management | .177** | .172** | **.310**** | .139* | -.075 | .071 | **.400**** | -.060 | -.008 | .107 | .123* |
| Economics | .223** | .121* | **.109** | .055 | **.125*** | .108 | **.226**** | **.174**** | -.108 | -.093 | .151* |
| Geography | .209** | .066 | **.182**** | .155* | .034 | **.253**** | **.254**** | .100 | -.072 | .012 | .165* |
| Law | .200** | .185** | **.280**** | .173** | -.056 | .077 | **.359**** | -.026 | -.064 | .050 | .123* |
| Psychology | .148* | .212** | **.285**** | .111 | -.059 | .111 | **.302**** | -.005 | .023 | .000 | .110 |
| American Government | .119 | .120* | **.256**** | .113 | .032 | .033 | **.351**** | .102 | -.089 | .025 | .094 |
| American History | .256** | .178** | **.299**** | .135* | -.014 | .103 | **.437**** | .037 | -.012 | .011 | .207** |
| Western Civilization | .168** | .123* | **.314**** | .044 | -.021 | .125* | **.469**** | .071 | -.047 | -.062 | .082 |
| American Literature | .113 | .125* | **.405**** | .072 | **-.157**** | .048 | **.495**** | -.103 | -.010 | -.010 | .077 |
| Art | .016 | .090 | **.429**** | .115 | **-.155*** | .119 | **.442**** | -.175** | -.082 | .122 | -.001 |
| Music | .130* | .156* | **.439**** | .232** | **-.127*** | .089 | **.439**** | -.114 | .000 | .161* | .084 |
| World Literature | .136* | .186** | **.453**** | .145* | **-.152*** | .101 | **.515**** | -.090 | .013 | .058 | .061 |
| Electronics | **.395**** | .234** | .183** | .199** | .040 | **.292**** | .196** | .107 | -.047 | -.006 | **.287**** |
| Technology | **.329**** | .187** | .279** | .198** | .068 | **.258**** | **.311**** | .180** | -.055 | .043 | **.253**** |
| Tools/Shop | **.463**** | .086 | .049 | .140* | .075 | **.251**** | .060 | .141* | -.137* | -.020 | **.423**** |

Note: $N$ (max) = 278 (combined younger and older samples). Boldface indicates salient correlations.
*$p < .05$; ** $p < .01$, two-tailed.

concept and self-estimates of mechanical knowledge correlated positively and significantly with individual differences in scores on the Natural/Physical Sciences Knowledge Scales, and with the Technology and Tools/Shop scales. Similarly, mathematical self-concept and self-estimates of mathematical ability correlated with Natural/Physical Sciences knowledge.

In a noteworthy but not surprising finding, individual differences in mathematical self-concept were significantly negatively associated with knowledge on the Arts and Literature scales. One reason for this is the negative or zero correlation between math self-concept and verbal self-concept [$r_{\text{math self-concept, verbal self-concept}}$=-.15, .02] for younger and older groups, respectively, even though objective math and verbal ability scores are positively correlated [$r_{\text{math ability, verbal ability}}$=.51, .46] for younger, older groups respectively. For a discussion of this issue see Ackerman, Kanfer, and Goff (1995). Briefly, the sense is that, across individuals, self-concept for math and verbal abilities are somewhat polarized, such that persons who think that they are good at one domain tend to discount their aptitudes or abilities in the other domain.

Verbal self-concept and self-estimates of verbal ability showed substantial positive correlations with many of the Knowledge Scales, and negative correlations with none of the scales. The largest communalities were found for Arts and Literature; History and Western and American Civilization; and for Social Sciences, Law, and Business. As expected, smaller communalities were found for Technology and Tools, and the Natural and Physical Sciences and Statistics knowledge categories. Such results are again consistent with the predictions made by the PPIK theory, supporting a broad framework for crystallized intelligence, both in aptitude and in nonability traits, such as self-concept.

## Interests-Knowledge Correlations

Table 9 shows the correlations between interest theme scores from the UNIACT and Knowledge-Scale scores, with the combined participant sample. Correlations between interests and Knowledge Scales are concordant with the predictions from the PPIK theory (Ackerman, 1996b). That is, the domains of knowledge under consideration were generally not associated with individual differences in Social, Enterprising, or Conventional in-

TABLE 9

**Correlations Between Interests (From UNIACT) and Knowledge-Scale Scores (Whole Sample)**

| | *UNIACT Interest Scale* | | | | | |
|---|---|---|---|---|---|---|
| ***Knowledge Scale*** | ***Realistic*** | ***Investigative*** | ***Artistic*** | ***Social*** | ***Enterprising*** | ***Conventional*** |
| Astronomy | .142* | **.215**** | .117 | -.124 | -.073 | -.014 |
| Biology | .173** | **.388**** | .199** | -.011 | -.178** | -.133* |
| Chemistry | .160** | **.299**** | -.039 | -.053 | -.166** | -.049 |
| Physics | .250** | **.292**** | .113 | -.054 | -.107 | -.020 |
| Statistics | .052 | .103 | .122 | .007 | .025 | .001 |
| Business/Management | .188** | **.276**** | .211** | -.053 | -.024 | -.008 |
| Economics | .134* | **.178**** | .071 | -.107 | .031 | .051 |
| Geography | .155* | **.232**** | .211** | -.068 | -.093 | -.042 |
| Law | .190** | **.198**** | .187** | -.144* | -.020 | .050 |
| Psychology | .120* | **.288**** | .240** | .103 | -.017 | -.035 |
| American Government | .089 | **.189**** | .197** | -.112 | -.043 | -.037 |
| American History | .165* | **.243**** | .271** | -.086 | -.023 | -.059 |
| Western Civilization | .104 | **.285**** | .255** | .001 | -.042 | -.102 |
| American Literature | .149* | **.320**** | **.332**** | -.024 | -.082 | -.131* |
| Art | .113 | **.297**** | **.417**** | -.060 | -.105 | -.186** |
| Music | .180** | **.299**** | **.366**** | -.047 | -.144* | -.096 |
| World Literature | .157** | **.349**** | **.373**** | -.026 | -.092 | -.098 |
| Electronics | **.319**** | **.360**** | .149* | -.108 | -.153* | .011 |
| Technology | **.292**** | **.388**** | .209** | -.086 | -.131* | -.018 |
| Tools/Shop | **.384**** | **.283**** | .043 | -.099 | -.124* | .039 |

Note: *N* (max) = 278 (combined younger and older samples). Boldface indicates salient correlations.
* $p < .05$; ** $p < .01$, two-tailed.

terests, but were positively and significantly associated with Realistic, Investigative, and Artistic interests. Salient positive correlations were found between Artistic interests and Knowledge Scales in the Arts and Literature category (namely, American Literature, Art, Music, and World Literature). Similarly, Realistic interests showed positive correlations with Knowledge Scales in the Technology and Tools category (namely, Electronics, Technology, and Tools/Shop). Finally, Investigative interests (which was originally called "Intellectual" interests by Holland, 1959), correlated positively and significantly with all of the Knowledge Scales except for one (Statistics), which appeared to be more indicative of flaws in the knowledge test more than anything else. Clearly, there is a substantial correspondence between such intellectual interests and actual level of knowledge acquired. The question of where to put the "causal arrow" (i.e., interests → knowledge; knowledge → interests, or some other variable determines both interests and knowledge), continues to be an important issue for future longitudinal research.

## Personality- and Motivational-Knowledge Correlations

The personality and motivational traits correlations with Knowledge-Scale scores, shown in Table 10, provide general confirmation of predictions. That is, Neuroticism and Agreeableness do not correlate signifcantly with Knowledge Scales. TIE, and to some degree Openness, do correlate highly and significantly with Knowledge Scales, especially in Arts and Literature domains. Interestingly, Conscientiousness fails to correlate significantly with any of the Knowledge Scales, providing additional support for the notion that this particular Big-Five personality factor is more about "plodding" kinds of behaviors than "dedicated" kinds of behaviors (e.g., see the Clerical/Conventional trait complex in Ackerman & Heggestad, 1997). Consistent with earlier discussion about Extroversion results, the correlations between Extroversion and Knowledge-Scale scores are uniformly large and significantly negative, indicating that higher levels of Extroversion are associated with lower scores on the knowledge tests.

TABLE 10

**Correlations Between Personality and Motivational Traits (From NEO-FFI, TIE, WOFO) and Knowledge-Scale Scores (Whole Sample)**

| | *Personality and Motivational Scales* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Knowledge Scale* | *Neuroticism* | *Extroversion* | *Openness* | *Agreeable-ness* | *Conscientious-ness* | *TIE* | *Work* | *Mastery* | *Competitive-ness* |
| Astronomy | .037 | -.288** | .214** | -.109 | -.081 | **.241**** | .035 | .088 | .063 |
| Biology | -.051 | -.296** | .275** | .014 | .044 | **.371**** | .154* | .054 | -.025 |
| Chemistry | -.039 | -.247** | .108 | .014 | -.021 | **.157**** | .048 | .028 | .048 |
| Physics | -.063 | -.275** | .213** | -.035 | -.002 | **.278**** | .100 | .038 | -.065 |
| Statistics | .007 | -.167** | .121 | -.071 | -.030 | **.199**** | .062 | .064 | .062 |
| Business/Management | -.044 | -.246** | **.306**** | .088 | .101 | **.364**** | .132* | -.018 | **-.267**** |
| Economics | -.032 | -.300** | **.170**** | -.037 | -.002 | **.252**** | .053 | .039 | .008 |
| Geography | .010 | -.261** | **.285**** | .017 | -.101 | **.325**** | -.025 | .033 | -.078 |
| Law | -.044 | -.292** | **.242**** | .024 | .089 | **.337**** | .132* | .061 | -.146* |
| Psychology | -.000 | -.235** | **.294**** | .101 | .047 | **.347**** | .211** | .004 | -.098 |
| American Government | -.007 | -.361** | **.253**** | .004 | -.045 | **.334**** | -.023 | -.085 | -.104 |
| American History | -.027 | -.324** | **.343**** | .045 | -.015 | **.447**** | -.007 | .015 | -.156* |
| Western Civilization | -.042 | -.267** | **.358**** | .058 | -.120 | **.425**** | -.015 | .003 | -.048 |
| American Literature | .013 | -.314** | **.460**** | .041 | -.049 | **.486**** | -.002 | -.017 | **-.257**** |
| Art | -.017 | -.222** | **.453**** | .070 | -.006 | **.459**** | .019 | .084 | **-.237**** |
| Music | .016 | -.298** | **.404**** | .065 | .053 | **.416**** | .024 | .036 | **-.214**** |
| World Literature | -.013 | -.290** | **.511**** | .107 | -.032 | **.556**** | .005 | .042 | **-.268**** |
| Electronics | -.126 | -.210** | .284** | .087 | .103 | **.340**** | .196** | .147* | **-.156*** |
| Technology | -.079 | -.302** | .372** | .081 | .047 | **.422**** | .133* | .058 | **-.169*** |
| Tools/Shop | -.108 | -.228** | .186** | .014 | -.078 | **.205**** | .070 | .009 | **-.148*** |

Note: *N* (max) = 278 (combined younger and older samples). Boldface indicates salient correlations.
* $p < .05$; ** $p < .01$, two-tailed.

The only scale of motivational traits to consistently correlate with the Knowledge Scales was Competitiveness, and that measure correlated negatively with Arts and Literature knowledge, Technology and Tools knowledge, but also with Business/Management knowledge. Such results are concordant with recent theorizing about adult motivation traits and assessment procedures (Kanfer & Heggestad, 1997) that have suggested that extant measures are missing substantial sources of individual-differences variance in motivation.

# Conclusion

At this stage of analysis, it is probably too soon to reach broad conclusions about the nature of adult intellect-as-knowledge, in the context of age, ability and nonability traits (e.g., personality, interests, self-concept), life experiences (e.g., education, work experience, avocational interests), and so on. Nonetheless, the results allow for several observations to be made (given the qualifications noted earlier about the nature of sampling for the younger/older groups). As predicted, although the older adult group (mean age 40.2, *sd* = 7.2) had significantly lower mean scores on Mathematical and Spatial Ability Tests, they performed better than the younger adults (mean age 19.2, *sd* = 1.2) on Verbal Ability Tests. In contrast, the older adult group performed significantly better than the younger adult group on all of the knowledge tests but one (Chemistry), where there was no significant difference between younger and older groups. In general even as the traditional mathematical and spatial abilities measures indicated negative effects associated with middle age, the older adults in this sample know a lot more than the younger adults across a broad range of domains, including those domains that are represented both inside and outside of standard college curricula.

The older adult sample showed much higher scores on the Knowledge Scales in comparison to the younger adult sample. However, not even one significant negative correlation was found between age and Knowledge-Scale performance for the older adult sample. One pos-

itive correlation was found for age and knowledge, namely for Tools/Shop knowledge.

The older adult sample showed higher levels of intellect-related interests (Realistic, Investigative, Artistic) than the younger adults, and higher levels of verbal ability self-concept, but lower levels of mathematical ability self-concept. Personality differences between the older and younger groups were concordant, in that the older adult sample had higher levels of Openness, Agreeableness, and Conscientiousness, but lower levels of Extroversion and Competitiveness. In general, the older adult group showed a much higher degree of orientation toward things "intellectual," as demonstrated by the much higher average scores on the Goff and Ackerman (1992) measure of TIE.

Graphical description of the Knowledge-Scale profiles, in conjunction with information about respective scores on traditional ability measures and nonability measures, demonstrates the richness of the Knowledge-Scale approach for integrating cognitive, affective, and conative trait approaches for understanding adult intellect.

A number of factors predict individual differences in knowledge. Among both the younger and older adult samples, general ability (*g*) and verbal ability (even after general intelligence was partialled from verbal ability) were positively and consistently related to individual differences on the 20 Knowledge Scales. No consistent pattern of correlations between spatial and mathematical abilities was found, once general intelligence was partialled from these abilities. Clearly, the verbal tests associated with traditional assessment of "crystallized" intelligence are most highly predictive of standing on the Knowledge Scales. However, it is important to note that verbal ability does not account for all of the Knowledge Scale performance. Indeed, many Knowledge Scales only weakly loaded on an independent verbal ability factor (e.g., scales from the Technology and Tools domain, and the Natural/Physical Sciences domain). It is thus important to note this asymmetry from these results. That is, at least qualitatively, the results demonstrate that knowledge is something more than verbal abilities (or crystallized intelligence as traditionally measured).

Vocational interests are very much in line with predictions from Ackerman's (1996b) PPIK theory, and from the review of interest-intelligence associations (Ackerman, 1997; Ackerman & Heggestad, 1997). That is, Realistic, Investigative, and Artistic interests were positively associated with Knowledge-Scale scores, across a wide variety of scales (with predictable correspondences, such as Artistic interests and Art and Music knowledge, and Realistic interests and Electronics and Tools/Shop knowledge). Interests in Social, Enterprising, and Conventional domains were largely uncorrelated with performance on the Knowledge Scales.

Personality traits of Openness and TIE were substantially positively correlated with many Knowledge Scales, especially in the Arts and Literature domains. In contrast, Competitiveness was negatively associated with several Knowledge Scales. Also, somewhat surprisingly, Extroversion was significantly negatively correlated with performance on nearly all of the Knowledge Scales.

In general, these results are consistent with the PPIK approach to adult intellect that represents the foundation for this program of research. Many more analyses remain to be completed, and more complex analytic procedures (such as structural equation modeling and multidimensional scaling) may provide additional insights to those provided above, or the may simplify the representation of this large corpus of data.

# Plans for Follow-Up

This initial study has shown that the current direction of research is indeed promising for both theoretical approaches to adult-intellectual development, and ultimately for testing applications in occupational and educational settings. That said, there is a lot of work to do before a battery of knowledge tests can be made available for assessment purposes of selection or classification. The 20 tests developed to date with the support of the College Board and local support, used in the current study, need some additional development work (including the addition of more items, and filling-in gaps in item difficulty distributions). The development of additional tests is planned, especially beyond strictly academic knowledge areas, such as in the areas of occupational knowledge and aspects of avocational knowledge areas. We also plan to develop a series of "current events" knowledge tests from the decades of this century (e.g., current events from the 1940s, 1950s, 1960s, etc.). The expectation is that different age cohorts will have the highest scores in the decade of that cohort's late teens or early 20s. Such tests will allow one to better calibrate differences between age and cohorts as longitudinal and/or lagged cross-sectional designs are used for future studies of knowledge acquisition and maintenance during adult development. As additional tests are developed, it is our hope to conduct larger studies (especially some with true stratified random sampling of adults of different ages from the community at-large), and begin a study that will allow for follow-up of knowledge levels over a several year time frame. In this way, it will be possible to track changes in

knowledge, abilities, and nonability traits as young adults transition from school to work and beyond. Such studies are expected, first, to yield a better means toward assessing adult intellect (for prediction of educational and occupational success and classification), but also provide for a better fundamental understanding of the nature of intellectual life throughout the adult years.

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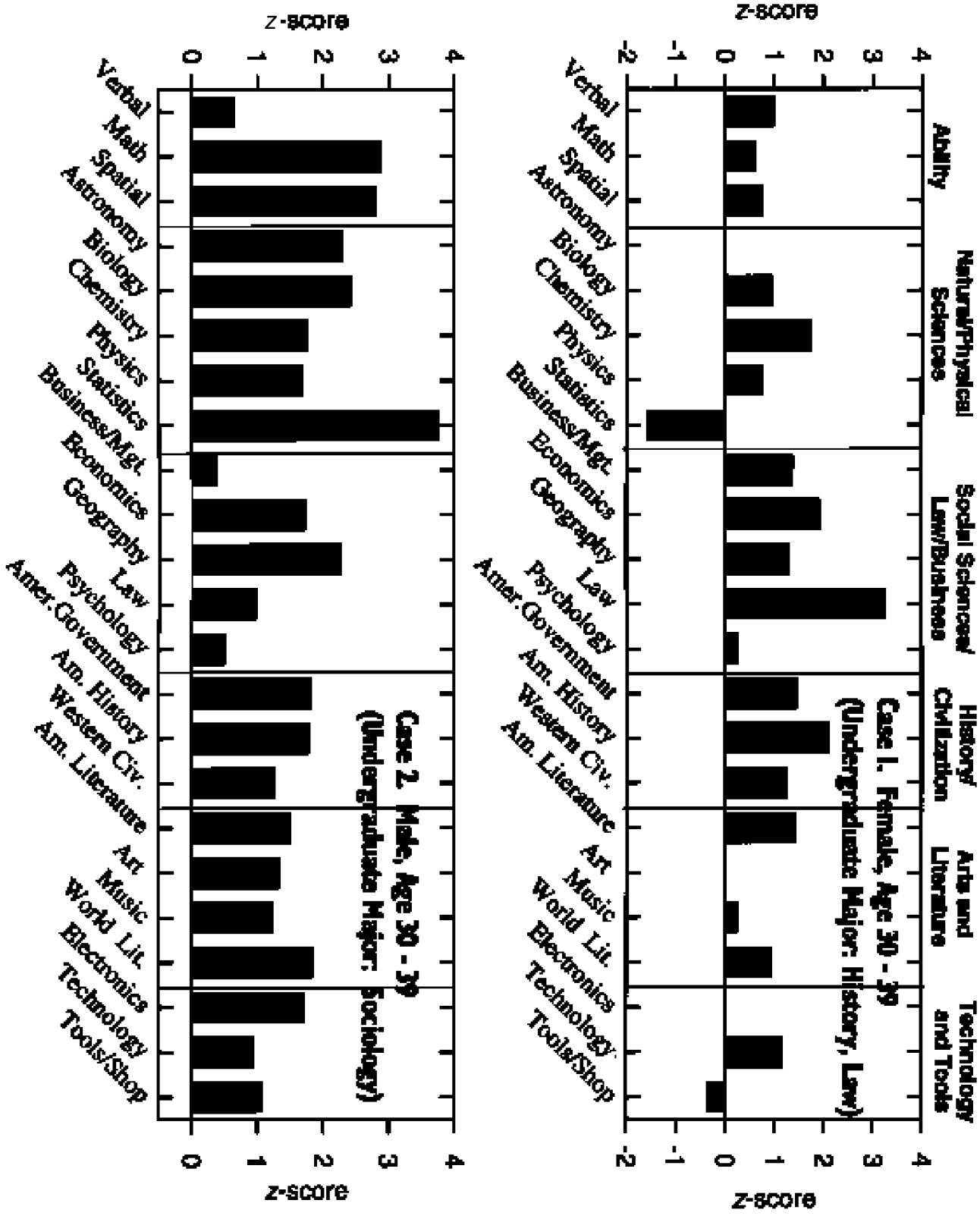
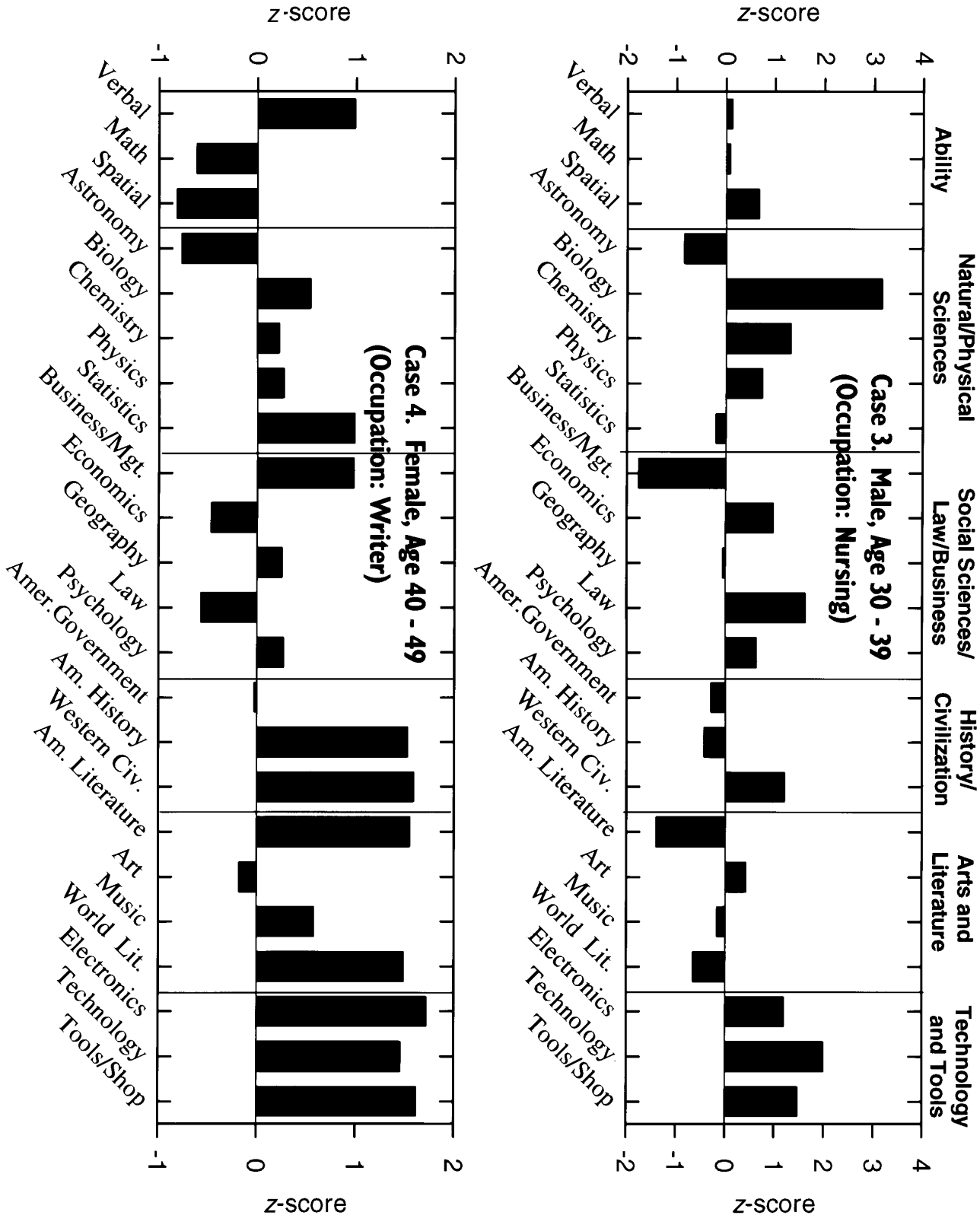
# Appendix

*Six Selected Case Profiles*



# Appendix (cont.)



# Appendix (cont.)