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Chapter 5

Intellectual Development Across Adulthood

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This chapter provides readers with a comprehensive view of intellectual development in adulthood by reviewing principles and theories as well as research findings on this topic. The chapter begins with definitions and theories of intelligence and cognition and later examines both the course and the antecedents of intellectual development. We also address issues related to the modifiability of adult cognitive development via cognitive interventions. A brief conclusion follows.

INTELLIGENCE AND COGNITION: PRINCIPLES AND DEFINITIONS

Before describing the theoretical and empirical findings on intellectual development in adults, we begin by defining the construct of intelligence. Intelligence continues to be used to categorize populations of individuals into groups of varying levels of competence. Furthermore, intelligence has served as an important component in the development of societal institutions, such as the educational system and the military, among others. Although levels of competence and social applications of intelligence serve as meaningful measures of intelligence, this chapter focuses on how intellectual development unfolds during the adult life span, including descriptions of the dynamic system of life span intellect and emphasizing individual differences in intellectual development. We emphasize cognitive products rather than the cognitive mechanisms treated in the information-processing context (e.g., Rybash, Hoyer, & Roodin, 1986). Measurement of intelligence has traditionally been concerned with operationalizing laboratory tasks that are thought to represent intelligent behaviors in the real world. As Binet and Simon (1905) already argued, "To judge well, to comprehend well, to reason well, these are the essentials of intelligence. A person may be a moron or an imbecile if he lacks judgment; but with judgment he could not be either" (p. 106).

There appears to be a natural hierarchy in the study of intelligence leading from information processing through the products measured in tests of intelligence to practical or everyday intelligence (e.g., Baltes, 1987; Sternberg & Berg, 1987, Willis & Schaie, 1993). The products or intellectual skills that characterize psychometric intelligence are likely to represent the most appropriate level for the direct prediction of life outcomes (Willis & Schaie, 1993) and capability of industrial work and maintenance of social productivity (see Avolio, 1991; Rabbitt, 1991; Welford, 1992). The entire age span from young adulthood to advanced old age must be included when examining intellectual development because it is not enough to simply compare young and old adults to be able to obtain a comprehensive depiction of intellectual development in adulthood. Instead, we need to know the life span trajectory of individual intellectual paths to ascertain the peaks of performance as well as the rate and pattern of improvement and decline (see Schaie, 1994).

THEORIES OF INTELLIGENCE IN THE STUDY OF ADULT DEVELOPMENT

At least four influential theoretical positions have informed empirical research on intelligence as products or performance indices. The earliest theoretical influence comes from Sir Charles Spearman's work (1904). He suggested that a general dimension of intelligence, known as (*g*), underlies all purposeful intellectual products. All other components of such products were viewed as task or item specific(s). Spearman's view provided the theoretical foundation for the family of assessment devices that originated from the work of Binet and Simon (1905). The concept of a single general form of intelligence may be more appropriate in childhood when scholastic aptitude represents an isomorphic and unidimensional validity criterion. However, this view is not very useful beyond adolescence because of the lack of a unidimensional criteria such as scholastic aptitude and also because of the convincing empirical evidence supporting the idea of multiple dimensions of intelligence with unique trajectories (see Horn, 1982; Schaie, 1994, 1996).

The first influential multidimensional theory was developed by E. L. Thorndike. Thorndike proposed different dimensions of intelligence, which he argued would display similar levels of performance within individuals. Thorndike also suggested that all categories of intelligence possessed three attributes: power, speed, and level (see Thorndike & Woodworth, 1901). This approach informed Wechsler's model (see Matarazzo, 1972), which specified 11 distinct scales derived from clinical observation and earlier mental tests that were combined into two broad dimensions: verbal intelligence and performance (nonverbal-manipulative) intelligence. These dimensions were combined to form a total IQ.

The Wechsler scales have had important applications in the clinical assessment of adults with psychopathology. Although the Weschsler verbal and performance scales are highly reliable in older persons, the difference between the two (often used as a rough estimate for age decline) is far less reliable (Snow, Tierney, Zorzitto, Fisher, & Reid, 1989). A major limitation of the Wechsler scales for research on intellectual aging has been the fact that the factorial structure of some of the individual scales does not remain invariant across age (McArdle & Prescott, 1992; Meredith, 1993; Sands, Terry, & Meredith, 1989). Consequently, studies of intellectual aging in community-dwelling populations have used subsets of primary mental abilities (see Cunningham, 1987; Hultsch, Hertzog, Small, McDonald-Miszlak, & Dixon, 1992; Schaie, 1990a).

A simpler model using multiple dimensions of intelligence was identified by L. L. Thurstone (1938) in his classic studies and was later expanded by Guilford (1967). The primary mental abilities described by Thurstone have formed the basis of intellectual research in the Seattle Longitudinal Study (SLS), which has used measurement instruments developed by Thurstone and Thurstone (1949) and by the Educational Testing Service (Ekstrom, French, Harman, & Derman, 1976) and based on the work of Thurstone and of Guilford (1967), as well as parallel forms developed in the SLS laboratory (Schaie, 1996).

Originally, research on primary mental abilities was conducted with children (Thurstone, 1938). Subsequent to research with children, there have been numerous studies using the factorial structure of various subsets of the primary mental abilities in adults. Second-order factor analyses of the primary mental abilities have identified several higher order dimensions, including those of fluid intelligence (applied to novel/educative tasks) and crystallized intelligence (applied to acculturated information), which was popularized by Cattell and Horn (e.g., Carroll, 1993; Cunningham, 1987; Horn & Hofer, 1992; Schaie, Willis, Hertzog, & Schulenberg, 1987; Schaie, Willis, Jay, & Chipuer, 1989).

The introduction of Piagetian thought into American psychology led some investigators to consider the application of Piagetian methods to adult development. This Genevan approach, however, has contributed only sparsely to the study of adult cognition (but see Alexander & Langer, 1990; Commons, Sinnott, Richards, & Armon, 1989; Kuhn, 1992; Labouvie-Vief, 1992; Schaie, 1977/78).

Cutting across these theoretical positions, there have also been distinct secular trends in relative emphases on different aspects of adult intelligence. Woodruff-Pak (1989) identified four stages describing the developmental trend of research on intellect. The first stage, prominent until the mid-1950s, was concerned with identifying steep and apparently inevitable age-related decline. During the 1950s and 1960s, a second stage emerged with evidence of stability as well as decline. Subsequent discoveries of external social and experiential effects influencing cohort differences in ability levels led to the third stage, which began in the 1970s and was dominated by attempts to manipulate age differences. The fourth and final stage grew from the influence of successful demonstrations of the modifiability of intellectual performance, which has led investigators to expand definitions of intelligence and explore new methods of measurement (Willis & Schaie, 1999b).

THE ROLE OF LONGITUDINAL STUDIES

The study of adult intelligence presents us with two related but nevertheless distinct objectives: describing age differences and describing change within individuals. Age comparative studies attempt to determine whether adults at different age levels also differ in intellectual performance at a particular moment in historical time, for which cross-sectional methods will suffice. This approach presents methodological problems in that cross-sectional research does not directly address how intelligence changes within individuals, nor will such data reveal the antecedents necessary to identify individual differences in the course of adult development. To solve this problem, researchers in the United States and Europe have conducted longitudinal studies to gather data on substantial age ranges over time (e.g., Busse, 1993; Costa & McCrae, 1993; Cunningham & Owens, 1983; Eichorn, Clausen, Haan, Honzik, & Mussen, 1981; Jarvik & Bank, 1983; Steen & Djurfeldt, 1993; for a review see Schaie & Hofer, 2001). Initiation of longitudinal studies represents an important new addition to the study of adult intellectual development. We hope we will soon have better information on age changes from research generated in the 1990s (e.g., Baltes, Mayer, Helmchen, & Steinhagen-Thiessen, 1993; Poon, Sweaney, Clayton, & Merriam, 1992).

OBSERVED AND LATENT VARIABLES

Most research on intelligence concerns itself not so much with age changes or differences in specific measures but rather with understanding the effects of intellectual aging on the underlying ability dimensions. Within the primary mental ability framework, the question has been raised whether specific abilities or second-order constructs are of greater importance. For adult development, however, assessment would seem to be optimal at the primary level because the role of general intelligence (g) becomes less central as expertise is developed in specific skills and because most age-related change in cognitive processes requires more than a single component to explain individual differences (Salthouse, 1988b, 1992).

Aging patterns differ between the various primary mental abilities (Schaie, 1996; Schaie & Willis, 1993) and the various second-order ability factors (Horn & Hofer, 1992). Measures of intellectual functioning are not always factorially invariant across age and time. Although the factor structure of abilities may be fairly stable across age, several studies reported differences in factor covariances, particularly in the regression of the observed marker variables on the factors (see Hertzog, 1987; Horn & McArdle, 1992; Schaie, Maitland, Willis, & Intrieri, 1998; Schaie et al., 1989). Although most factor scores based on multiple markers provide valid comparisons across age, the same cannot be said for individual scales whose regression on the given ability factor may vary markedly from young adulthood into old age.

THE COURSE OF ADULT INTELLECTUAL DEVELOPMENT

In this section, we review substantial research conclusions from the current literature. We gathered information from a broad array of current studies, with particular emphasis on data derived from the SLS. The following section highlights findings from the SLS and traces the course of adult intellectual development as understood from the data.

Population Parameters in Adult Intellectual Aging

Intellectual aging as a multidimensional process in normal community-dwelling populations has been studied very intensively in the SLS (Schaie, 1993, 1994, 1996, 2005). The principal variables in this study, which has extended thus far over a 45-year period, were five measures of psychological competence known as *primary mental abilities* (Schaie, 1985; Thurstone & Thurstone, 1949): verbal meaning, space, reasoning, number, and word fluency (the ability to recall words according to a lexical rule). Over the last three SLS test occasions, six multiple-marked abilities were assessed at the factor level: inductive reasoning, spatial orientation, perceptual speed, numeric facility, verbal comprehension, and verbal memory.

Various combinations of the primary mental abilities are represented in all meaningful activities of a person's daily living and work (Willis, Jay, Diehl, & Marsiske, 1992; Willis & Schaie, 1986a, 1994a). The SLS has followed large numbers of individuals over each 7-year interval over the age range from 25 to 88 years. On average, there is gain until the late thirties or early forties are reached, and then there is stability until the mid-fifties or early sixties. Beginning with the late sixties, however, seven-year decrements are statistically significant throughout. These data suggest that average decline in psychological competence may begin for some as early as the mid-fifties, but that early decrement is of small magnitude until the mid-seventies. Because of the modest gains from young adulthood to middle age, longitudinal comparisons from a young adult base (age 25) show significant cumulative decline only by the mid-seventies.

At the factor level, longitudinal decline is noted by the mid-fifties for perceptual speed and numeric ability, by the late sixties for inductive reasoning and spatial orientation, and by the late seventies for verbal ability and verbal memory. Figures 5.1 and 5.2 show longitudinal gradients for five observed mental abilities and six derived ability factors.

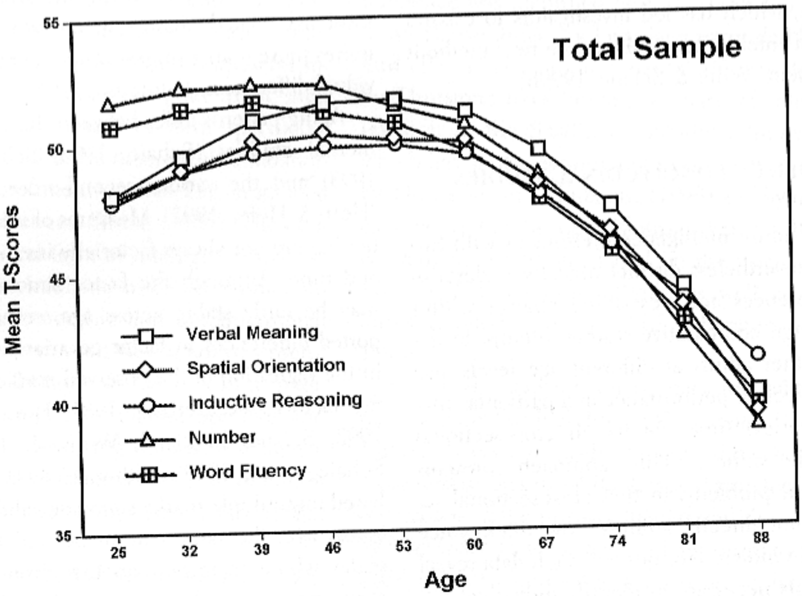

FIGURE 5.1 Longitudinal estimates of age changes on observed measures of five primary mental abilities.

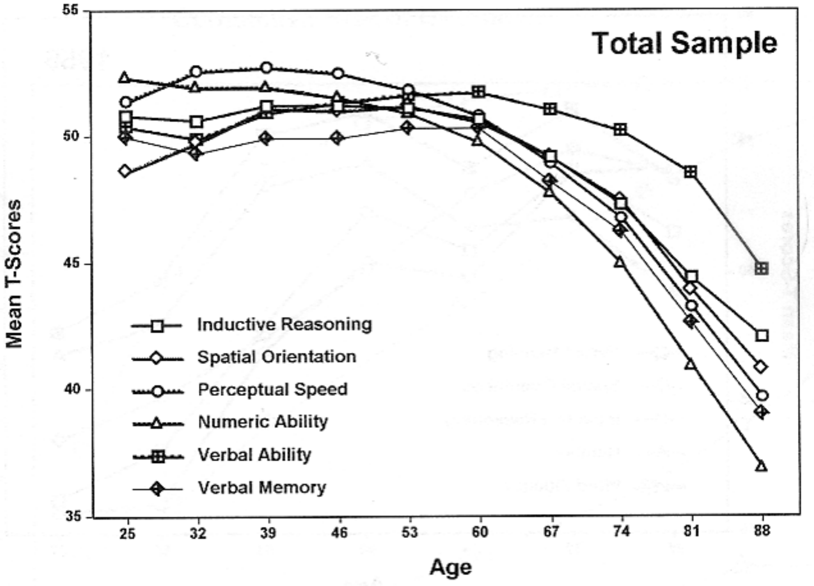

FIGURE 5.2 Longitudinal estimates of age changes in factor scores on six primary mental abilities at the latent construct level.

Several recent short-term longitudinal studies confirm the finding that cognitive functions due to age change is a slow process. At least two major studies have found virtual stability over a three-year period (Hultsch et al., 1992; Zelinski, Gilewski, & Schaie, 1993). Arbuckle, Maag, Pushkar, and Chaikelson (1998) examined the intellectual development for Canadian World War II veterans over a 45-year period from World War II to the 1990s. They found that performance declined for picture completion, picture anomalies, paper formboard, verbal analogies, and arithmetic. However, there was improvement in vocabulary performance. The correlations between the extreme time points indicated stability of individual differences in intelligence over the 45 years, demonstrating relative intellectual change and showing a somewhat positive view of intellectual aging.

Substantial intellectual changes within individuals occur for most persons only late in life and tend to occur earliest for those abilities that were less central to the individuals' life experiences and thus perhaps less practiced. Nevertheless, in our community-based studies we found that virtually everyone had declined modestly on at least one of five mental abilities by age 60. But none of the study participants had declined on all five abilities even by age 88 (Schaie, 1989a).

But what about findings from age comparative (cross-sectional) studies of intellectual performance in which young and old adults are compared at a single point in time? Due to substantial cohort differences (see later discussion), these studies show far greater age differences than do longitudinal data. Typically, ages of peak performance occur earlier (for later born cohorts). By the early fifties, there are modest age differences for some abilities from peak performance. By 60, most dimensions of intelligence show changes. Because of the slowing in the rate of positive cohort differences, age different profiles have begun to converge somewhat more with the age change data from longitudinal studies. Figure 5.3 shows age difference patterns from the SLS over the age range 25–81 years in 1956 and 1998. As can be seen, both peak performance and onset of decline seem to be shifting to later ages for most variables.

Recent work on the Wechsler Adult Intelligence Scale (WAIS) with data sets based on normal individuals has shifted to approaches that involve latent variable models (see Horn & McArdle, 1992; McArdle & Prescott, 1992; Millsap & Meredith, 1992; Rott, 1993). Alternatively, analyses have been conducted at the item level. An example of the latter approach is a study by Sands et al. (1989) of two cohorts spanning the age range 18–61 years. Consistent improvement in performance was found between the ages of 18 and

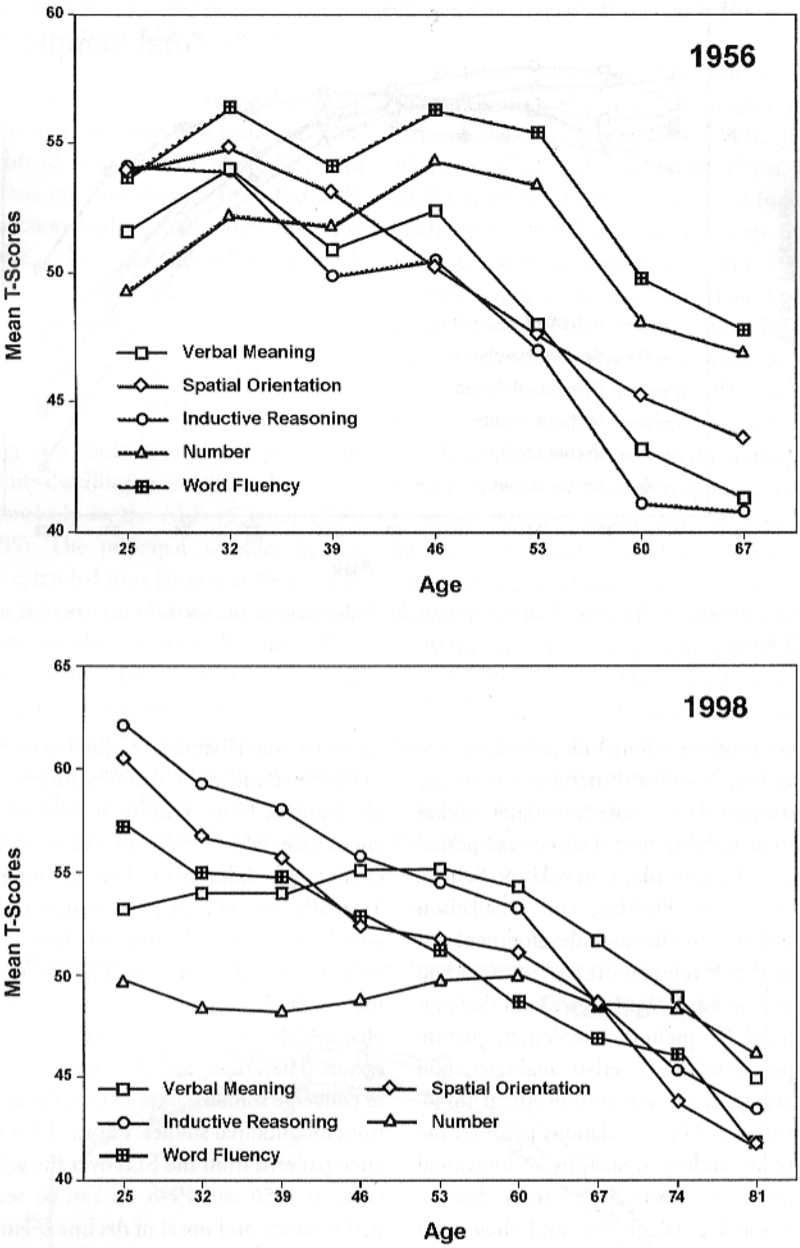

FIGURE 5.3 Cross-sectional age differences on five primary mental abilities for samples tested in 1956 and 1998.

40 and between 18 and 54. Between ages 40 and 61 improvement was found for the information, comprehension, vocabulary subtest; mixed change (gain on the easy items and decline on the difficult items) on picture completion; and decline on digit symbol and block design (with decline only for the most difficult items of the latter tests).

Individual Differences in Level and Rate of Change

Is decline in psychological competence a global or highly specific event? SLS data graphed in figure 5.4 show cumulative proportions by age of participants whose level of cognitive functioning had declined on

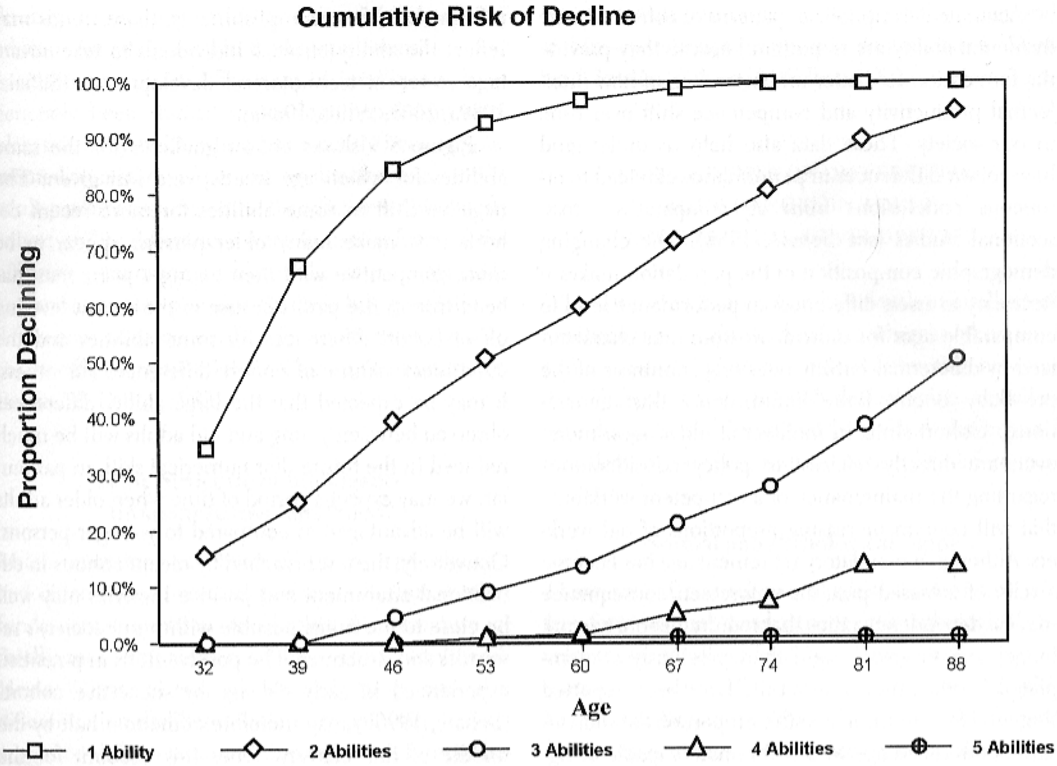

FIGURE 5.4 Cumulative proportion by age of individuals who show significant decline on one or more primary mental abilities.

one or more abilities. Although by age 60 virtually every participant had declined on one ability, few individuals showed global decline. Few showed universal decline on all abilities monitored, even by the eighties. Optimization of cognitive functioning in old age may well involve selective maintenance of some abilities but not others (see Baltes & Baltes, 1990). Moreover, such optimization seems to be a highly individualized phenomenon (see Rabbitt, 1993; Schaie, 1989a, 1990b).

Despite these encouraging data, it is clear that significant reductions in psychological competence occur in most people by ages 80 and 90. However, even at such advanced ages, many persons in familiar circumstances can expect competent behavior. Much of the observed loss occurs in highly challenging, complex, or stressful situations that require activation of reserve capacities (see Baltes, 1993; Raykov, 1989). The belief that the more able are also more resistant to intellectual decline remains generally unsupported (see Christensen & Henderson, 1991). But those who start out at high levels remain advantaged even after suffering some decline.

Why Do Cohort Effects Matter?

There have been marked generational shifts in levels of performance on tests of mental abilities (Schaie, 1989b, 1996; Willis, 1989a). Empirical findings suggest that later-born cohorts are generally advanced when compared with earlier cohorts at the same age. The phenomenon has been explained by increased educational opportunities and improved lifestyles. Nutrition and mastery over childhood diseases have enabled successive generations to reach ever higher ability asymptotes, similar to the observed secular trends of improvement for anthropometrics and other biological markers (Shock et al., 1984). Although linear trends have been found for some variables, there seems to be contrary evidence that such trends may have been time limited, domain explicit, or even variable specific (see Schaie, 1990c; Willis, 1989a).

Accurate descriptions of patterns of cohort change in mental ability are important because they provide the foundation for better understanding of how intellectual productivity and competence shift over time in our society. These data also help us understand how cohort differences in performance can lead to erroneous conclusions from age-comparative cross-sectional studies (see Schaie, 1988). The changing demographic composition of the population makes it necessary to assess differences in performance level to comparable ages for individuals from eras characterized by differential fertility rates (e.g., contrasts of the pre–Baby Boom, Baby Boom, Baby Bust generations). Cohort shifts in intellect at older ages, moreover, are directly relevant to policy considerations regarding the maintenance of a competent workforce that will contain increasing proportions of old workers. Although a mandatory retirement age has become a relic of a biased past, an unforeseen consequence may be dependency ratios that require people to work longer and to greater ages than previously contemplated. Cohort trends over time have been reported that are likely to influence the proportions of individuals of advanced age who will remain capable of significant late-life accomplishments; these trends may reflect the ability of older individuals to take advantage of recent technological developments (Schaie, 1989a, 2005; Willis, 1989a).

Figure 5.5 shows cohort gradients for the same abilities for which age trends were just given. The negative shift in some abilities for more recent cohorts may make many older persons appear to be more competitive with their younger peers than has been true in the past. Because of the recent leveling off of cohort differences for some abilities and the curvilinear nature of cohort differences for others, it may be expected that the large ability differences observed between young and old adults will be much reduced in the future. For numerical skill, in particular, we may expect a period of time when older adults will be advantaged as compared to younger persons. Conversely, the level reached by recent cohorts in educational attainment and positive lifestyles may well be close to the limits possible within our society's resources and structures. The positive shifts in potential, experienced in early old age by successive cohorts (Schaie, 1990b) may therefore come to a halt by the middle of this century. Does this account for the

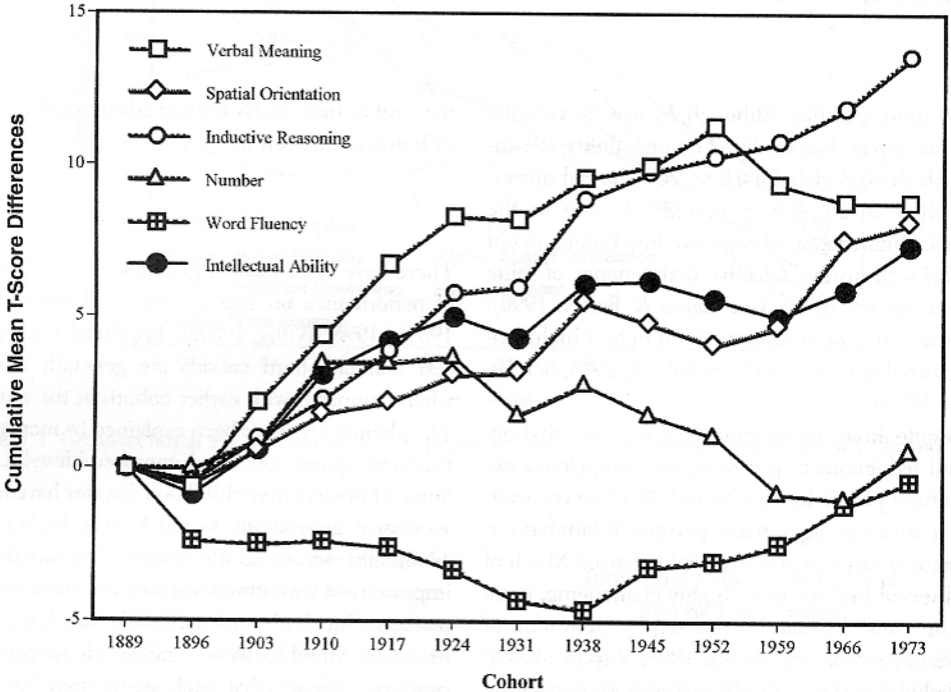

FIGURE 5.5 Cohort gradients showing cumulative cohort difference on five primary mental abilities for cohorts born in 1889 to 1973.

diversity in our population and the disparity among educational attainment in these populations?

Although cohort differences in intelligence have generally been studied in random population samples, this body of literature has recently been supplemented in a study of generational differences in 531 adult parent-offspring pairs. Significant within-family cohort ability differences were found in favor of the offspring generation in about the same magnitude as shown in the previous studies, but generational differences became smaller for more recently born parent-offspring pairs (Schaie, Plomin, Willis, Gruber-Baldini, & Dutta, 1992).

Is the Structure of Intelligence Invariant Across Adulthood?

Much attention has been given to age changes and differences in level of performance, but another fundamental question is whether the structure of intelligence remains constant across adulthood. Heinz Werner (1948) was an early proponent of a differentiation-dedifferentiation hypothesis, which suggested differentiation of dimensions of human behavior during the growth stage and eventual dedifferentiation or reintegration as individuals aged. Reinert (1970) extended this hypothesis to intellectual development.

The introduction of confirmatory factor analysis permitted testing of the hypothesis by designing studies that formally assess factorial invariance across age (see Alwin, 1988; Horn & McArdle, 1992; Millsap & Meredith, 1992). The same numbers of dimensions generally suffice to describe the ability domains across adulthood, but the relative importance of observed measures as estimates of the underlying latent constructs changes across age. In the SLS work, we have found configural invariance across adulthood in the eighties in cross-sectional data but could not accept complete metric invariance (Schaie et al., 1989). This means that in age-comparative studies one should not compare means for observed variables, but should instead compare estimated factor scores on the latent constructs. In the SLS we conducted longitudinal within-cohort factor analyses and found that metric invariance can be demonstrated over seven years, except for participants in their eighties (Schaie, 1994, 1996). Later weak factor invariance and configural invariance was demonstrated for all cohorts (Schaie et al., 1998). Finally, gender equivalence in covariance structures across the adult life span and within separate age groups was demonstrated (Maitland, Intrieri, Schaie, & Willis, 2000).

ANTECEDENTS OF DIFFERENTIAL AGE CHANGES IN ADULT INTELLECTUAL DEVELOPMENT

Why is it that some maintain high levels of intellectual functioning into advanced old age whereas others tend to decline early? Here, we make a distinction between the effects of normal and pathological aging, as well as consider both the impact of behavioral slowing and the effects of social context and personality differences.

Normal and Pathological Aging

There are, of course, neurological diseases that can transform normal development into pathological development, resulting in diminished cognitive performance (Mahoney, 2003; Shimada, Meguro, Inagaki, Ishizaki, & Yamadori, 2001). However, neurological diseases are not the only illnesses associated with negative intellectual effects. Better health has been shown to predict less cognitive decline (Arbuckle et al., 1998). Many investigators have therefore attempted to control for or measure the impact of acute or chronic disease on age-related diseases and age-related decline in intellectual functioning (see Anstey, Stankov, & Lord, 1993). Simple questionnaires on subjective health status often yield fairly strong relationships with levels of cognitive functioning (see Field, Schaie, & Leino, 1988; Hultsch et al., 1993; Perlmutter & Nyquist, 1990). More ambitious efforts have involved intense studies of health history data or the inclusion of partial or complete medical workups in some studies of intellectual development.

Cognitive performance can be challenged during the onset of diseases as well as by treatments used to control diseases (Tabbarah, Crimmins, & Seeman, 2002). Stroke and Alzheimer's disease/dementia have direct biological consequences causing impairment in brain functioning; hence there are negative consequences for cognitive ability (Klimkowicz, Dziedzic, Slowik, & Szczudlik, 2002; Kukull et al., 1994). However, there also appear to be negative cognitive consequences from diseases that do not directly affect the brain. For example, there is evidence that heart disease (Almeida & Flicker, 2001; Almeida & Tamai, 2001; Rabbitt et al., 2002; Seeman, McEwen, Rowe, & Singer, 2001), chronic obstructive pulmonary disease (Fioravanti, Nacca, Amati, Buckley, & Bisetti, 1995; Incalzi et al., 1993), diabetes (Jackson-Guilford, Leander, & Nisenbaum, 2000; McCarthy, Lindgren, Mengeling, Tsalikian, & Engvall, 2002), and pneumonia (Iwamoto et al., 2000; Medina-Walpole & McCormick, 1998) can all negatively affect cognitive performance.

Impact of Cardiovascular Disease

It seems reasonable to suspect that the presence or absence of cardiovascular disease might be related to the rate of intellectual aging. This possible relationship has been investigated in the Duke Longitudinal Study (Manton, Siegler, & Woodbury, 1986; Palmor, Busse, Maddox, Nowlin, & Siegler, 1985) and in the SLS. In the latter, it was found that individuals who were at risk of cardiovascular disease tended to decline earlier on average on all mental abilities studied than did individuals not so affected (see Gruber-Baldini, 1991; Schaie, 1996, 2005). Those who declined have significantly greater numbers of illness diagnoses, as well as clinic visits for cardiovascular disease.

The effects of hypertension, however, are far more complicated than those of other cardiovascular conditions. When distinctions are made between moderate or medically controlled and severe hypertension, it is often found that mild hypertension may actually have positive effects on intellectual functioning (e.g., Elias, Elias, & Elias, 1990; Sands & Meredith, 1992; Schultz, Elias, Robbins, & Streeten, 1989).

Impact of Other Chronic Diseases

Other chronic diseases that affect maintenance of intellectual functioning include arthritis, neoplasms (tumors), osteoporosis, and sensory deficits. In one study of the very old, visual and hearing deficits accounted for almost half of the total individual differences variance and for more than 90% of the age-related portion of those differences (Lindenberger & Baltes, 1994).

Data from the SLS suggest that arthritics have lower functioning and greater decline on verbal meaning, spatial orientation, and inductive reasoning. When malignant and benign neoplasms are distinguished, persons with benign neoplasms (other than skin tumors) were found to have earlier onset of intellectual decline but less overall decline. Persons with malignant neoplasms and benign skin neoplasms have indirect negative influences on performance (through reduced activity). Results of the influence of neoplasms on cognition might be specific to type of tumor (malignant versus nonmalignant) as well as location (skin, bone, etc.). Osteoporosis and hip fractures were predictive of earlier decline on word fluency. Hearing impairment was associated with increased risk of experiencing verbal meaning decline but was associated with better performance and later decline on space (Gruber-Baldini, 1991; Schaie, 2005).

Impact of Medical Treatment

It is not always the biological consequences of the disease that lead to impairment in cognitive abilities. Negative cognitive effects may also result from treatments used in attempts to control the disease. Several studies have shown that treatments of heart disease (Stanley et al., 2002), cancer treatments (Abayomi, 2002; Armstrong et al., 2002; Green et al., 2002), and diabetes treatments (Drexler & Roberston, 2001) can adversely affect cognitive performance. It has been hypothesized that some of the negative cognitive effects seen following treatment may be due to fatigue or limited biological viability, redistribution of physical resources, or simply biological changes that produced unexpected cognitive side effects.

The relationship between disease and intellectual functioning, however, should not be overinterpreted. This relationship may be biased by the fact that the more able are also more likely to engage in appropriate health maintenance behavior, modestly supported in SLS (Maier, 1995; Zanjani, 2002). They also tend to seek competent help earlier and are therefore more likely to postpone the onset or the more disabling stages of chronic disease (Royak-Schaler & Alt, 1994). The relationship between disease and cognitive ability may also be a function of the relationship between time to death and cognitive trajectories. There has been some evidence that distance from death may serve as one of determinants of cognitive decline. Conversely, significant declines in cognitive functioning may be a risk factor for mortality (Bosworth, Schaie, & Willis, 1999; Bosworth, Schaie, Willis, & Siegler, 1999). Thus, cognitive decline in advanced old age may simply be a consequence of coming closer to one's demise.

Behavioral Slowing and Intellectual Aging

It is quite evident that the slowing of reaction time with age adversely affects performance on tests of intellectual abilities. Many questions remain, however, as to whether the behavioral slowing involves a single or multiple mechanisms (see Salthouse, 1988a, 1993c, 1994). Slowing of performance seems to have differential effects depending not only on the particular cognitive processes or abilities involved but also on the format used in the presentation of test materials (Hertzog, 1989). Other factors include the level of familiarity, imageability, primacy, and recent exposure to stimuli (Kennet, McGuire, Willis, & Schaie, 2000). Although group data on age-related changes in reaction time or perceptual speed often take linear form, analyses of individual differences tend to reveal individual patterns of change that follow a stair-step pattern (Schaie, 1989b). Birren argued long ago that loss in speed of performance should be seen as a species-specific characteristic of normal aging and concluded that if one cannot think quickly, one cannot think well (Birren & Botwinick, 1951; Birren & Fisher, 1992). Stankov (1988), moreover, showed that speed of search is related to efficient processing of information. When statistical adjustments were made for the effects of individual differences in attention, age differences in fluid abilities were markedly reduced, whereas crystallized abilities tended to show increases into later life.

A number of studies have investigated the specific impact of level of performance on measures of perceptual speed. A typical method has been to partial out perceptual speed from the correlations between age and intellectual performance. Most studies report that age differences are markedly reduced or completely eliminated after adjustments for perceptual speed (Hertzog, 1989; Lindenberger, Mayr, & Kliegl, 1993; Salthouse, 1993c; Schaie, 1989b). Other possible adjustments of speed-mediated age differences in intelligence have involved measures of psychomotor speed (see Hertzog, 1989; Schaie & Willis, 1991).

Some argue that cognitive decline is a diminution of resources of which speed of behavior is a prime component (Salthouse, 1988b). But other cognitive mechanisms may also be implicated. For example, reduction in the efficiency of verbal memory occurring with increasing age would reduce the preservation of information during processing of any complex cognitive task (Salthouse, 1993a). Considerable amounts of cognitive load imposed by time-based prospective memory tasks have been found to disproportionately penalize older adults (Martin & Schumann-Hengsteler, 2001). DeLuca et al. (2003) claimed that executive skills may also be vulnerable to negative age changes that can cause declines in cognitive performance. On the other hand, superior resources, such as crystallized knowledge, might reduce age differences on verbal tasks even when older participants display slower processing speed (Salthouse, 1993b).

Social Context and Intellectual Aging

Intellectual aging occurs within a social context. Hence, a number of demographic dimensions have been identified that tend to affect the rate of cognitive decline (see Schaie, 1994; Willis, 1989a). Because of different socialization patterns, gender roles can result in differential performance levels on certain mental abilities. On the primary mental abilities, women consistently excel over men on reasoning and verbal skills, whereas men do better on spatial skills (Schaie, 1996). On the WAIS, adult gender differences have been found to favor men on arithmetic, information, and block design, with women excelling on digit symbol (Kaufman, Kaufman-Packer, McLean, & Reynolds, 1991). Because of women's greater life expectancy, men are always closer to death at any given age. Thus at comparable advanced ages, women tend to perform better cognitively. Gender differences in rates of decline, moreover, are greater for those skills in which each gender excels in young adulthood (Feingold, 1993; Schaie, 1996).

Not only are high levels of education implicated in slower rates of intellectual decline (Schaie, 1989a), but lengthy marriage to a well-educated and intelligent spouse has also been identified as a positive risk factor (Gruber & Schaie, 1986). There has been some indication that support from a partner may enhance problem-solving efforts (Dixon & Gould, 1998; Schaie & Willis, 2000). High occupational status and its more subtle aspects (such as high workplace complexity) are positive predictors for maintenance of intellectual functioning into old age (DeFrias & Schaie, 2001; Dutta, 1992; Miller, Slomczynski, & Kohn, 1987; Schooler, 1987). Moreover, retirement seems to have favorable cognitive sequelae for those retiring from routinized jobs but accelerates decrement for those retiring from highly complex jobs.

Higher social class has also been found to compensate for some of the negative effects of cognitive risk factors (Jefferis, Power, & Hertzman, 2002). Other contextual variables that have favorable impact on cognitive aging include intact marriages, exposure to stimulating environments, and the use of cultural and educational resources throughout adulthood (Schaie, 1984). Lifestyle variables such as those already mentioned were also identified as positive risk factors in the Boston Normative Aging study (Jones, Albert, Duffy, & Hyde, 1991), and in studies of memory functioning in older Canadian men (Arbuckle, Gold, Andres, Schwartzman, & Chaikelson, 1992). Arbuckle et al. (1998) also found that individuals with a more engaged lifestyle show less intellectual decline.

Personality, Cognitive Styles, Motivation, and Expertise

Certain personality traits, cognitive styles, motivation, and expertise levels have also been found to affect maintenance of intellectual functioning. For the most part, research on personality traits and cognitive ability have used these two constructs simultaneously as predictors of noncognitive performance outcomes (Kickul & Neuman, 2000; LePine, 2003). However, the existing research relating personality traits and cognitive performance has indicated a modest relationship between the two in both cross-sectional and longitudinal research. For example, Costa, Fozard, McCrae, and Bosse (1976) found that subjects high in anxiety scored lower on their General Aptitude Test Battery, and those scoring high on openness to experience and introversion had mixed scores on the battery. However, they had also concluded that cross-sectional age differences in cognitive performance were not mediated by personality. On the other hand, Arbuckle, Gold, and Andres (1986) found that individual differences in memory performance were better accounted for by education, intellectual activity, extroversion, and neuroticism than by age. There have also been some indications for abnormally high rates of trait impulsivity and aggression being associated with lower IQs (Dolan & Anderson, 2002).

Recently, in the SLS, a relationship between personality traits and cognitive performance was also found (Schaie, Willis, & Caskie, 2004). The study examined the relationships between cognitive performance and 13-factor personality model and the NEO trait personality model (Costa & McCrae, 1992). They found several significant concurrent relationships between inductive reasoning, spatial orientation, perceptual speed, numeric facility, verbal comprehension, and verbal memory with neuroticism, extraversion, openness, agreeableness, and conscientiousness. Also, examining the longitudinal relationship between 13-factor personality scores and cognitive abilities showed that personality consistently predicted cognitive performance over as long as a 35-year lag between personality assessment and cognitive ability.

There seems to be a modest positive relationship between self-efficacy and intellectual functioning, although it remains to be resolved whether this relationship is unidirectional or reciprocal (Dittmann-Kohli, Lachman, Kliegl, & Baltes, 1991; Grover & Hertzog, 1991; Lachman & Leff, 1989). Intellectual performance, for example, may be affected by the participants' self-appraisal of their age changes in performance. This question has been studied empirically by assessing perceived change in performance with objectively measured change (Schaie, Willis, & O'Hanlon, 1994). Study participants were categorized as those who maintained earlier performance level, significantly increased their performance, or experienced decline in their performance. A typology linking actual and perceived change in performance was created to express personality differences. Realists were identified as those who accurately estimated change in their performance. Optimists overestimated positive change. Pessimists overestimated negative change. The majority of participants made realistic appraisals for changes in intellectual functioning. However, women were more likely to be pessimists on spatial orientation than men. Older individuals were more likely to be pessimists on verbal meaning and inductive reasoning abilities but tended to be realists on number ability compared to younger participants. By contrast, Rabbitt and Abson (1991) found that their participants failed to predict objective performance on simple memory tasks, although their predictions were related to the Beck Depression Inventory. They suggested that their participants rated their memory relative to reduced memory requirements in their current environment. In the SLS, further exploration in this area has concluded that the relationship between congruence type and actual performance varies by ability, implying that individual perceptions do not uniformly affect individual cognitive performance across abilities (Roth, Schaie, & Willis, 2001; Schaie, Willis, & Caskie, 2004).

Levels of expertise, exposure, and interest in specific domains have been explored as indicators for unique intellectual development. Reeve and Hakle (2000) found a positive relationship between individual interest and knowledge, indicating that personal motivation in certain tasks can assist in the maintenance of certain abilities. Hershey, Jacobs-Lawson, and Walsh (2003) found that increases in task-specific experiences, specifically in financial investment problems, lead to increases in patterns of information selection and search consistency for most adults across the life span. However, this did not hold true for untrained older adults, indicating a possibility for limited capacity in the ability to attain new expertise after a certain age.

Personality and cognitive styles are salient indicators for intellectual development. For example, individuals with higher cognitive levels have been found to use a wider array of thinking styles compared to individuals who display lower cognitive levels (Zhang, 2002). LePage-Lees (1997) has found that despite a disadvantaged upbringing, individuals with high levels of emotional intelligence have been found to display positive intellectual development.

Rigid and flexible personality characteristics have been identified as antecedents for intellectual development. Longitudinal studies suggest that one's lifelong standing on flexible behaviors is maintained for most persons into their seventies, whereas on average, people develop more rigid attitudes by the early sixties (see Schaie, 1996). It has also been shown that those with flexible attitudes in midlife tend to experience less decline in psychological competence with advancing age than those who were observed to be fairly rigid at that life stage (Schaie, 1984, 1996). These studies also concluded that high levels of motor-cognitive flexibility at the young-old stage are highly predictive of one's standing on numerical and verbal skills as well as psychological energy when reaching the old-old stage (also see O'Hanlon, 1993; Schaie, Dutta, & Willis, 1991).

A cross-sectional study, comparing adults ranging from 18 to 87 years also found a relationship between cognitive styles, age, and intelligence (Hood & Deopere, 2002). They found a relationship between age and cognitive styles; specifically their older adults displayed a stronger tendency toward dualism, thus envisioning the world more in terms of Us (good) versus Them (bad). They also found an unexpected positive relationship between scores on intelligence tests and age, implying a possible relationship between intelligence and dualism. Incidentally, there was a negative relationship with scores on intelligence tests and the level of dualism. The discrepancy may have evolved from educational differences among their participants. Education was found to have a negative relationship with dualism and a positive relationship with relativism (which was displayed more in younger adults). Education also had a negative relationship with age, indicating that individuals of advanced age tended to have lower educational levels.

Family Environment

Certain aspects of the family environment may influence intellectual development. Despite the fact that most work on this topic is grounded in earlier parts of the life span, there are still implications for the adult life span.

There has been some indication that negative effects of low family income on early cognitive development can be compensated for by using constructive family strategies and interactions (Hustedt & Raver, 2002; Poehlmann & Fiese, 2001; Ramey, Campbell, & Ramey, 1999) and by providing a supportive home environment (Kalmar, 1996; Kalmar & Boronkai, 2001; Kelley, Smith, Green, Berndt, & Rogers, 1998; Liang & Sugawara, 1996). Higher parental educational levels (Zhang & Yu, 2002) and supportive family environments (Dubowitz et al., 2001) have been found to have a positive relationship with offspring intelligence. A positive relationship has been found between the availability of resources within families for each member and intellectual outcomes, tending to imply that the fewer the number of members in a household, the more resources are likely to be available for each member, which can promote positive intellectual development (Downey, 2001). In addition, higher levels of stress and perceived difficulty in a family environment can negatively affect offspring cognitive development (Miller, Miceli, Whitman, & Borkowski, 1996) as well as experiencing or witnessing domestic violence (Huth-Bocks, Levendosky, & Semel, 2001). Families that provide children with proper nutrition have been found to have higher verbal ability scores (Quinn, O'Callaghan, Williams, Najman, & Andersen, 2001).

There is still some debate over whether the cognitive effects that are displayed within families result from genetic transmission of abilities or from effects of the early family environment (Guo & Stearns, 2002; Plomin, Fulker, Corley, & DeFries, 1997; Schaie & Zuo, 2001). The most reasonable interpretations of these data argue for a strong gene–environment interaction.

INTERVENTIONS IN ADULT INTELLECTUAL DEVELOPMENT

Adult Intellectual Decline: Irreversible or Remediable?

Findings on individual differences in intellectual change and the identification of antecedents for differential intellectual aging cast at least some doubt on the inevitability of general intellectual decline for all individuals and provide an optimistic picture of the continued ability to learn throughout life. More substantive evidence for such doubts is provided by cognitive intervention research that has successfully remediated some intellectual decline in the elderly. Longitudinal studies make it possible to distinguish effects of training that remediate age deficits from improvement in the performance of individuals above their previous levels. The former outcome, however, is of particular theoretical interest because it suggests that much of the intellectual aging seen in community dwelling elderly may be experiential in nature. Training studies conducted in a longitudinal context also permit the identification of antecedent conditions that predict the likelihood of training success or failure (Willis, 1989b, 1990, 2001).

Remediation of Deficits Versus Reduction of Cohort Effects

Much of the work on cognitive training has been conducted in the context of the Adult Development and Enrichment Project (ADEPT, Baltes & Willis, 1982) and the SLS (Schaie & Willis, 1986; Willis & Schaie, 1986b). Both studies involved pre- and posttest designs, with five hours of instruction in strategies at the ability level, administered in small groups in the ADEPT study and individually in the SLS. In the former study, significant training gains were demonstrated for participants over age 60 for the primary mental abilities of figural relations and inductive reasoning, whereas in the latter study, significant training gains occurred for inductive reasoning and spatial orientation. In the SLS, moreover, significant gain occurred for participants who had declined as well as for those who had remained stable. Women experienced greater training effects on spatial orientation, whereas training benefited both speed and accuracy in women but primarily accuracy in men (Willis & Schaie, 1988). Greater training effects were seen in the SLS for inductive reasoning when there was evidence of strategy use, suggesting that strategy use may be a possible mechanism for training effects (Saczynski, Willis, & Schaie, 2002). There is also some evidence that personality may be associated with training gains (Boron, 2003), and there may be mediating relationships with psychomotor speed, total systemic conditions, and respiratory conditions for training gains (Saczynski, 2001). In both ADEPT and SLS, near transfer was shown to occur for alternate markers within each ability, but there was no far transfer to other primary abilities.

Variations of the ADEPT study, introducing multiple training conditions or conditions involving self-programmed training conditions, have for the most part replicated the original findings in a German sample (Baltes & Lindenberger, 1988; Baltes, Sowarka, & Kliegl, 1989) and in American studies by Blackburn, Papalia-Finley, Foye, and Serlin (1988) and by Hayslip (1989). A study of figural relations training by Denney and Heidrich (1990) showed equal magnitudes of improvement for young, middle-aged, and old subjects.

Does cognitive training change the structural characteristics of the primary abilities by converting a pretraining fluid ability to a crystallized ability (see Donaldson, 1981)? In the SLS, invariance of factor structure across training was confirmed in the training groups. Minor shifts occurred in the factor loadings of the individual markers of the abilities trained, but training did not result in any of the marker loadings on factors other than those hypothesized (Schaie et al., 1987).

Long-Term Effects of Cognitive Interventions

Cognitive training will clearly yield significant improvement in the performance of older persons on the targeted abilities, but skepticism remains as to whether such training produces any lasting effects. Long-term follow-up over a seven-year period has been conducted for both the ADEPT and SLS training studies. Significantly lower decline over seven years was shown in the ADEPT study for those individuals trained on figural relations as compared to the control group (Willis & Nesselroade, 1990). In the SLS, similar findings occurred for both inductive reasoning and spatial orientation abilities (Willis & Schaie, 1994b). In the latter study, those who declined prior to the initial training were at greater comparative advantage at the follow-up. Both studies also examined effects of booster training. As would be expected, as subjects entered advanced old age, booster training, although yielding significant effects, resulted in somewhat lower magnitudes of training effects (Schaie, 2005). It seems, then, that periodic reactivation of specific mental skills is likely to reduce the magnitude of intellectual decline in community-dwelling persons.

CONCLUSION

It was previously argued that there had been a turning away from studies that simply defined the extent and ability specificity of age differences and age changes in intelligence. Instead the field is turning toward a greater preoccupation with individual patterns of change and identification of antecedent variables that might account for the vast array of individual differences and the potentiality of preventing cognitive decline. Progress in the study of practical intelligence has also expanded the field in directions that have practical and social policy implications. Progress has also continued in identifying the social structure, health, and personality variables that influence individual differences in intellectual competence. No longer are contextual variables treated as methodological confounds; rather, increasing efforts are being made to identify the precise influences that will eventually predict individual hazards of intellectual decline and maintenance. Important theoretical efforts therefore have been directed toward replacing index variables, such as age or cohort, with more direct explanations of individual differences.

Findings presented in this chapter lead to the prediction that intellectual age differences in adulthood will become more compressed over the next decade because of the apparent plateauing of positive cohort differences for some abilities and the occurrence of negative effects for others. For example, a cross-sectional study using individuals aged 18–87 years found a positive relationship between age and individual intelligence (Hood & Deopere, 2002). It is quite likely, therefore, that future studies will provide a more optimistic picture for cognitive development in old age, at least until that point when physiological infrastructure and social support systems begin to crumble. Monitoring the cognitive development of the Baby Boom cohorts who are now in midlife as they reach old age is of great importance given the enormous and unique demographic pressures as well as the huge economic and policy impact affecting this group (Willis & Schaie, 1999a).

However, even more work is needed on the role of lifelong experience in the maintenance of intellectual functions and productive performance in societal roles. Information gathered with retrospective questionnaires indicates that the role of experience on intellectual development may be less than common sense would suggest (e.g., Salthouse & Mitchell, 1990). But the sparse relations found between age and job performance (Avolio & Waldman, 1990; Salthouse & Maurer, 1996) suggest that experience cannot yet be written off as an important source of compensation for loss of speed and cognitive efficiency. Furthermore, the context or act of learning needs to be explored. The effects of adults remaining in school longer (and with more adults returning to school at later ages) on intellectual development needs to be explored. Graham and Donalson (1999) found that adult learners, despite relatively less involvement in campus activities and more involvement in family caring, reported slightly higher levels of growth in academic and intellectual items than their younger counterparts. In addition, the effects of computer exposure on intellectual development need further exploration (see Subrahmanyam, Greenfield, Kraut, & Gross, 2001).

There is relatively little comparative work on intellectual aging within minority groups in the United States, and there is also a lack of cross-cultural comparisons of intellectual aging in other societies (see Dai, Xie, & Zheng, 1993). As reviewed in this chapter, surrounding environmental factors affect individual development. Life course sociologists have taken advantage of substantial environmental interventions (e.g., the Great Depression, farm crises, the Cultural Revolution) that may have differential effects on human development (e.g., Elder, Rudkin, & Conger, 1994). Adult cognitive psychologists have yet to emulate this useful approach in their work. One such example is Schaie, Nguyen, Willis, Dutta, and Yue's

(2001) investigation of intellectual aging in Chinese adults. They found a linear relationship within their sample between age and most primary mental abilities. They were also able to conclude that intellectual environment was related to individual abilities in their sample. Another study, also using a Chinese sample (Geary et al., 1997) found no computational or reasoning skill differences in older adults (60–80 years old) relative to U.S. performance. They did, however, find a difference in adolescents in favor of the Chinese sample. They concluded that the Chinese advantage was due to a parallel cross-generational intellectual decline in the United States and a cross-generational intellectual improvement in China, leaving older adults functioning at an equal plain between the two nations with adolescents functioning at different plains. Similar studies need to be done comparing and contrasting intellectual aging in ethnic groups that reside in the United States as well as adults of other nations, to explore unique antecedents and trajectories for intellectual development.

Further progress has been made in cognitive intervention work to show that intellectual decline in old age is not necessarily irreversible in all persons and that formal intervention strategies are available that might allow longer maintenance of high levels of intellectual function in community-dwelling older persons. The data on successful cognitive interventions have now been supplemented by evidence of positive long-term effects of these interventions. It is still necessary, however, to remove these techniques from the laboratory to a broader social context. This would require the implementation of clinical trials as well as the investigation of modes of intervention that are indigenous to the daily experience of older persons (such as games and other activities that may be cognitively challenging; e.g., Tosti-Vasey, Person, Maier, & Willis, 1992). Also needed are efforts to relate the effect of cognitive training to specific activities of daily living. An example of such an effort is the Advanced Cognitive Training in Vital Elderly (ACTIVE) project, a multiple-center clinical trial, using multiple modes of intervention that focus on training effects for perceptual speed, inductive reasoning, verbal memory, and everyday functioning (Ball et al., 2002). Preliminary results from this trial have shown positive cognitive training effects.

In addition to the existing literature, it is also necessary to explore biological antecedents for unique intellectual development. Kennet, Revell, and Schaie (1999; also see Schaie, 2005) found some indication that allele type may differentiate individual cognitive trajectories. There has also been some evidence from age comparative studies, using functional magnetic resonance imaging, that individuals of different ages may experience activation of different brain regions in response to the same cognitive tasks (Gaillard et al., 2000; Klingberg, Forssberg, & Westerberg, 2002; Tamm, Menon, & Reiss, 2002). Thus, there is additional need for exploration to answer whether there are neurological antecedents for intellectual development and whether intellectual development is to some degree genetically predetermined. These types of studies are also needed to examine whether there are cohort differences in the use of the brain or whether instead we may use our own brains differently with age for the same cognitive tasks.

With more individuals reaching old age and the resulting increase in the prevalence of neuropathological conditions, there is an urgent need for early detection of any risk for dementia. There has been much development and progress in the area of detection and diagnosis (i.e., Morris et al., 1989, 1993). The next step will be to extend this exploration into prevention and early detection, which can be provided through longitudinal cognitive studies. Schaie, Caskie, Revell, Willis, Kaszniak, & Teri (2005) have recently explored empirically the implementation of procedures that might allow early detection of risk for dementia prior to the appearance of clinically diagnosable symptoms or neuropathology. Using individual change in cognitive ability test performance, the researchers were able to successfully identify predictors of cognitive impairment (seven years preceding actual neuropsychological dementia ratings). Similar studies need to prospectively and retrospectively compare cognitive trajectories for individuals who develop cognitive impairment with trajectories of those who do not to assist in the prevention and early diagnosis of dementia.

The field of adult intelligence has matured from a descriptive science toward one that is increasingly concerned with the identification of precise mechanisms and the identification of antecedents for individual differences. The area has also progressed to the stage of interventions developed by findings from the basic sciences in the interest of improving intellectual competence in old age. With the continued compelling and functional research being conducted and with continual practical needs in the area of intellectual development, progress and growth in this substantial area appears promising and crucial.

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