TECHNOLOGY FOR ADAPTIVE AGING

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Cognitive Aging

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DEFINITION OF COGNITIVE AGING

Research on cognitive aging is concerned with the basic processes of learning and memory as well as with the complex higher-order processes of language and intellectual competence or executive functioning. Much of the literature in this field has been concerned with explaining the mechanism of cognitive decline with advancing age. However, there has also been pervasive interest in issues such as compensation and the role of external support including external aids as well as collaborative problem solving. The study of cognitive aging has followed two rather distinct traditions. The first grew out of experimental child psychology, whereas the second derived from psychometric roots that included the assessment of intellectual competence and development in normal and abnormal populations.

Experimental Study of Memory Functions and Language

The literature on memory functions and language has been concerned with the identification of potentially causal variables that might be responsible for the memory loss and decline observed in many older adults in complex manipulation of language variables such as text processing. Conventional approaches in this literature involve the design of experiments that test for the effects of single variables in carefully controlled laboratory settings and that require only a limited number of subjects. Because there is often little interest in individual differences or population parameters, study participants are typically drawn from convenience samples (McKay and Abrams, 1996). In addition, this literature includes primarily age-comparative studies (see below for the implicit methodological problems inherent in such studies). Hence, little is known from this literature regarding the extent of individual differences or major types of differential patterns of cognitive aging, nor is it clear how findings generalize to broader or specialized populations.

The literature described above may suggest many hypotheses that would be useful for designing technical aids that could compensate in general for age-related changes. However, the literature is as yet too limited to be helpful in determining typologies of age changes that may be needed for customization of devices for optimal individual use.

Descriptive Study of Adult Intellectual Development

Many studies of adult intellectual development originated from the longitudinal follow-up of samples that were first assessed in childhood or adolescence. Other studies, however, represent carefully stratified samples from defined populations, first assessed at a particular life stage, whether in early adulthood or in early old age. Descriptive studies often began as cross-sectional inquiries that were expanded into long-term longitudinal studies. Longitudinal data were required because the interest here is typically in the study of individual differences in intraindividual change, or in the identification of typologies of individuals who follow different growth trajectories. Such studies frequently involve large samples, and they typically employ correlational or quasi-experimental approaches (Baltes and Mayer, 1999; Schaie, 1996b). This literature will be particularly helpful in predicting characteristics of future older adults as well as to provide an understanding of different patterns of age changes.

METHODOLOGICAL ISSUES

Two major methodological issues in cognitive aging research are whether one should employ age-comparative (between participants) or age-change (within participants) designs and how investigators should address the role of response speed.

Age-Comparative Versus Age-Change Designs

The bulk of reported findings from the experimental cognitive aging literature is based on age-comparative studies that usually contrast a group of young adults (typically college students) with convenience samples of community-dwelling older adults in their 60s and 70s. How-

ever, it is often unreasonable to assume that the two age groups can be adequately matched for other status variables that might provide rival explanations for any observed age difference on the dependent variable of interest. This internal validity threat (cf. Campbell and Stanley, 1966) creates particular problems for identifying the mechanisms that may be implicated in age-related decline from young adulthood into old age. Age-comparative designs are also inadequate in explaining individual differences in intraindividual age changes. The latter can be investigated only by means of longitudinal paradigms (Schaie, 1965, 1996a). The internal validity of longitudinal studies, moreover, can also be impaired by failure to attend to issues such as participant attrition, impact of history, and reactivity (practice) effects.

Data from cross-sectional and longitudinal studies have rather different implications for guiding the design of compensatory devices or interventions. Figure 2-1 provides an illustration of this for the case of age differences and age changes from 25 to 81 years for a measure of verbal meaning

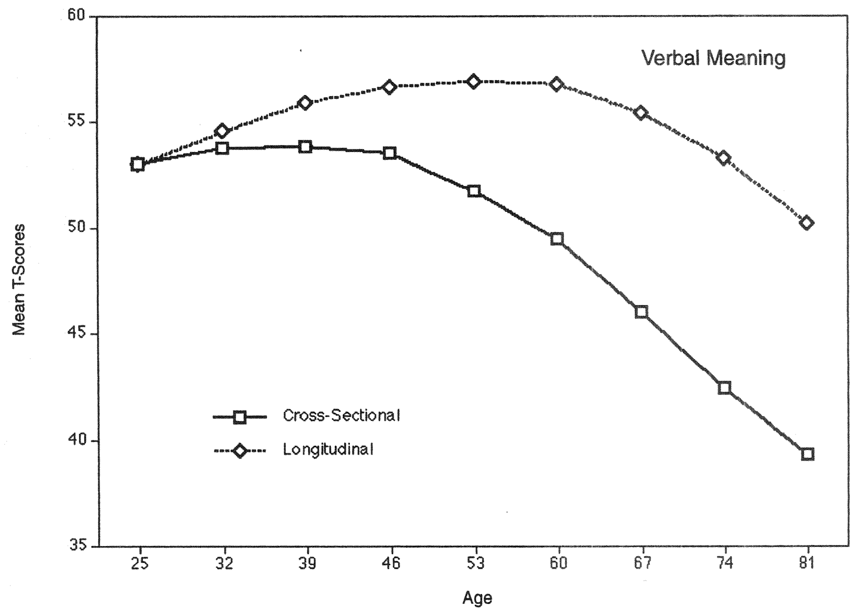

FIGURE 2-1 Comparison of cross-sectional age differences and longitudinal age changes on the Verbal Meaning Test. T-scores are standardized scores with a mean of 50 and a standard deviation of 10.
SOURCE: Adapted from Schaie (in press).

(vocabulary comprehension) from the Seattle Longitudinal Study (Schaie, in press; also see Schaie, 1996b). This figure shows steady negative cross-sectional differences from young adulthood to old age. However, the longitudinal (within-persons) data suggest that verbal meaning increases until late middle age and shows only modest decline thereafter. These findings can be interpreted to suggest that there is little age-related decline in verbal comprehension; but they also suggest that older persons may benefit from simplified (less esoteric) language in instruction manuals. Current older adults may be impacted by technological obsolescence that may not similarly impact future cohorts of older adults. In other words, cross-sectional data can be used to determine current differences in performance level for different age groups, but longitudinal data are required to predict within-individual changes with age.

The Role of Response Speed

Several theorists have suggested that general changes in the central nervous system are the primary common cause for the observed age-related declines in cognitive performance. An unbiased marker of such change might be the commonly observed increase in simple reaction time. Many published analyses show a substantial reduction in age differences, if some measure or measures of reaction time or perceptual speed is partialled out of the relation between measures of a cognitive process and chronological age (Madden, 2001; Salthouse, 1999). The average increase in many measures of reaction time is a factor of approximately 1.6 from the early 20s to the late 60s (Cerella, 1990). However, it is not clear whether the observed average increase in reaction time, although reliably demonstrable in the laboratory, is of significance in many or most tasks of daily living. Nevertheless, it is critical therefore in cognitive aging studies to disaggregate changes in speed of response from changes in accuracy of performance (cf. Willis, 1996; Willis and Schaie, 1986).

The literature also has many findings of a trade-off between accuracy and speed (cf. Ketcham and Stelmach, this volume; Salthouse, 1999). Given the need for accuracy in programming compensatory devices, it might therefore be desirable to increase response windows to facilitate better performance by individuals whose speed of reaction time has declined.

The Role of Individual Differences

Although empirical findings on age differences or age changes suggest virtually linear declines for many cognitive functions, it is difficult to reproduce linear decline patterns at the individual level. Indeed, it appears that there are many different aging patterns of which linear decline

may be only a sparsely represented phenomenon. More common are stairstep patterns that reflect decline occurring in response to an unfavorable event (perhaps severe physiological insult or the loss of a spouse) followed by a period of stability at a lower level, with further decline upon the occurrence of other unfavorable events (cf. Schaie, 1989).

It has been shown that a significant percentage of individuals will remain stable over a 7-year period even at advanced ages and that a small percentage of individuals will even show a significant increase in performance levels. Figure 2-2 shows the percentage of community-dwelling individuals declining, remaining stable, or showing an increase in performances from ages 60 to 67, 67 to 74, 74 to 81, and 81 to 88 on the Verbal Meaning Test. Although there is a modest increase in the percentage declining over each older 7-year span, the largest proportion remains stable even into an advanced age (Schaie, in press; also see Schaie, 1989).

Recent advances in multilevel analyses and growth curve modeling provide new and exciting tools for the identification and analyses of typologies of cognitive aging patterns (cf. Rudinger and Rietz, 2001).

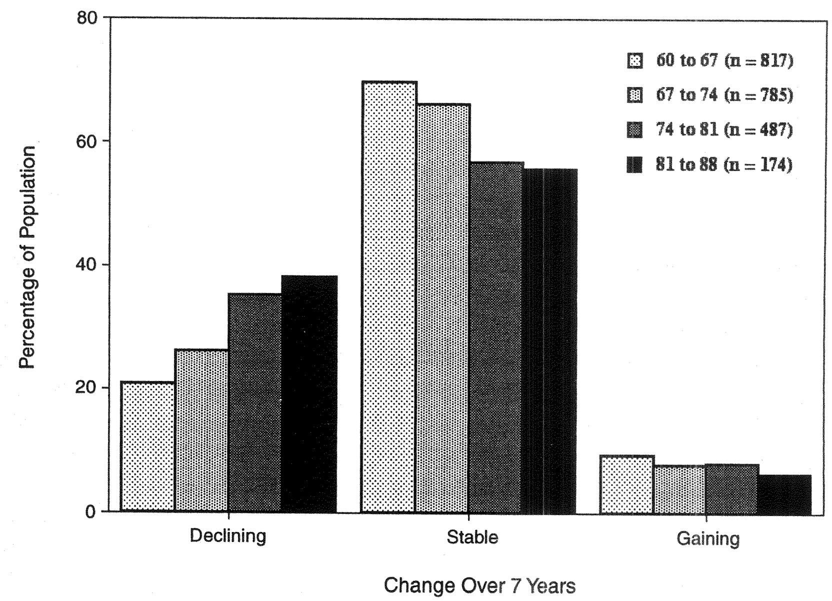

FIGURE 2-2 Percentage of individuals who decline, remain stable, or gain significantly on the Verbal Meaning Test (criterion for significant decline or gain is ±1 standard error of measurement).
SOURCE: Adapted from Schaie (in press).

Sensory-Perceptual Limitations in Older Adults

An important meta-issue in the study of aging and cognition addresses the extent to which the decline in cognitive processes in older adults can be attributed to changes in peripheral sensory functions. I briefly review here some of the major age-related declines in sensory-perceptual processes that aging researchers need to consider. For more extensive reviews, the reader is referred to Fozard and Gordon-Salant (2001) or Schieber (2003).

Vision

Anatomical changes. The size of the pupil declines with advancing adult age (*senile miosis*), and the lens becomes more opaque. This loss of transparency is particularly pronounced at short wavelengths (e.g., for blue light). Lenticular opacity and reduced pupil size result in less retinal illumination. Almost half of those over 65 years of age have sufficiently reduced lenticular transparency to be diagnosed as having cataracts. There is also some evidence of age-related photoreceptor and ganglion cell loss. Macular degeneration and glaucoma also impair vision in significant numbers of older persons.

Visual acuity. This is the indicator of how well fine spatial detail can be recognized. A distinction is made between near and far acuity. By age 40, difficulty is experienced focusing on printed text that is closer than about a foot, and by age 60 it becomes difficult for most people to focus on objects located within 3 feet. Decreases in both near and far acuity until around age 70 are usually due to refractive errors that can be corrected with eyeglasses or contact lenses. However, visual difficulties that remain after wearing eyeglasses increase sharply in the late 70s and 80s. Impaired visual acuity among those in the oldest groups is attributable to greater prevalence of diseases of the retina. Age-related deficits in visual acuity become more severe when there is low luminance or low-contrast stimuli. Figure 2-3 shows the age-related increase in the percentage of people requiring correction for visual defects and the percentage of those who suffer from cataracts, glaucoma, or other visual impairments (National Center for Health Statistics, 1994).

Dark adaptation and glare. Changing the level of illumination results in a significant reduction in visual sensitivity. There is some age-related slowing in the rate of dark adaptation, and older adults have more difficulty throughout the dark adaptation cycle. The rate of loss is greater for short-wavelength light (i.e., blue, green) due to the age-related yellowing of the lens.

Age-related decrements in visual function are also observed when glare is present. The aging lens scatters light across the retina decreasing the contrast of the retinal image. Visual difficulties due to glare increase

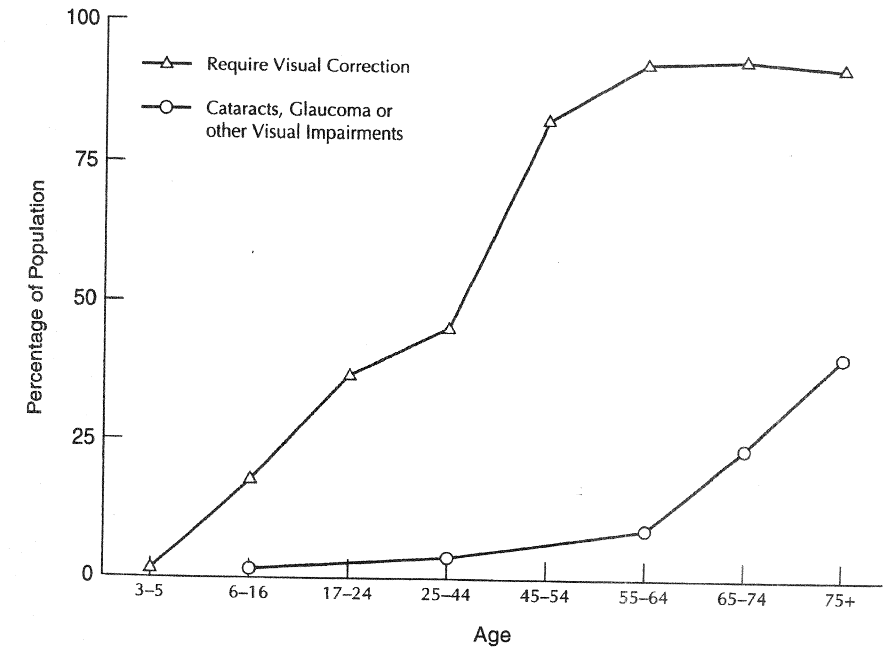

FIGURE 2-3 Percentage of people requiring corrections for visual defects and percentage of those who suffer from cataracts, glaucoma, and other visual impairments.
SOURCE: Schaie and Willis (2002); adapted from National Center for Health Statistics (1994).

markedly for low-contrast stimuli, and recovery time for lost visual sensitivity in response to glare also increases.

Color vision. Small age-related declines have been found in the ability to distinguish between similar hues past age 70. This phenomenon has been attributed to a differential loss of sensitivity in short-wavelength photoreceptors. Difficulties in color vision are greater under low light conditions, and age differences in blue-green color discrimination can be reduced at high levels of illumination. Color constancy mechanisms remain relatively intact in older adults, possibly minimizing performance decrements on real-world tasks.

Motion perception. Age-related decrements have been found in motion sensitivity and accuracy of speed perception although the nature and magnitude of these effects vary across different investigations. It has been suggested that these age-related losses may be mediated by neural rather than optical mechanisms. There are also age differences in thresholds for the detection of motion, as well as age differences in the ability to judge the apparent speed of automobiles (Fozard, 2000; Schieber, 2003).

Hearing

Anatomical changes. Changes in the outer ear include accumulations of earwax that block the auditory canal and a narrowing of the auditory canal. The joints connecting the bones of the middle ear often become less elastic with advancing age. In the inner ear there is age-related loss in the number of hair cells. This loss occurs principally among hair cells transmitting high frequencies. There is also an age-related reduction in the number of neurons in the auditory nerve and the auditory cortex.

Auditory sensitivity and discrimination. Age-related loss of sensitivity (presbycusis) particularly affects high-frequency sounds, requiring greater stimulus intensity for detection of a sound. Age-related hearing loss is more prevalent in males than in females in the current older population. This phenomenon has often been attributed to gender differences in workplace noise exposure. Loss of sensitivity proceeds at a pace of about 1 dB per year after age 60 and at 1.5 dB per year after age 80 in both genders.

Age-related decrements have also been found in the ability to discriminate small changes in the frequency or intensity of sounds during speech recognition and sound localization. Older adults are less able to discriminate between similar sounds that differ slightly in intensity or frequency. Age-related difficulties in frequency discrimination are greater with very brief tones, i.e., older persons in conversations have greater difficulty processing phonemes than syllables. There is also increasing difficulty in discriminating the arrival of sounds, especially for low-frequency sounds.

Speech recognition. Speech recognition for monosyllabic words at normal conversational levels has been found to decrease from almost 100 percent correct at age 30 to less than 60 percent correct for those 80-89 years of age. Particularly severe age-related decrements in speech intelligibility occur when there is background noise, echo, and time compression. Figure 2-4 shows the percentage decrement in speech intelligibility under various conditions from the 20s to the 80s (Bergman et al., 1976).

There is a question as to the relative contribution of peripheral versus central mechanisms in these decrements. Remediation of decrements in speech perception due to sensory factors would require interventions in signal processing, whereas decrements due to cognitive deficits would need to be addressed by comprehensive training approaches (see below). Decrements in understanding speech are lessened when stimulus intensity levels are increased and when speech stimuli are presented within "sentence" or "paragraph" contexts.

Advances in hearing-aid technology provide many ways of compensating for a variety of the hearing problems described above. However, the increasing miniaturization of these devices poses additional problems for

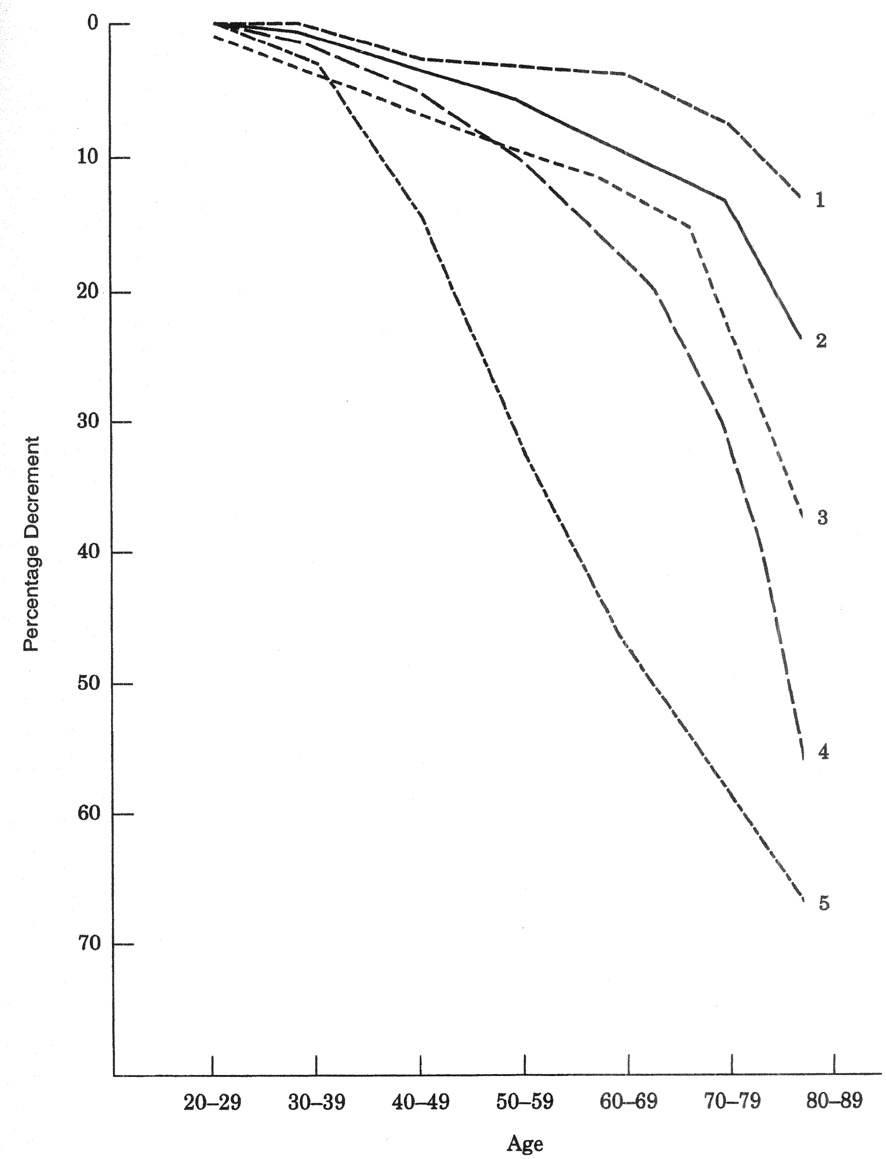

FIGURE 2-4 Percentage decline in speech intelligibility for various ages and listening conditions. Conditions are (1) normal speech; (2) speeded speech, twice the normal rate; (3) selective listening, tracking one speaker of many, as at a cocktail party; (4) reverberated or echoed speech, as in a hall with unfavorable acoustics; and (5) interrupted speech, as with a poor telephone connection.
SOURCE: From Bergman et al. (1976), reproduced by permission.

frail elders. Individual programming of the devices becomes increasingly difficult due to accompanying declines in vision and manipulation of very small objects. Technology will therefore be needed that provides for far more user-friendly methods to fine-tune hearing aids than are currently available.

BASIC FINDINGS FROM THE EXPERIMENTAL LITERATURE ON COGNITIVE AGING

Much of the literature on cognitive aging is cross sectional in nature and frequently includes convenience samples of young adults (often sophomore psychology students) that are compared with other community-dwelling older adults (often participants in adult education programs). The major findings from this literature regarding age differences in cognitive performance include memory, attention, and language.

Memory

Older adults are currently thought to be at a disadvantage in retrieving information from memory when the information to be retrieved is complex and when there are few cues or other environmental supports. Hence, age differences are far greater in recall than in recognition of information. The magnitude of age differences in memory is also thought to be far greater when a task involves effortful processing than when automatic processing is involved. Hence, greater age differences have been found for explicit than for implicit or automatized and overlearned memory (such as responses needed to drive an automobile). Older adults seem to have greater difficulty in integrating the context of information they are trying to remember. Moreover, working memory capacity (that is, the information that is immediately accessible) becomes reduced with increasing age. But there is little evidence for age differences in long-term storage. Memory deficits occurring with age include nonverbal tasks such as memory for spatial location, memory for faces, and memory for actions and activities. Studies of prospective memory (i.e., remembering something to be done in the future) suggest that older people do well in remembering simple and event-based tasks, but are at a disadvantage when tasks become complex or are time-based. In sum, it appears that age differences are known to increase in magnitude as a function of the processing requirements of a given task (Bäckman, Small, and Wahlin, 2001).

Attention

Another recent body of research has considered the role of attention in explaining age differences in other cognitive processes. Attentional

processes are implicated whenever individuals engage in multitasking or time-sharing activities. Examples of the consequence of age-related attention deficits can be found in research on inhibition, reading comprehension (see below), and many everyday activities that may be affected by age-related deficits in the ability to attend simultaneously to multiple tasks (e.g., Schieber, 2003; West, 1999; Zacks and Hasher, 1997). On the other hand, attention deficits have not been found to underlie age differences in episodic memory that involve remembering items associated with a specific time or place (Nyberg, Nilsson, Olofsson, and Bäckman, 1997). Age-related differences in attention may also be implicated in executive functioning, the ability to put things together on the basis of several items of information. One example would be considering the price and utility of a computer system in making a purchase decision (cf. Kramer, Larish, Weber, and Bardell, 1999).

Although some of the most exciting research in this area is the exploration of neurological bases for attention processes, there are also many practical applications in areas such as aging and technology use (cf. Rogers and Fisk, 2001).

Language

Age-related differences in language behavior are closely related to the processes of encoding and retrieving verbal materials as discussed above. In addition, there are greater age differences in textual tasks that involve recent connections than in those that involve recollection of older connections. Language production is adversely affected in older adults under intense time pressure. Word-finding difficulty (the interesting tip-of-the-tongue phenomenon), however, seems to be more likely with infrequently used words. Significant age differences have also been found in planning what one intends to say and how to say it during language production. Older adults are therefore more likely to hesitate, have false starts, as well as to engage in repetitions. Age-linked deficits in story recall may be more of a general deficit in connection formation than in specific communication ability. Older adults tend to benefit from textual material that provides priming of associations because it contains learned semantically linked information (McKay and Abrams, 1996). On the other hand, certain aspects of language processing seem to be relatively age invariant. These include particularly lexical access and semantic memory, which are resistant to normal aging, even though they are affected by Alzheimer's disease (Kemper and Mitzner, 2001).

Recent research on language and aging has also included applications of basic research knowledge to the development of guidelines for consumer standards and for electronic communication (cf. Charness, Park, and Sabel, 2001; Park, Nisbett, and Hedden, 1999).

BASIC FINDINGS FROM THE DESCRIPTIVE LITERATURE ON AGE CHANGES IN INTELLECTUAL COMPETENCE

Included here are findings from two rather different traditions. The first originated early in the history of psychology when the research on mental testing in children was extended to normal adults and older adults. The second tradition, now represented by the field of neuropsychology, originated with the clinical interest in assessing cognitive impairment and in diagnosing various forms of dementia.

Normal Populations

Investigations of the course of intellectual competence over the adult life span in normal populations has been dominated by research either with the Wechsler Intelligence Scale or with ability batteries derived from the Thurstonian Primary Mental Ability framework (Schaie, 1996b; Schaie and Hofer, 2001). A primary distinction is often made between fluid abilities, thought to be innate, and crystallized abilities, which involve the utilization of culturally acquired knowledge (Cattell, 1963). Further distinctions have been introduced more recently between the mechanics (or basic processes) of intellectual competence and the pragmatics that involve cultural mediation (Baltes, Dittman-Kohli, and Dixon, 1984).

Most longitudinal studies have found that the adult life course of mental abilities is not uniform. The fluid abilities (sometimes defined as cognitive mechanics or primitives) tend to peak in early midlife and begin to decline by the early 60s. Crystallized abilities that represent abilities acquired in a given cultural context (particularly verbal abilities), by contrast, do not usually peak until the 50s are reached and begin to show significant decline only in the 70s and often show only minimal decline even in the 80s (Schaie, 1996a). But with advanced age, increasing convergence and steeper decline for both aspects of intellectual competence may occur, probably caused by the increasing decline of sensory and central nervous system functions (Baltes and Lindenberger, 1997; Baltes and Mayer, 1999). Figure 2-5 provides longitudinal data on six cognitive abilities illustrating differences in average decline patterns for the different abilities.

Cross-sectional snapshots, obtained at a particular time, may yield very different ability profiles because of the fact that consecutive population cohorts reach different asymptotes in midlife. For the six abilities whose age trajectories are shown in Figure 2-5, the cumulative magnitude

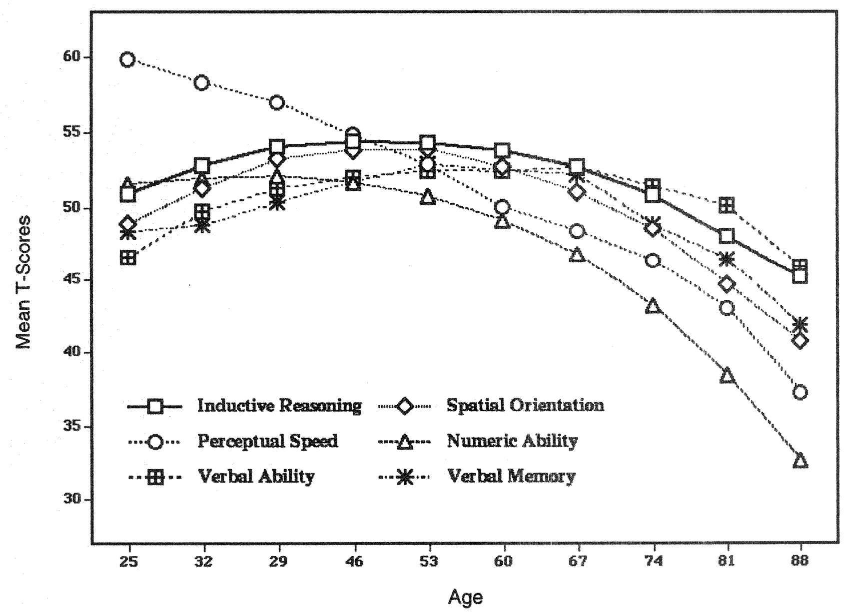

FIGURE 2-5 Longitudinal age changes from 25 to 88 years on six cognitive abilities. T-scores are standardized scores with a mean of 50 and a standard deviation of 10.
SOURCE: Schaie (1996a).

of the individual 7-year cohort differences are presented in Figure 2-6. For example, for the time frame shown there has been a positive linear cohort trend for inductive reasoning, the basic component of most problem-solving tasks, whereas there has been a negative trend in numeric skills. The magnitude of cohort differences in abilities over the past half-century has been comparable to the average age changes observed from young adulthood into the 70s (cf. Flynn, 1987). In the presence of positive cohort changes, older adults may appear to have declined markedly in comparison with their younger peers, even though they have not declined at all but simply attained a lower asymptote in young adulthood. Likewise, when there are negative cohort differences, older adults may compare favorably with their younger peers even when they are functioning below their earlier levels of performance (Schaie, 1996a; Schaie and Hofer, 2001).

Investigations of individual differences suggest that most persons have declined on some aspect of intellectual functioning from their own midlife peak as the 60s are reached. But specific patterns of decline may well depend on complex patterns of individual life experience. Most

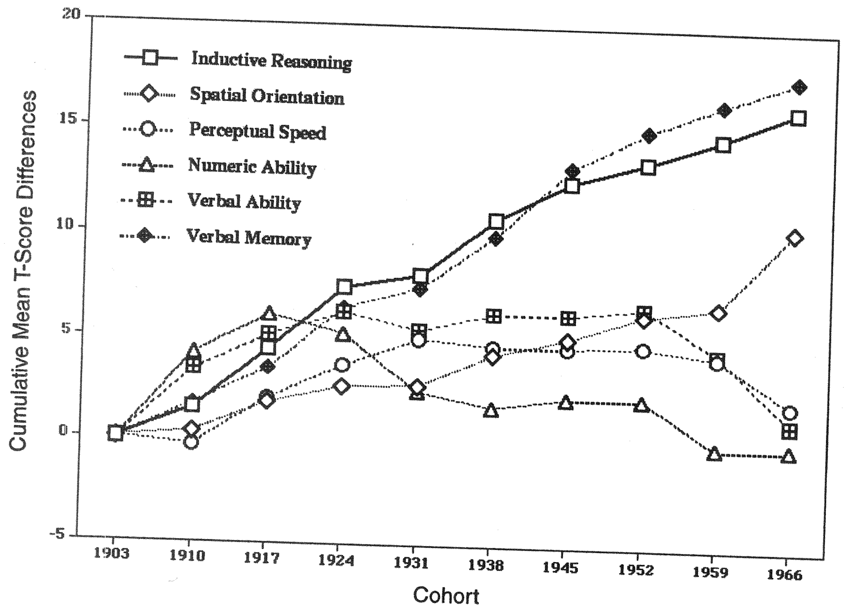

FIGURE 2-6 Cohort differences on six cognitive abilities for cohorts born from 1903 to 1966. T-scores are standardized scores with a mean of 50 and a standard deviation of 10.
SOURCE: Schaie (1996a).

healthy community-dwelling persons are able to maintain a high level of function until an advanced age (but see Baltes and Mayer, 1999, for the consequences of sensory dysfunctions). Because most tasks of daily living represent complex combinations of basic cognitive processes, many individuals can maintain their abilities above the minimally necessary threshold level for independent functioning by engaging in compensatory processes that may often be quite complex (cf. Baltes et al., 1984; Baltes and Mayer, 1999).

Neuropsychological Assessments of Normal and Cognitively Impaired Individuals

Measures used for neuropsychological assessment have also originated from the psychometric tradition (e.g., subtests from the Wechsler Memory Scales often form important components of neuropsychological assessment batteries). However, many measures designed for the identification of cognitive impairment and the diagnosis of the dementias are not particularly suitable for the study of cognitive aging because they were

developed specifically to identify neuropathology. Hence, variability on these measures among cognitively unimpaired individuals may be quite limited, and such measures may therefore be less than ideal for the study of cognitive aging (cf. Lezak, 1995). This is unfortunate, for advances in prevention approaches to dementia may very well require the early detection of persons at excess risk for the eventual detection of dementia. This would require tests sensitive enough to detect small deviations from normal scores or subtle changes over time within individuals. Because of the age-related increase in the incidence of preclinical cognitive impairment, the detection of such individuals is of special interest to obtain better estimates for normal age changes.

Research is in progress in my laboratory to extend a neuropsychological battery into the primary mental ability space so as to facilitate the use of assessment instruments with wider ranges that are suitable for younger adults for the purpose of early detection of cognitive impairment (Schaie et al., in press).

DECISION MAKING AND PROBLEM SOLVING

An important extension of the research in cognitive psychology has been in the direction of going beyond the laboratory to the environmental context within which individuals solve problems of daily living and make consequential decisions. The decisions to be made are usually goal directed; in older adults, these decisions are related to instrumental activities of daily living and maintenance of independence (Schaie and Willis, 1999; Willis, 1996). Such decisions include management of one's medication regime and decisions about one's financial affairs. Antecedents of successful decision making in older adults have been identified as good physical health, adequate levels of functioning on basic intellectual skills, tolerance for ambiguity, as well as realistic beliefs about ways of knowing. Lessened tolerance of ambiguity in older adults has been noted to affect medical decision making in that older adults act more quickly to reduce ambiguous situations (Leventhal, Leventhal, Schaefer, and Easterling, 1993).

The problem-solving process involves task characteristics and knowledge systems. In older adults, task novelty can have a negative influence on effective problem solutions, as does task complexity and lack of task structure. Also of importance is the availability of declarative knowledge that is relevant to a particular decision. Older individuals tend to make critical decisions with less information than young or middle-aged adults (for an example of decision making and aging with a breast cancer scenario, see Meyer, Russo, and Talbot, 1995).

Decision making may also be affected by age-related processing styles. Youthful styles involve a bottom-up approach that involves intensive data gathering. Recourse must be had to formal integrated knowledge bases in order to compensate for a lack of personal experiences. The mature middle-aged style balances data gathering with the integration of accumulated experience. By contrast, the style of the older adult is to use acquired knowledge sometimes indiscriminately and inappropriately by applying heuristics that have worked well in the past (cf. Sinnot, 1989).

CAN COGNITIVE AGING BE SLOWED OR REVERSED?

Cognitive training programs have been developed in a number of laboratories (primarily in the United States and Germany). They have been applied in the laboratory, and more recently in cooperative multisite intervention trials (cf. Ball et al., 2002). Unlike training young children, where it can be assumed that new skills are conveyed, older adults most often have had access to the skills being trained, but have lost their proficiency through disuse. Information from longitudinal studies is therefore useful in distinguishing individuals who have declined from those who have remained stable. For those who have declined, the training objective involves remediation of loss. But for those who have remained stable, enhancement of previous levels of functioning is intended to compensate for possibly cohort-based disadvantages of older persons (cf. Willis, 2001).

Findings from cognitive intervention studies suggest that cognitive decline in old age, for many older adults, might be attributed to disuse rather than to the deterioration of the physiological or neural substrates of cognitive behavior. For example, a brief 5-hour training program for persons over age 65 resulted in average training gains of about 0.5 standard deviation on the abilities of spatial orientation and inductive reasoning. All study participants had been followed for 14 years prior to the intervention. Approximately half had remained stable and half had shown significant decline.

Of those participants for whom significant decrement could be documented over a 14-year period, roughly 40 percent were returned to the level at which they had functioned when first studied. Figure 2-7 shows findings by gender for the percentage of individuals who showed significant training gain, as well as the percentage whose performance was raised to the level they had achieved 14 years earlier (cf. Schaie, 1996a; Willis and Schaie, 1994).

The analyses of structural relationships among the ability measures prior to and after training further allow the conclusion that training does not result in qualitative changes in ability structures and is thus highly specific to the targeted abilities. A 7-year follow-up study further demonstrated that those subjects who showed significant decline at initial training retained a substantial advantage over untrained comparison groups

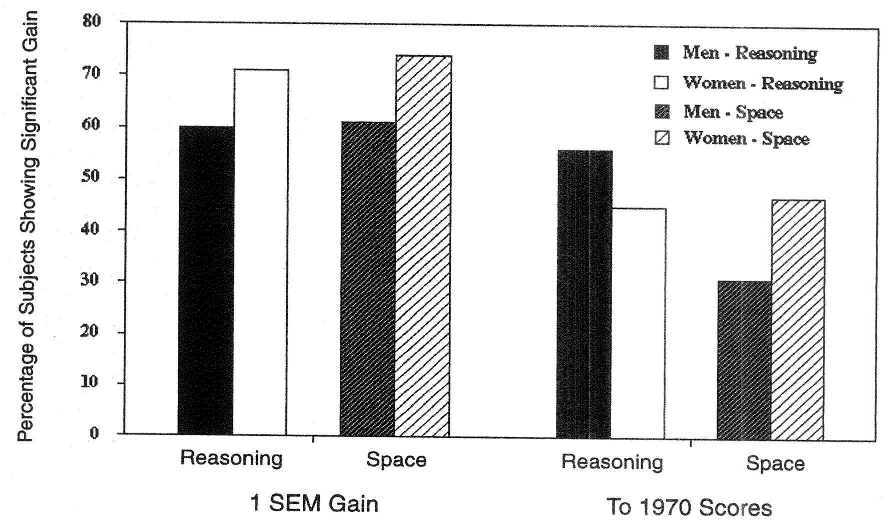

FIGURE 2-7 Percentage of study participants with significant training improvement of ±1 standard error of measurement (SEM) and with return to ability levels 14 years prior to the training intervention.
SOURCE: Schaie (1996a).

(Willis and Schaie, 1994). It should be noted, however, that although cognitive training may improve performance in older adults and may function to reduce effects of age decrement, such training will also be effective in enhancing the performance of young adults, so age differences tend to remain robust (cf. Baltes and Kliegl, 1992).

Many technologies that promise to compensate for age-related changes in behavioral efficiency will also require the increased utilization of cognitive skills that have become "rusty" through disuse. Cognitive training paradigms may therefore be helpful in enhancing the cognitive infrastructures required for the successful utilization of complex technology.

OTHER RELATED TOPICS IN COGNITIVE AGING

Research on cognitive aging in the past has been largely concerned with age-related aspects of the development of the basic processes of cognition. It should be recognized that the current focus in the study of cognitive aging is beginning to turn to the determination of how these basic processes operate within more complex domains. Of particular interest here are the study of wisdom and creativity (e.g., Baltes and Staudinger, 2000; Sternberg and Lubart, 2001), the application of basic cognitive processes to social cognition (e.g., Staudinger, 1998), and the development of software expert systems (e.g., Charness and Bosman, 1990). Although the extensive literature on these topics is beyond the scope of this chapter, it should be noted that this is the area of cognitive content where older adults often compare relatively well with the young whenever content is examined that was present in the life experience of older adults.

FUTURE DIRECTION

It is to be expected that much future research in cognitive aging will be directed toward detecting the neural substrates of cognitive processes over the adult life span. An essential element of such research, however, will be to attend to change over time within individuals, as much of what has been done thus far is largely limited to cross-sectional studies (Albert and Killiany, 2001). Similarly, we are just beginning to see longitudinal data emerging on the traditional measures of memory and executive functioning (cf. Bäckman et al., 2001).

To apply much of the basic knowledge on cognitive aging to everyday behavior and human factors considerations involved in the better utilization of modern technology (cf. Schaie and Charness, 2003), we still need to obtain a better understanding of the relationship between basic cognitive processes and everyday function. Similarly, further research will be needed to determine how interventions designed to enhance basic cognitive processes will express themselves in improving effective functioning on complex processes. And above all, far more attention needs to be paid to individual differences in adult cognitive development so that we can move beyond the naive notion that a single grand scheme can account for the behavior of all.

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