In K.W. Schaie (Ed.),
ANNUAL REVIEW OF GERONTOLOGY AND GERIATRICS
Volume 7, 1987

New York: Springer.

The Role of Experience in Cognitive Aging

TIMOTHY A. SALTHOUSE
SCHOOL OF PSYCHOLOGY
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA

Although it is generally expert rather than novice levels of performance that are the most esteemed in society, expertise has been a largely neglected dimension of human performance. In fact, most psychological researchers deliberately attempt to eliminate the effects of prior experience in their evaluations of an individual's capabilities by utilizing novel and unfamiliar tasks and materials. Although this experience-minimizing strategy has a long tradition in psychology (dating at least to Ebbinghaus and the invention of nonsense syllables) and has influenced the development of numerous psychometric tests of cognitive functioning, it can be considered somewhat misdirected and possibly even perverse from the perspective of ecological validity because the effects of experience are frequently orders of magnitude greater than the performance differences observed across individuals at the same level of experience. At minimum, therefore, researchers interested in individual differences in behavior should be familiar with the nature of the variations in performance attributable to experience and, ideally, should be cognizant of how those experience effects interact with the individual difference of interest. The present chapter addresses these issues with reference to individual differences in cognition associated with increased age in adulthood.

At the outset it is important to clarify how the terms *expertise*, *experience*, *practice*, and *training* will be used in the present context. Basically, expertise is viewed as the extremely high levels of skill in a given activity domain that sometimes occur as a consequence of experience, and practice and training are interpreted as systematic ways of providing that experience. Training is usually distinguished from practice in that there is an attempt to control the nature of the

This chapter was written while the author was supported by an NIA Research Career Development Award (K04 AG00146-01A1). I would like to thank Neil Charness and Bill Hoyer for thoughtful comments on an earlier draft.

experience acquisition in training situations, whereas there is little direction or control in practice situations; but they are similar in that both try to manipulate the quality or quantity of relevant experience received by an individual.

Conceptualizing experience in this task-specific, or at least domain-restricted, manner has the advantage of allowing at least a theoretical separation of the effects of age and the effects of experience. This potentially important distinction has been blurred when experience has been interpreted in very general terms, almost as if it were synonymous with time or age. It is extremely difficult to determine the cognitive effects of something as ill-defined as life experience, but it does seem feasible to examine the consequences on cognition of experience with a specific activity. Moreover, only in the latter case is it practical to ask questions about the reciprocal influences on cognition of age and experience.

The chapter is organized into six distinct sections. The first is simply a brief overview of basic research on expertise with unselected populations, that is, individuals from a broad variety of backgrounds and individual-difference groupings. The second section consists of an examination of the classical distinction between cognitive abilities that do and do not exhibit declines with increased age from the perspective of a contrast between novice and expert levels of performance. Practice effects in studies of aging are reviewed in the third section, with practice referring both to specific intervention manipulations and to the effects of mere repetition. Studies of the effects of age in actual occupational activities are discussed in the fourth section, including the limitations of this type of research for the purpose of investigating the role of experience in cognitive aging.

The fifth section of the chapter is devoted to discussing a promising new approach for investigating experience effects termed the Molar Equivalence–Molecular Decomposition Strategy. This strategy differs from earlier approaches in that the focus is not on the examination of age differences in adults with comparable amounts of experience but instead on the determination of how people of different ages, and presumably different amounts of relevant experience, accomplish the same overall level of performance. The final section in the chapter consists of a discussion of alternative conceptualizations of the relations between age and experience. Of particular interest is whether experience should be considered a causal factor contributing to observed age differences in cognitive performance, or whether experience is best conceptualized as a dimension limiting potential generalization of results obtained in laboratory settings.

BRIEF OVERVIEW OF EXPERTISE RESEARCH

The fundamental question of concern in most research on expertise is, in what way do experts and novices differ that allows the former to achieve such dramatically better levels of performance than the latter? Answers to this question obviously vary across activity domains, and in only a few domains are the answers yet definitive. Nevertheless, some very intriguing findings have emerged from research in this area, and a few of these results will be briefly summarized here to lay a foundation for the subsequent discussion of the joint effects of age and experience.

It is certainly not surprising that research has revealed that expertise in a given domain is associated with more extensive declarative (factual) and procedural (action or "how to") knowledge relevant to that domain. However, recent discoveries have revealed that this knowledge is also better organized in experts than in novices and that there appear to be more automatic connections between the perceptual or pattern-recognizing processes and the procedural or response processes among the more skilled individuals in a given domain.

Evidence for these inferences derives from a variety of sources. For example, experts in physics (Chi, Feltovich, & Glaser, 1982), mathematics (Schoenfeld & Herrmann, 1982), and computer programming (Adelson, 1981, 1984) have been found to sort or group domain-relevant items according to underlying "deep-structure" principles, whereas novices rely on more superficial "surface" features. It has also been reported that the internal representations of expert problem solvers are more principled and structured than those of novices (e.g., Chase & Chi, 1981; Chi, Feltovich, & Glaser, 1981; Chi & Glaser, 1980; Greeno, 1980; Voss, Tyler, & Yengo, 1983), thereby leading more directly to appropriate action sequences. And finally, there are numerous demonstrations that experts in an area are superior to novices in recalling domain-specific material but no different in recalling material that is not organized or structured according to the conventions of that area. This result, which has been interpreted as indicating that the expertise is associated with a facilitation of the encoding of domain-specific information, has been reported in studies of chess (Chase & Simon, 1973; Chi, 1978; DeGroot, 1978; Frey & Adesman, 1976; Lane & Robertson, 1979), bridge (Charness, 1979; Engle & Bukstel, 1978), music (Halpern & Bower, 1982), the game of go (Reitman, 1976), and with technical electronic drawings (Egan & Schwartz, 1979).

It is important to note that the effects of practice or expertise are not restricted to complex higher-order activities, because substantial practice effects have been reported in tasks as elementary as memory span (e.g., Ericsson, 1985), signal detection, perceptual discrimination, and choice reaction time (Salthouse & Somberg, 1982). In fact, beneficial effects of experience seem to be so pervasive that it has been suggested (Salthouse, 1985, Chap. 5) that they can be found in nearly all stages or components of information processing that have been identified. To the extent that this is true, the study of the effects of extensive experience and expertise has obvious implications for investigating individual differences in information processing. The remaining sections of the chapter contain discussions of some of these implications for the variable of age in adulthood.

DOES EXPERIENCE PRODUCE CRYSTALLIZED KNOWLEDGE?

From the very earliest systematic investigations of adult age differences in cognitive functioning, researchers have made distinctions between intellectual abilities that exhibit rather dramatic age-related declines and intellectual abilities that either do not decline, or may actually increase, across adulthood. (See Table 4.1 in Salthouse, 1982, for illustrations of some of the terminology used to characterize this contrast.) The most popular terms in recent years have been the labels *fluid* and *crystallized* (e.g., Cattell, 1972; Horn, 1982; Horn & Cattell, 1967), with fluid abilities assumed to decline with age and crystallized abilities assumed to at least be maintained, or possibly even increase, with age.

Examination of the types of tasks postulated to assess the age-stable or age-increasing crystallized abilities suggests that, for the most part, what is being evaluated are the products of earlier processing, or what might be termed the crystallized residue of prior experience. For example, tests of vocabulary, factual knowledge, remote associations, or analogies based on esoteric information have been used as indices of an individual's level of crystallized ability, and all of these are clearly dependent on the quantity and quality of one's past experiences. Because increased age is generally associated with greater amounts of experience, it is certainly not surprising that performance on tasks dependent on experience does not decline with increased age (at least not until the typical retirement age of 65 to 70). In fact, the most puzzling aspect of the relation between age and crystallized abilities seems to be why, in light of the greater experience of older adults, there are so few reported increases in crystallized ability across adulthood. That is, if crystallized abilities primarily depend on cumulative experience, and if adults in their 60s have had about 40 more years of experience than adults in their 20s, why are the former not markedly superior to the latter in the performance of experience-dependent tasks rather than merely performing at roughly comparable levels?

At least four hypotheses can be advanced to account for the general failure to find more pervasive age-related increases in crystallized abilities. One hypothesis is that decreases in the efficiency of fluid ability processes presumed to be responsible for the effective conversion of experience into knowledge more than offset the increases attributable to greater experience. This hypothesis is clearly plausible because considerable research seems to support the idea that fluid abilities experience fairly substantial age-related declines, but at present one can only speculate about the specific correspondence between the benefits of increased experience and the costs of impaired efficiency of fluid abilities.

A second hypothesis, first proposed by Hebb (1942), is that there is a threshold level of experience relevant to performance on tests of crystallized abilities, and that once that threshold is exceeded, further increments in experience do not contribute to increases in performance. This interpretation seems reasonable if one assumes that the pool of potential information to which one is exposed (or from which relevant test items are sampled) is finite and relatively small. However, the existence of the well-publicized "information explosion" in contemporary society tends to weaken the credibility of the finite-knowledge assumption, and thus the hypothesis, at least in its strong version, should probably not be considered very tenable at the present time.

The third hypothesis to account for the failure to discover more age-related increases in crystallized abilities is that after a certain amount of knowledge has been acquired, further knowledge results in a higher level of abstraction and is not necessarily reflected by increments in measures designed to assess quantity of information. For example, Horn (1982) suggested that "improvements in . . . [crystallized ability] . . . probably reflect individuals' restructurings of their knowledge systems to make the knowledge increasingly more cohesive, correct, and accessible" (p. 266). Birren (1969) also speculated that ". . . with increased experience the adult forms broader concepts . . . [and consequently] . . . the adult, as he grows older, may be able to deal with his environment on a more abstract basis" (p. 25). Unfortunately, there currently seems to be very little evidence relevant to the existence or nature of these hypothesized qualitative changes in knowledge, and thus this hypothesis must also be considered speculative at the present time.

A fourth hypothesis that might be proposed to account for the general absence of expected increases with age in crystallized abilities is that as people grow older their opportunities to acquire new information often decrease because of occupational specialization and a narrowing of professional and personal interests. This hypothesis is distinct from the previous two hypotheses because no threshold level of knowledge or qualitative shift in the type of acquired knowledge is assumed, but instead there are postulated to be limits on the range of information to which one is exposed because of circumstances of one's life. Two implications of this view are that clearly increasing trends should be observed (1) when the information being queried falls within the individual's current realm of interests; or (2) when it is reasonable to assume that, because of the nature of one's occupation, opportunities to acquire new information have not been restricted.

Both of these expectations have largely been supported in the research literature. For example, Demming and Pressey (1957) found that older adults were better than young adults at answering questions based on "practical" information, such as the meaning of common legal terms, the use of yellow pages in the telephone book, and the type of people who might be called on to perform specific services. Gardner and Monge (1977) also reported an advantage of older adults in answering questions about death and disease. Furthermore, there are a number of reports that scores on tests of general information or vocabulary tend to increase with age among individuals drawn from occupations such as teachers or college professors (e.g., Garfield & Blek, 1952; Lachman & Lachman, 1980; Lachman, Lachman, & Taylor, 1982; Sorenson, 1933; Sward, 1945). Because these occupations, perhaps more than most others, seem to provide a nearly continuous exposure to new ideas and terminology, the findings that teachers and professors tend to exhibit age-related increases in measures of crystallized ability is consistent with the reduced-exposure interpretation of the failure to find more age-related increases in measures of crystallized ability.

Regardless of which of the four hypotheses to account for the lack of more frequent findings of age-related increases in crystallized ability is eventually supported, it seems reasonable to suggest that many cases of stability or increments in performance associated with increased age are attributable to greater experience on the part of older adults. It is still too early to conclude that abilities labeled as crystallized differ from those labeled as fluid solely in terms of the amount of experience adults typically receive with each class of ability, but this speculation seems generally consistent with the available data and certainly deserves further investigation.

DIRECT MANIPULATION OF EXPERIENCE

One means of investigating the role of experience in cognitive aging is to determine whether age trends can be modified with direct manipulation of experience. Two distinct approaches to this issue have been employed. In both cases researchers have attempted to manipulate the quantity or quality of experience the individuals receive, but the goals of these manipulations have been quite different. Research conducted under the rubric of "training" has generally concentrated on demonstrating the existence of considerable plasticity or modifiability in the behavior of older adults, whereas age-comparative practice studies have attempted to determine whether the effects of age are invariant across different amounts of experience.

Many of the training studies (for reviews, see Baltes & Willis, 1982; Willis, 1985) have been motivated by a desire to investigate the validity of a stereotype of hopelessly incompetent older adults, as exemplified by clichés such as, "You can't teach an old dog new tricks." This pessimistic view warranted serious challenge because it has had considerable public acceptance and was advocated by no less a distinguished figure than William James, generally acclaimed as the father of American psychology:

> Outside of their own business, the ideas gained by men before they are twenty-five are practically the only ideas they shall have in their lives. They cannot get anything new. Disinterested curiosity is past, the mental grooves and channels set, the power of assimilation gone. (James, 1890, p. 402)

For a variety of reasons, including results from training studies, extreme views such as these are no longer held by most contemporary researchers in the area of

cognitive aging. For example, the following remarks appeared a decade ago in an introduction to a review of age effects in learning and memory: "If the adage, 'You can't teach an old dog new tricks,' was not buried in the previous handbook . . . the research reported since then should complete the internment" (Arenberg & Robertson-Tchabo, 1977, p. 421).

To most cognitive-aging investigators, therefore, the issue is not whether older adults are capable of learning or exhibit behavioral plasticity but the degree to which their learning effectiveness or range of plasticity differs from that of young adults. Because numerous studies have convincingly demonstrated that the ability to learn or improve with experience is not completely lost in later adulthood, the meaningful question is not whether there is a complete or *absolute* loss in cognitive modifiability with increased age but rather whether there is a *relative* loss, and if so, why.

Unfortunately, because the focus of most training studies was on the existence of behavioral plasticity in later life, many have employed only a single (typically older adult) age group and are consequently of limited value with respect to the issue of relative loss. That is, when only one age group receives the training, it is impossible to determine whether the benefits of training would have been larger, smaller, or equivalent had the training been administered at different ages.

Age-comparative practice studies are also limited in value because very few studies have been reported in which adults of different ages have been administered practice or some type of experimental manipulation extending across more than a single session. Moreover, most of those studies have involved perceptual–motor activities such as choice reaction time, visual search, and card-sorting (e.g., Berg, Hertzog, & Hunt, 1982; Leonard & Newman, 1965; Madden & Nebes, 1980; Murrell, 1970; Noble, Baker, & Jones, 1964; Plude & Hoyer, 1981; Rabbitt, 1964; Salthouse & Somberg, 1982), although memory span tasks (Kliegl & Baltes, 1987; Taub, 1973; Taub & Long, 1972) and mental computation tasks (Charness, 1984, personal communication) have also been investigated.

The dominant finding from the available age-comparative practice studies has been that practice results in considerable improvement among all age groups but that age differences in overall level of performance are seldom completely eliminated with experience. It is still not clear from the existing literature whether there are reliable age differences in the rate of improvement associated with practice or experience, or whether such differences do occur but are a function of as yet unidentified parameters of the task or conditions of the practice.

Two points regarding the literature concerning effects of manipulated experience on age differences in cognitive functioning warrant special emphasis. The first is that there is at present no evidence that some degree of expertise in most cognitive tasks cannot be acquired by adults up to at least age 75. A discovery that many older adults with a few hours of experience outperform even the most talented of inexperienced young adults on a large variety of cognitive activities should therefore not be surprising. An obvious implication is that one's level of performance should always be evaluated relative to the amount of relevant practice or experience one has received and relative to the amount one can expect to receive in the context to which the researcher wishes to generalize. Very misleading conclusions could be reached if individuals are compared when they differ in the quantity of relevant experience, or if novice performance is assessed when attempting to predict performance in a work situation where people will have considerable experience.

The second point with respect to the results of the manipulated-experience studies is that the currently available evidence suggests that the age differences on many cognitive tasks are relatively invariant across at least moderate levels of experience. As noted above, adults of all ages appear to benefit from experience, and therefore experienced older adults will often be found to perform better than most young adults with lesser amounts of experience. However, when the confounding between age and task-specific experience is eliminated, the bulk of the existing data seems to suggest that age differences in performance still remain. This conclusion should be considered quite tentative because only a few task domains have been subjected to investigation, and the range of experience examined thus far has been quite limited; but it is of considerable importance for theoretical interpretations of the cause of age differences in cognitive functioning. We will return to this issue in the final section of the chapter.

OCCUPATIONAL EXPERIENCE STUDIES

One important limitation of research attempting to manipulate the amount of relevant experience an individual receives is that it is enormously difficult to provide quantities of experience that come close to approaching that encountered in daily life or in most occupational situations. To illustrate, very few experimental studies have been reported in which age differences have been examined after 5 hours of practice—which might be considered equivalent to a single day on a new job. Furthermore, there have apparently been no studies in which the performance of young and old adults was contrasted after the equivalent of 1 month's experience, approximately 100 hours; and yet in many occupations people would still be considered rank novices after only a month on the job.

One means of overcoming these limitations of experimentally imposed experience studies might be to inspect the relationship between age and performance in actual occupational activities. Of course, there are numerous factors that complicate the interpretation of these relations simply in terms of experience, but occupational studies do have the distinct advantage of allowing examination of a

much larger range of experience than is generally possible in experimental studies.

Unfortunately, but perhaps not unexpectedly, recent reviews of the effects of age on job performance (e.g., Davies & Sparrow, 1985; Rhodes, 1983; Waldman & Avolio, 1986) suggest that there is little overall consistency in the relevant literature. The nature of the relationship between age and performance apparently depends not only on the level of experience possessed by the worker but also on the type of job and the specific performance measure employed.

A particular concern from the perspective of determining the effects of experience on possible age differences in performance is that the measures available to assess actual job performance are rather crude (e.g., production records, supervisor ratings, performance appraisals) and may not be sensitive enough to detect age differences should they actually exist. Doubts about measurement insensitivity could possibly be resolved by making performance comparisons between experienced and inexperienced individuals in the relevant activity and demonstrating that age-related differences in performance can be detected among the inexperienced individuals even if they are not apparent among experienced individuals. For example, LaRiviere and Simonson (1965) and Smith and Greene (1962) both reported that age trends in speed of handwriting were minimal to nonexistent among adults from clerical and managerial occupations in which handwriting is a common daily activity, but that pronounced age-related declines in handwriting speed were evident for occupational groups in which handwriting was less frequently used.

Two studies by Murrell and his colleagues provide an especially intriguing demonstration of this interaction between age and experience. In the first study, Murrell, Powesland, and Forsaith (1962) compared inexperienced adults in their 20s with inexperienced adults in their 50s, and experienced adults in their 20s with experienced adults in their 50s, in the speed of aiming an industrial drill. The primary result was that "typical" age-related deficits in speed of performance were evident among the inexperienced or novice adults, but experienced workers in their 50s were just as fast as experienced workers in their 20s. A later study by Murrell and Humphries (1978) involving the activity of simultaneous translation revealed a similar age-by-experience interaction in that young novices were superior to old novices, but older professional translators performed equivalently to young professional translators.

Although the studies just discussed appear to provide convincing evidence that experience may attenuate or eliminate at least some of the detrimental effects associated with aging, there are at least two reasons why one should be cautious in accepting this interpretation. First, it is quite possible that something like "survival of the fittest" could have occurred among the experienced workers so that the older workers who remain available for performance comparison are more competent in certain occupationally relevant dimensions than their age cohorts who left that occupation. This type of selective attrition would have the consequence of biasing the contrast of experienced workers in favor of older adults, with no comparable bias operating among the inexperienced workers. Such a confounding would obviously jeopardize the interpretation of age-by-experience interactions in terms of experience attenuating the age effects, and thus the question of its existence must be resolved before the results should be considered strong support for the experiential interpretation.

A second weakness of the studies discussed above is that they were not analytical with respect to how experience could have led to the elimination or attenuation of age effects. In other words, even if one were to accept the interpretation that the absence of age trends among experienced individuals is due to experience somehow compensating for age-related declines, the studies provide no hint as to the mechanisms or processes that might have been used to achieve this compensation. It is primarily to address the question of exactly how experience might compensate for age-related impairments that the research strategy described in the following section was formulated.

THE MOLAR EQUIVALENCE–MOLECULAR DECOMPOSITION STRATEGY

The preceding two research approaches each have advantages and disadvantages for the purpose of investigating the joint effects of age and experience. Practice studies have the advantage of rigorously controlling the amount of experience each individual receives and generally allowing very precise measurements of performance. However, they have the disadvantage of a quite restricted range of practice or experience that can be investigated because of the practical difficulties associated with providing extensive experience within a laboratory setting. Occupational studies allow the examination of much greater amounts of experience, albeit with some vagueness about the specific quantity or quality of experience received by any given individual. However, because performance in occupational settings is commonly evaluated with existing measures relevant to actual employment, and not with measures selected for their theoretical or analytical precision, the results from such studies are frequently not as theoretically informative as one would desire.

A new research strategy designed to avoid the problems of attempting to provide realistic amounts of experience in the laboratory, and the imprecision associated with relying on available measures of occupational assessment, was introduced several years ago by Neil Charness. This strategy, which I have called the Molar Equivalence–Molecular Decomposition Strategy (Salthouse, 1984), relies on naturalistic activities to capitalize on real-world experience but then decomposes those activities into their meaningful components to allow the detailed analysis and sensitivity of measurement characteristic of laboratory-based research.

The strategy involves selecting a sample of adults from a wide range of ages and a wide range of proficiency on some molar activity that in the aggregate exhibits no correlation between age and overall competence on the molar activity. The molar activity is then decomposed into molecular processes, and age trends are examined in each component process. By equating adults of different ages on molar proficiency it becomes possible to determine how people of different ages, and presumably different degrees of competency on relevant molecular processes, are able to achieve the same level of performance on the molar activity. A distinct advantage of this strategy is that the focus on the mechanisms responsible for accomplishing a given level of molar performance allows the investigator to determine what compensatory mechanisms are used by older adults to overcome the deficits normally experienced with increased age.

As mentioned above, the Molar Equivalence–Molecular Decomposition Strategy was introduced by Neil Charness in his studies of skilled bridge (Charness, 1979, 1983) and chess (Charness, 1981a, b, c) players. A consistent finding in these studies was that memory for domain-relevant information was positively related to measures of skill in the activity but was negatively related to the player's age. This was evident in a measure of the accuracy of recalling the identities of an assemblage of cards in bridge (1979) and in the accuracy of reproducing configurations of chess pieces (1981a, c). Unfortunately, no definitive conclusions were possible concerning the mechanisms used by older adults to compensate for their declining memory efficiency and still perform at a level of overall skill comparable to that of young adults.

One possible compensatory mechanism considered by Charness in the domain of chess was that older players had a more extensive knowledge base or "vocabulary" of chess patterns and associated actions. However, a discovery that there were no age differences in the quality of static evaluation of games in progress (1981a), together with the finding that older players relative to young players either had smaller-sized memory chunks (1981a) or did not differ in chunk size (1981c), was inconsistent with this interpretation because greater knowledge should result in better evaluations and larger knowledge units or chunks.

A finding that older players took less time than young players to select an equally good move led to the suggestion that "the compensating mechanism is more efficient search of the problem space" (1981a, p. 37). However, this interpretation was later placed in doubt when analyses (1981b) of the verbal protocols of the players while selecting the moves revealed that the older players considered significantly fewer alternative moves than did young players. The shorter time on the part of older players may therefore reflect search that is less extensive, rather than search that is more efficient. Charness himself seems to have accepted an interpretation of this type because in a recent discussion of these results (1985) he suggests that the age differences in search time may be an artifact of the young players continuing to search until the time limit, whereas older players stopped searching as soon as they found an acceptable move.

Another application of the Molar Equivalence–Molecular Decomposition Strategy has been reported by Salthouse (1984) in the domain of transcription typing. Typists between 19 and 72 years of age and ranging from 17 to 104 net words per minute in skill participated in the activity of normal typing, and in a series of typing-like tasks. Molar equivalence was established by selecting the sample of typists so that there was a near-zero ($r = -.01$) correlation between age and typing skill evaluated in terms of net words per minute, and then the activity of typing was decomposed by examining performance on a variety of tasks designed to assess proficiency on molecular processes presumed to be involved in typing.

A number of different measures of molecular proficiency were examined in this study. Several measures of perceptual–motor speed (e.g., choice reaction time, speed of repetitive tapping, rate of digit symbol substitution) revealed typical differences in favor of young adults (i.e., correlations between age and speed ranging from -0.4 to -0.6), but only one measure exhibited a difference favoring older adults ($r = +0.37$) consistent with the operation of a compensatory mechanism. This measure was derived from a manipulation of the number of simultaneously visible to-be-typed characters and was interpreted as an indication of how far ahead of the currently typed character the typist was focusing his or her attention. Because a greater span of anticipation minimizes the importance of the speed of perceptual–motor processes as a major factor in skilled typing, the larger span on the part of older typists was considered an extremely effective compensatory mechanism.

Research with the Molar Equivalence–Molecular Decomposition Strategy is still in its infancy, and it has thus far been applied only to the activities of bridge, chess, and transcription typing. It seems natural to extend it to activities like medical diagnosis, economic or weather forecasting, and virtually any type of multidimensional decision-making in which successful performance is dependent both on abilities that might be expected to exhibit age-related declines and abilities that might be expected to improve with experience. Many questions also remain unanswered concerning issues that might be addressed by the Molar Equivalence–Molecular Decomposition Strategy. Three of particular interest at present are described below.

One intriguing question, for which the answer is likely to be no but which currently lacks relevant data, is whether an extended anticipatory period is the only compensatory mechanism available to older adults. A larger eye–hand span with increased age among skilled typists is the only age-related compensatory mechanism with unequivocal evidence discovered thus far, but it seems reasonable to expect that a variety of different mechanisms might be employed by older adults to optimize their performance in activities in which they are highly experienced. Further systematic research with a number of different activities should allow this issue to be explored and should increase understanding of the nature of age-related compensation in cognitive functioning.

Another interesting question is whether the mechanisms presumably employed by older adults to compensate for their declining capacities are the same mechanisms used by skilled individuals at any age to accomplish their high degree of skill. In the case of typing it was discovered that a similar mechanism of expanded anticipation, as reflected in a larger eye–hand span, was employed by skilled typists and by older typists. However, it is at least possible that the processes used by highly skilled individuals to achieve a superior level of proficiency are not identical to those used by older adults to achieve a moderate level of proficiency in the face of declines in relevant capacities.

This distinction is of considerable theoretical importance because it might allow the researcher to determine whether what appears to be compensation is not actually a case of selective decline. That is, the mechanism might have developed during or after the period in which the decline occurred as a conscious or unconscious means of compensation, or it could have been developed during the skill-acquisition phase and for some reason was preserved at a high level while other components of overall performance experienced age-related declines. Expensive and laborious longitudinal studies could be conducted to investigate this issue, but the viability of the selective decline interpretation would be severely weakened if it were discovered that highly skilled individuals at any age employed different mechanisms from those utilized by moderately skilled older individuals.

A related question is whether it might be possible to selectively train compensatory mechanisms, or whether they are developed only after an extensive period of skill acquisition. Should the former prove to be the case, there might be tremendous potential for remediating age-related performance differences in activities considered important enough to warrant specific training procedures. Unfortunately, because so little is yet understood about the nature of age-related compensatory mechanisms, it is still too early to know whether these mechanisms might be selectively facilitated by short-term interventions.

CONCEPTUALIZATIONS OF THE ROLE OF EXPERIENCE IN ADULT COGNITION

This final section of the chapter is concerned with discussing, and provisionally evaluating, two alternative conceptualizations of the role of experience in age differences in cognition. From one perspective, differential experience is viewed as a causal factor contributing to many of the age differences observed in cognitive functioning; from the other perspective, experience is merely thought of as a dimension to be considered when attempting to generalize from a particular set of results.

It is often claimed, in both the popular press and in the scientific literature, that age effects are less pronounced in familiar activities than in novel or unfamiliar activities. This assertion probably has a large degree of truth because familiar activities are, by definition, those with the greatest amount of experience, and older adults will often be found to have had more experience than young adults. What is not yet known is whether this assertion is also true when the amount of experience is equated across age groups.

There are two reasons for this lack of knowledge about age trends when the amount of experience is extensive and equivalent among all individuals. One is that the relevant studies have been, and will probably continue to be, very rare, because it is extremely expensive and time-consuming to provide enough experience to achieve highly competent levels of performance on a complex activity in the laboratory. It might be possible to obtain precise records of the amount and quality of experience received by people of different ages in occupational settings, but this would probably require much more monitoring than is the practice at the present time.

The second reason it is difficult to determine whether age differences are truly attenuated when experience is equated at high levels is that the sensitivity of measurement is generally reduced when performance reaches expert levels. That is, the tasks and measures designed for assessment in the general population will likely have little discriminability at extremely high levels of performance. This again is not an insurmountable problem, but measurement insensitivity has probably contributed to a lack of solid knowledge about age effects with highly practiced activities.

It is also not known at present whether experience retards, prevents, or even remediates age-related declines, or whether it simply obscures those declines by superimposing experience-related improvements on top of them. The issue here is, exactly what is the role of experience in cognitive aging? The following discussion considers two different perspectives on this issue.

What is sometimes referred to as the "disuse theory of aging" postulates that at least some of the age-related deficits observed in cognitive tasks are attributable to older adults being less familiar or experienced with those activities, or the materials used in them, than young adults. To the extent that there is this type of confounding, with older adults having less experience with the materials or tasks than young adults, then it is at least conceivable that some of the cognitive performance differences observed across adults of different ages are artifacts of differential experience.

Although this line of reasoning is quite plausible, several issues should be carefully considered before accepting the interpretation that previously reported age differences in cognitive functioning are artifacts of differential experience. One issue is whether or not there is actually evidence that cognitive tasks in which performance differences in favor of young adults are typically found are those with which young adults have had more experience than older adults. It is often speculated that older adults, compared to young adults, have had less recent practice with "school-related activities" if for no other reason than the

greater interval elapsing since their formal schooling; but this assertion has seldom been convincingly documented. Cornelius (1984) did report that fluid tests of cognitive ability are rated less familiar than crystallized ability tests by adults of all ages, and particularly so by older adults who performed at the lowest levels on the fluid tests. These results are consistent with the disuse interpretation, but they cannot be considered conclusive because the ratings were generated by the participants after having performed the tests, and hence it is possible that perceptions of one's performance influenced the ratings of familiarity.

Research indicating that age trends can be reversed by reliance on specialized knowledge favoring older adults is sometimes cited in support of the differential-familiarity interpretation. A number of studies have reported that older adults, compared to young adults, are either faster at identification or more accurate in recall with "dated" words or objects (e.g., Barrett & Watkins, 1986; Barrett & Wright, 1981; Poon & Fozard, 1976; Worden & Sherman-Brown, 1983) and with names or information about politicians, musicians, or actors and actresses popular before 1945 (e.g., Hawley-Dunn & McIntosh, 1984; Hultsch & Dixon, 1983).

The meaning of these results with generation-specific materials is still unclear, however, because although they unequivocally demonstrate an age-related increase in performance attributable to specific experience, the opportunities for young adults to acquire this type of information was severely limited. The findings therefore serve to confirm the idea that the possession of specialized knowledge can influence performance on a variety of cognitive tasks, but they do not necessarily implicate lack of familiarity with tasks or materials as a factor contributing to the frequently reported age differences in performance. Only if it could be assumed that older adults had many fewer opportunities than young adults to acquire information about the materials commonly used in assessments of cognitive functioning would these findings be relevant to an experiential interpretation of age differences in performance. Because evidence relevant to this assumption currently seems to be lacking, it is consequently premature to claim, as some have suggested, that this type of material provides the only truly "age-fair" cognitive assessment currently possible and that results suggesting age-related decreases in effectiveness of cognitive functioning are merely artifacts of differential experience across the adult years.

Another issue that should be addressed with respect to the disuse interpretation of cognitive aging phenomena is whether differential experience is truly sufficient to account for commonly observed age differences in cognitive performance. That is, even if a correlation were established between the existence or magnitude of age differences in cognitive performance and the degree of inexperience or unfamiliarity with the tasks or materials, one would not know whether differential experience was the primary factor contributing to age differences in cognitive functioning.

Two sets of observations seem to rule out this latter interpretation. The first is that fairly typical patterns of age differences are often reported in measures of fluid cognition (e.g., reasoning, problem solving, and memory) when comparisons are made between young and old students (e.g., Arenberg & Robertson-Tchabo, 1985; Hartley, 1986; Hooper, Hooper, & Colbert, 1984), or between people of different ages engaged in the same intellectually demanding profession, such as teachers (e.g., Alpaugh & Birren, 1977; Lachman & Lachman, 1980; Lachman, Lachman, & Taylor, 1982) or college professors (e.g., Perlmutter, 1978; Sward, 1945). To the extent that people in the same occupational category share similar experiences, it seems unreasonable to attribute the existence of age differences in certain types of cognitive functioning to variations in quality or quantity of experience.

The second set of observations relevant to the proposal that age differences in certain cognitive abilities might originate because the tasks are more familiar to young adults than to older adults is that typical age trends favoring young adults have been observed when the tasks were deliberately oriented toward adult activities. For example, concept identification abilities have been assessed in the context of discovering which foods were poisoned after a meal in a restaurant (e.g., Arenberg, 1968; Hartley, 1981; Hayslip & Sterns, 1979); reasoning and problem-solving abilities have been evaluated with practical problems deliberately constructed to appeal to adults rather than children (e.g., Cohen, 1981; Denney & Palmer, 1981; Denney, Pearce, & Palmer, 1982); critical thinking ability has been assessed in the form of questions about the interpretations of newspaper-like stories (e.g., Burton & Joel, 1945; Cohen & Faulkner, 1981; Friend & Zubek, 1958) or familiar proverbs (e.g., Bromley, 1957); and memory ability has been assessed with items from a fictitious shopping list (e.g., McCarthy, Ferris, Clark, & Crook, 1981) and items from coherent stories (e.g., Arbuckle & Harsany, 1985; Byrd, 1985; Cohen, 1979; Cohen & Faulkner, 1984; Hartley, 1986; Petros, Tabor, Cooney, & Chabot, 1983; Spilich, 1983; Surber, Kowalski, & Pena-Paez, 1984), as well as by asking questions about previously exposed scenes or maps (e.g., Bartlett, Till, Gernsbacher, & Gorman, 1983; Bruce & Herman, 1983; Light & Zelinski, 1983; Perlmutter, Metzger, Nezworski, & Miller, 1981; Thomas, 1985); recently experienced events, conversations, or activities (e.g., Bromley, 1958; Horn, Donaldson, & Ekstrom, 1981; Kausler & Hakami, 1983a, b; Kausler, Lichty, & Davis, 1985; Kausler, Lichty, & Freund, 1985; Kausler, Lichty, Hakami, & Freund, 1986; Peak, 1968, 1970), or recently viewed motion pictures (e.g., Jones, Conrad, & Horn, 1928). Despite the apparent ecological validity of these assessments, each of the studies cited above reported increased age to be associated with poorer performance. The available evidence, therefore, does not seem to support the view that the only reason older adults perform poorly on cognitive tasks is that they are less familiar with activities of this type than are young adults.

A third type of evidence that could be of considerable relevance to the disuse

interpretation would be results indicating that age differences in performance are eliminated after all individuals have received comparable amounts of experience or training. A finding of this nature might be especially convincing because it would suggest that the initial age differences were apparently reversible and thus may well have been caused by low levels of prior experience on the part of older adults.

Although this kind of experiential intervention involving either training or practice is currently very popular in the area of cognitive aging, the results of such studies are not often easily interpretable. The major problem is that interventions can have a number of effects that have quite different types of implications. For example, greater benefits of manipulated experience on the part of older adults compared to young adults could be due to the experience (1) altering the mechanism responsible for the initial age differences, (2) altering some other mechanism, or (3) reducing the gap between one's performance and one's competence.

Fortunately, there appear to be ways in which these possibilities could conceivably be discriminated. For example, the third alternative might be distinguished from the first two by examining the intervention effects over an extended period. That is, the performance–competence gap alternative should be operative only at relatively low levels of experience because if the behavior is not easily changed, then it probably reflects true competence rather than mere performance. Examination of the specificity of the effects associated with the experiential intervention might further allow a distinction between the first and second alternatives. If the experience manipulation influences the mechanism responsible for the initial differences between young and older adults, then not only should the latter improve more than the former, but this improvement should be restricted to the abilities in which older adults are inferior to young adults and for which the experience has been relevant.

Interpretation of intervention studies is hampered by still another complication. This is that even when ideal results are obtained (i.e., the older adults improve more in the impaired ability after the provision of relevant experience so that the age differences are eliminated), one cannot necessarily conclude that the initial age differences were remediated, because quite different mechanisms may have been involved in the development of those differences and in their apparent elimination by the intervention. To illustrate, providing bifocal corrective lenses will likely improve the visual performance of adults who have become presbyopic, but the intervention of glasses would not be considered to remediate the deficit because the mechanism is not identical to that responsible for producing the initial deficit. A conclusion that remediation was actually involved in the elimination of the deficit therefore requires a detailed analysis of the processes contributing to performance while the impairments were developing and after the introduction of the intervention.

Preliminary results from this type of analysis were reported in a recent study by Willis (1986), in which an attempt was made to characterize longitudinal decline and training benefits in terms of speed and accuracy components of performance. The major finding in this study was that both speed and accuracy declined with age but that training was primarily associated with an increase in accuracy. Although this might be interpreted as suggesting that different mechanisms are involved in age-related decline and experience-mediated improvements, further research is obviously necessary before a definitive conclusion can be reached concerning the possibility of truly reversing age-related differences in cognition by experiential interventions.

The role of experience as a causal factor responsible for age differences in cognition is therefore still very much an open question. Experience has been demonstrated to exert considerable influence on nearly all aspects of performance; thus, if there are age differences in the type or amount of experience, then experiential factors could be an important determinant of age differences in cognitive performance. However, the available evidence suggests that differential experience is not the only factor involved in cognitive age differences because similar types of young superiority are found even when the materials or tasks are designed to be ecologically valid for adults of all ages, and consequently for which experience is presumably equivalent across the adult years or to the advantage of older adults. Studies in which the nature or quantity of experience received by the research participants is manipulated via practice or training may eventually help resolve this question, but problems of interpretation have thus far limited the contributions of this approach.

A second way of conceptualizing the role of experience in cognitive aging is in terms of a dimension to be considered when attempting to make generalizations about occupational effectiveness or everyday functioning based on results from laboratory studies. Because the research evidence clearly suggests that adults of all ages can benefit from experience and because increased age will generally be found to be positively correlated with amount of relevant experience, it seems reasonable to suggest that research based on adults with little or no experience in the activities being measured may not be particularly meaningful for the purpose of predicting competence of experienced individuals. Although differential experience may not be the source of most age differences observed in cognitive functioning, amount of relevant experience is still a vastly more important source of variations in many types of cognitive performance than is an individual's age. For most practical purposes, therefore, the more important question may not be the individual's age, but his or her level of expertise in the activity of interest.

SUMMARY

A major theme of this chapter has been that specific experience is an extremely important variable moderating human performance and one that should be considered when attempting to examine any type of individual differences in

behavior. It is possible that differential experience is responsible for the distinct age trends evident in process, or fluid, as opposed to product, or crystallized, aspects of cognitive functioning; and it is certainly the case that level of experience is an important consideration in attempting to generalize from laboratory situations to real world activities. Research has convincingly demonstrated that adults of all ages benefit from experience; thus, comparisons of experienced older adults with inexperienced young adults will probably favor the former in many situations. The mechanisms responsible for improvement associated with experience are still not known—particularly whether or not they are the same as those involved in the decline in performance associated with increased age—but a promising new approach, the Molar Equivalence–Molecular Decomposition Strategy, may eventually provide answers to this question. And finally, the evidence still appears inconclusive on the issue of whether differential experience is a causal factor in the age differences in cognitive functioning.

REFERENCES

Adelson, B. (1981). Problem solving and the development of abstract categories in programming languages. *Memory & Cognition, 9*, 422–433.

Adelson, B. (1984). When novices surpass experts: The difficulty of a task may increase with expertise. *Journal of Experimental Psychology: Learning, Memory and Cognition, 10*, 483–495.

Alpaugh, P. K., & Birren, J. E. (1977). Variables affecting creative contributions across the adult life span. *Human Development, 20*, 240–248.

Arbuckle, T. Y., & Harsany, M. (1985). Adult age differences in recall of a moral dilemma under intentional, incidental, and dual-task instructions. *Experimental Aging Research, 11*, 175–177.

Arenberg, D. (1968). Concept problem solving in young and old adults. *Journal of Gerontology, 23*, 279–282.

Arenberg, D., & Robertson-Tchabo, E. A. (1977). Learning and aging. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (pp. 421–449). New York: Van Nostrand.

Arenberg, D., & Robertson-Tchabo, E. A. (1985). Adult age differences in memory and linguistic integration revisited. *Experimental Aging Research, 11*, 187–191.

Baltes, P. B., & Willis, S. L. (1982). Plasticity and enhancement of intellectual functioning in old age: Penn State's Adult Development and Enrichment Project (ADEPT). In F. I. M. Craik & S. Trehub (Eds.), *Aging and cognitive processes* (pp. 353–389). New York: Plenum.

Barrett, T. R., & Watkins, S. K. (1986). Word familiarity and cardiovascular health as determinants of age-related recall differences. *Journal of Gerontology, 41*, 222–224.

Barrett, T. R., & Wright, M. (1981). Age-related facilitation in recall following semantic processing. *Journal of Gerontology, 36*, 194–199.

Bartlett, J. C., Till, R. E., Gernsbacher, M., & Gorman, W. (1983). Age-related differences in memory for lateral orientation of pictures. *Journal of Gerontology, 38*, 439–446.

Berg, C., Hertzog, C., & Hunt, E. (1982). Age differences in the speed of mental rotation. *Developmental Psychology, 18*, 95–107.
Birren, J. E. (1969). Age and decision strategies. In A. T. Welford & J. E. Birren (Eds.), *Interdisciplinary topics in gerontology, Vol. 4* (pp. 23–36). Basel: S. Karger.
Bromley, D. B. (1957). Some effects of age on the quality of intellectual output. *Journal of Gerontology, 12*, 318–323.
Bromley, D. B. (1958). Some effects of age on short-term learning and remembering. *Journal of Gerontology, 13*, 398–406.
Bruce, P. R., & Herman, J. F. (1983). Spatial knowledge of young and elderly adults: Scene recognition from familiar and unfamiliar perspectives. *Experimental Aging Research, 9*, 169–173.
Burton, A., & Joel, W. (1945). Adult norms for the Watson-Glaser Tests of Critical Thinking. *Journal of Psychology, 19*, 43–48.
Byrd, M. (1985). Age differences in the ability to recall and summarize textual information. *Experimental Aging Research, 11*, 87–91.
Cattell, R. B. (1972). *Abilities: Their structure, growth, and action*. Boston: Houghton-Mifflin.
Charness, N. (1979). Components of skill in bridge. *Canadian Journal of Psychology, 33*, 1–16.
Charness, N. (1981a). Aging and skilled problem solving. *Journal of Experimental Psychology: General, 110*, 21–38.
Charness, N. (1981b). Search in chess: Age and skill differences. *Journal of Experimental Psychology: Human Perception and Performance, 7*, 467–476.
Charness, N. (1981c). Visual short-term memory and aging in chess players. *Journal of Gerontology, 36*, 615–619.
Charness, N. (1983). Age, skill, and bridge bidding: A chronometric analysis. *Journal of Verbal Learning and Verbal Behavior, 22*, 406–416.
Charness, N. (1985). Aging and problem-solving performance. In N. Charness (Ed.), *Aging and human performance* (pp. 226–259). Chichester, England: Wiley.
Chase, W. G., & Chi, M. T. H. (1981). Cognitive skill: Implications for spatial skill in large-scale environments. In J. H. Harvey (Ed.), *Cognition, social behavior, and the environment* (pp. 111–136). Hillsdale, NJ: Erlbaum.
Chase, W. G., & Simon, H. A. (1973). Perception in chess. *Cognitive Psychology, 4*, 55–81.
Chi, M. T. H. (1978). Knowledge structures and memory development. In R. C. Siegler (Ed.), *Children's thinking: What develops?* (pp. 73–96). Hillsdale, NJ: Erlbaum.
Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5*, 121–152.
Chi, M. T. H., & Glaser, R. (1980). The measurement of expertise: Analysis of the development of knowledge and skill as a basis for assessing achievement. In E. L. Baker & E. S. Quellmalz (Eds.), *Educational testing and evaluation: Design analysis and policy* (pp. 37–47). Beverly Hills, CA: Sage.
Cohen, G. (1979). Language comprehension in old age. *Cognitive Psychology, 11*, 412–429.
Cohen, G. (1981). Inferential reasoning in old age. *Cognition, 9*, 59–72.
Cohen, G., & Faulkner, D. (1981). Memory for discourse in old age. *Discourse Processes, 4*, 253–265.

Cohen, G., & Faulkner, D. (1984). Memory for text: Some age differences in the nature of the information that is retained after listening to texts. In H. Buoma & D. G. Bouwhuis (Eds.), *Attention and performance*, Vol. 10 (pp. 501–513). Hillsdale, NJ: Erlbaum.
Cornelius, S. W. (1984). Classic pattern of intellectual aging: Test familiarity, difficulty, and performance. *Journal of Gerontology, 39*, 201–206.
Davies, D. R., & Sparrow, P. R. (1985). Age and work behaviour. In N. Charness (Ed.), *Aging and human performance* (pp. 293–332). Chichester, England: Wiley.
DeGroot, A. D. (1978). *Thought and choice in chess* (2nd ed.). The Hague: Mouton.
Demming, J. A., & Pressey, S. L. (1957). Tests indigenous to the adult and older years. *Journal of Counseling Psychology, 4*, 144–148.
Denney, N. W., & Palmer, A. M. (1981). Adult age differences in traditional and practical problem-solving measures. *Journal of Gerontology, 36*, 323–328.
Denney, N. W., Pearce, K. A., & Palmer, A. M. (1982). A developmental study of adults' performance on traditional and practical problem-solving tasks. *Experimental Aging Research, 8*, 115–118.
Egan, D. E., & Schwartz, B. J. (1979). Chunking in recall of symbolic drawings. *Memory & Cognition, 7*, 149–158.
Engle, R. W., & Bukstel, L. (1978). Memory processes among bridge players of differing expertise. *American Journal of Psychology, 91*, 673–689.
Ericsson, K. A. (1985). Memory skill. *Canadian Journal of Psychology, 39*, 188–231.
Frey, P. W., & Adesman, P. (1976). Recall memory for visually presented chess positions. *Memory & Cognition, 4*, 541–547.
Friend, C. M., & Zubek, J. P. (1958). The effects of age on critical thinking ability. *Journal of Gerontologist, 13*, 407–413.
Gardner, E. F., & Monge, R. H. (1977). Adult age differences in cognitive abilities and educational background. *Experimental Aging Research, 3*, 337–383.
Garfield, S. L., & Blek, L. (1952). Age, vocabulary level, and mental impairment. *Journal of Consulting Psychology, 16*, 395–398.
Greeno, J. G. (1980). Some examples of cognitive task analysis with instructional implications. In R. E. Snow, P. Federico, & W. E. Montague (Eds.), *Aptitude, learning and instruction*, Vol. 2 (pp. 1–21). Hillsdale, NJ: Erlbaum.
Halpern, A. R., & Bower, G. H. (1982). Musical expertise and melodic structure in memory for musical notation. *American Journal of Psychology, 95*, 31–50.
Hartley, A. (1981). Adult age differences in deductive reasoning. *Journal of Gerontology, 36*, 700–706.
Hartley, J. (1986). Reader and text variables as determinants of discourse memory in adulthood. *Psychology and Aging, 1*, 150–158.
Hawley-Dunn, P., & McIntosh, J. L. (1984). Meaningfulness and recall of names by young and old adults. *Journal of Gerontology, 39*, 583–585.
Hayslip, B., & Sterns, H. (1979). Age differences in relationships between crystallized and fluid intelligences and problem solving. *Journal of Gerontology, 34*, 404–414.
Hebb, D. O. (1942). The effect of early and late brain injury upon test scores and the nature of normal adult intelligence. *Proceedings of the American Philosophical Society, 85*, 275–292.
Hooper, F. H., Hooper, J. O., & Colbert, K. C. (1984). *Personality and memory correlates of intellectual functioning: Young adulthood to old age*. Basel: S. Karger.

Horn, J. L. (1982). The theory of fluid and crystallized intelligence in relation to concepts of cognitive psychology and aging in adulthood. In F. I. M. Craik & S. Trehub (Eds.), *Aging and cognitive processes* (pp. 237–278). New York: Plenum.
Horn, J. L., & Cattell, R. B. (1967). Age differences in fluid and crystallized intelligence. *Acta Psychologica, 26,* 107–129.
Horn, J. L., Donaldson, G., & Ekstrom, R. (1981). Apprehension, memory and fluid intelligence decline in adulthood. *Research on Aging, 3,* 33–84.
Hultsch, D. F., & Dixon, R. A. (1983). The role of pre-experimental knowledge in text processing in adulthood. *Experimental Aging Research, 9,* 17–22.
James, W. (1890). *Principles of psychology,* Vol. 2. New York: Holt.
Jones, H. E., Conrad, H., & Horn, A. (1928). Psychological studies of motion pictures. II. Observation and recall as a function of age. *University of California Publications in Psychology, 3,* 225–243.
Kausler, D. H., & Hakami, M. K. (1983a). Memory for activities: Adult age differences and intentionality. *Developmental Psychology, 119,* 889–894.
Kausler, D. H., & Hakami, M. K. (1983b). Memory for topics of conversation: Adult age differences and intentionality. *Experimental Aging Research, 9,* 153–157.
Kausler, D. H., Lichty, W., & Davis, R. T. (1985). Temporal memory for performed activities: Intentionality and age differences. *Developmental Psychology, 21,* 1132–1138.
Kausler, D. H., Lichty, W., & Freund, J. S. (1985). Adult age differences in recognition memory and frequency judgments for planned versus performed activities. *Developmental Psychology, 21,* 647–654.
Kausler, D. H., Lichty, W., Hakami, M. K., & Freund, J. S. (1986). Activity duration and adult age differences in memory for activity performance. *Psychology and Aging, 1,* 80–81.
Kliegl, R., & Baltes, P. B. (1987). Theory-guided analysis of mechanisms of development and aging through testing-the-limits and research on expertise. In C. Schooler & K. W. Schaie (Eds.), *Cognitive functioning and social structure over the life course* (pp. 95–119). Norwood, NJ: Ablex.
Lachman, R., & Lachman, J. L. (1980). Age and the actualization of world knowledge. In L. W. Poon, J. L. Fozard, L. S. Cermak, D. Arenberg, & L. W. Thompson (Eds.), *New directions in memory and aging* (pp. 285–311). Hillsdale, NJ: Erlbaum.
Lachman, R., Lachman, J. L., & Taylor, D. W. (1982). Reallocation of mental resources over the productive lifespan: Assumptions and task analyses. In F. I. M. Craik & S. Trehub (Eds.), *Aging and cognitive processes* (pp. 279–308). New York: Plenum.
Lane, D. M., & Robertson, L. (1979). The generality of the levels of processing hypothesis: An application to memory for chess positions. *Memory & Cognition, 7,* 253–256.
LaRiviere, J. E., & Simonson, E. (1965). The effect of age and occupation on speed of writing. *Journal of Gerontology, 20,* 415–416.
Leonard, J. A., & Newman, R. C. (1965). On the acquisition and maintenance of high speed and high accuracy in a keyboard task. *Ergonomics, 8,* 281–304.
Light, L. L., & Zelinski, E. M. (1983). Memory for spatial information in young and old adults. *Developmental Psychology, 19,* 901–906.
Madden, D. J., & Nebes, R. D. (1980). Aging and the development of automaticity in visual search. *Developmental Psychology, 16,* 377–384.

McCarthy, M., Ferris, S. H., Clark, E., & Crook, T. (1981). Acquisition and retention of categorized material in normal aging and senile dementia. *Experimental Aging Research, 7,* 127–135.
Murrell, K. F. H. (1970). The effect of extensive practice on age differences in reaction time. *Journal of Gerontology, 25,* 268–274.
Murrell, K. F. H., & Humphries, S. (1978). Age, experience, and short-term memory. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical aspects of memory* (pp. 363–365). London: Academic Press.
Murrell, K. F. H., Powesland, P. F., & Forsaith, B. (1962). A study of pillar-drilling in relation to age. *Occupational Psychology, 36,* 45–52.
Noble, C. E., Baker, B. L., & Jones, T. A. (1964). Age and sex parameters in psychomotor learning. *Perceptual & Motor Skills, 19,* 935–945.
Peak, D. T. (1968). Changes in short-term memory in a group of aging community residents. *Journal of Gerontology, 23,* 9–16.
Peak, D. T. (1970). A replication study of changes in short-term memory in a group of aging community residents. *Journal of Gerontology, 25,* 316–319.
Perlmutter, M. (1978). What is memory aging the aging of? *Developmental Psychology, 14,* 330–345.
Perlmutter, M., Metzger, R., Nezworski, T., & Miller, K. (1981). Spatial and temporal memory in 20 and 60 year olds. *Journal of Gerontology, 36,* 59–65.
Petros, T., Tabor, L., Cooney, T., & Chabot, R. J. (1983). Adult age differences in sensitivity to semantic structure of prose. *Developmental Psychology, 19,* 907–914.
Plude, D. J., & Hoyer, W. J. (1981). Adult age differences in visual search as a function of stimulus mapping and processing level. *Journal of Gerontology, 36,* 598–604.
Poon, L. W., & Fozard, J. L. (1976). Speed of retrieval from long-term memory in relation to age, familiarity, and datedness of information. *Journal of Gerontology, 33,* 711–717.
Rabbitt, P. M. A. (1964). Set and age in a choice response task. *Journal of Gerontology, 19,* 301–306.
Reitman, J. S. (1976). Skilled perception in GO: Deducing memory structures from inter-response times. *Cognitive Psychology, 8,* 336–356.
Rhodes, S. R. (1983). Age-related differences in work attitudes and behavior: A review and conceptual analysis. *Psychological Bulletin, 93,* 328–367.
Salthouse, T. A. (1982). *Adult cognition.* New York: Springer-Verlag.
Salthouse, T. A. (1984). Effects of age and skill in typing. *Journal of Experimental Psychology: General, 113,* 345–371.
Salthouse, T. A. (1985). *A theory of cognitive aging.* Amsterdam: North-Holland.
Salthouse, T. A., & Somberg, B. L. (1982). Skilled performance: The effects of adult age and experience on elementary processes. *Journal of Experimental Psychology: General, 111,* 176–207.
Schoenfeld, A. H., & Herrmann, D. J. (1982). Problem perception and knowledge structure in expert and novice mathematical problem solvers. *Journal of Experimental Psychology: Learning, Memory and Cognition, 8,* 484–494.
Smith, K. U., & Greene, D. (1962). Scientific motion study and ageing processes in performance. *Ergonomics, 5,* 155–164.
Sorenson, H. (1933). Mental ability over a wide range of adult ages. *Journal of Applied Psychology, 17,* 729–741.

Spilich, G. J. (1983). Life-span components of text processing: Structural and procedural differences. *Journal of Verbal Learning and Verbal Behavior, 22,* 231–244.
Surber, J. R., Kowalski, A. H., & Pena-Paez, A. (1984). Effects of aging on the recall of extended expository prose. *Experimental Aging Research, 10,* 25–28.
Sward, K. (1945). Age and mental ability in superior men. *American Journal of Psychology, 58,* 443–479.
Taub, H. A. (1973). Memory span, practice and aging. *Journal of Gerontology, 28,* 335–338.
Taub, H. A., & Long, M. K. (1972). The effects of practice on short-term memory of young and old subjects. *Journal of Gerontology, 27,* 494–499.
Thomas, J. L. (1985). Visual memory: Adult age differences in map recall and learning strategies. *Experimental Aging Research, 11,* 93–95.
Voss, J. F., Tyler, S. W., & Yengo, L. A. (1983). Individual differences in the solving of social science problems. In R. F. Dillon & R. R. Schmeck (Eds.), *Individual differences in cognition,* Vol. 1 (pp. 205–232). New York: Academic Press.
Waldman, D. A., & Avolio, B. J. (1986). A meta-analysis of age differences in job performance. *Journal of Applied Psychology, 71,* 33–38.
Willis, S. L. (1985). Towards an educational psychology of the older adult learner: Intellectual and cognitive bases. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (2nd ed.) (pp. 818–847). New York: Van Nostrand Reinhold.
Willis, S. L. (1986, August). *Inductive reasoning: Longitudinal change and cognitive training.* Paper presented at the meeting of the American Psychological Association, Washington, DC.
Worden, P. E., & Sherman-Brown, S. (1983). A word-frequency cohort effect in young versus elderly adults' memory for words. *Developmental Psychology, 19,* 521–530.