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Influence of Experience on Age Differences in Cognitive Functioning

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To the extent that adult age differences in measures of cognitive performance have implications for functioning outside the psychological laboratory, the question of the role of experience as a potential moderator of these differences becomes extremely important. Three categories of research relevant to this issue are reviewed, and methodological limitations of each type of research are discussed. Although it is frequently asserted that experience minimizes cognitive differences associated with aging, the evidence currently available does not appear consistent with a strong experiential moderation of age-related effects in cognitive performance. However, the paucity of relevant studies and the methodological weaknesses of those that do exist preclude a definitive conclusion at the present time. Additional research with improved methodology is necessary before strong conclusions can be reached concerning effects of experience on age differences in cognition.

INTRODUCTION

Cross-sectional comparisons of adults of different ages frequently reveal that increased age is associated with lower performance on various measures of cognitive functioning. Among the questions often raised in connection with these findings are the following: Are these age differences confined to measures from novel and abstract tasks, and are they much reduced or even completely absent in measures from familiar and concrete tasks? Can the age differences be attenuated or eliminated with additional practice or training? Do the age differences disappear when individuals of all ages have extensive experience with relevant activities? The purpose of this article is to review the research literature relevant to these questions concerning the influence of experience as a potential mediator, or moderator, of age-related differences in cognition.

In order to provide an appropriate context for interpreting the research relevant to age and experience, a brief summary of previous findings on the relation between age and cognition will first be presented. One of the earliest and least controversial results in the cognitive aging literature is the finding that age-related effects vary as a function of the type of cognition being assessed. Over the years a number of different labels have been used to characterize the major categories of cognition; the terms *crystallized* and *fluid*, or *product* and *process*, are currently the most popular. The distinction is essentially be-

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tween measures of cognitive functioning based on the crystallized residue or accumulated products from processing at earlier times and measures reflecting the efficiency of acquiring, transforming, and retaining—or, more generally, processing—information at the current time.

Results from many studies with a variety of psychometric test batteries have revealed that age-related effects are usually very small and are sometimes manifested in increases rather than decreases for crystallized or product measures of cognition, such as scores on tests of vocabulary or general information. In contrast, measures reflecting the efficiency of current processing—as required by tests or tasks emphasizing speed or accuracy of associations, transformations, decisions, or responses—are generally found to decrease with age. The magnitudes of the adult age relations on process or fluid measures of cognition are not great up to about age 75 (e.g., Salthouse, 1985b, reported a median age correlation across 54 comparisons of −0.36), but the extreme group (i.e., young adults vs. older adults) differences are often larger than those associated with most other individual difference classifications, such as race, sex, or personality type. There is still controversy concerning the age at which the cross-sectional decline in fluid or process aspects of cognition first begins; some researchers suggest that it starts in the 20s and others argue that declines are not noticeable until the 50s or 60s. One possibility is that with relatively easy tests the predominant age trend is a period of stability followed by a decline beginning at about the decade of the 50s, whereas for very demanding tests the pattern is one of relatively monotonic declines beginning in the late 20s or early 30s.

For both practical and theoretical reasons it is important to determine the effects of experience on age differences in measures assumed to reflect the level of an individual's current processing efficiency. The practical significance derives from the assumption that age-related differences in these aspects of cognitive functioning may be detrimental to older adults' effectiveness in many occupational situations. However, a minimal negative effect of older adults in the workplace, and in society in general, would be expected if increased experience is found to attenuate, or possibly even eliminate, the age differences in cognitive functioning observed in inexperienced adults.

It should probably be mentioned that some researchers have disputed the assumption that age-related differences in fluid or process aspects of cognition could have negative implications for real-world functioning, even in the absence of experiential influences. For example, Schaie (e.g., 1988a) has argued that the reported age differences are generally too small to have meaningful consequences in most occupational activities. Perlmutter, Adams, Berry, Kaplan, Person, and Verdonik (1987) have even suggested that in certain situations there may be advantages of mild cognitive impairments such as unreliable memory. Although the validity of these speculations remains an open question, it is important to note that the age-related effects typically observed are large enough to lead to estimates (Fozard and Nuttall, 1971) that the average 60-year-old would be unqualified for more than half of the occupations for which predictive validity has been established with the General Aptitude Test Battery. (It should also be acknowledged, however, that most validation samples have been composed primarily of young adults, and thus it is possible that different estimates might be generated if validity information were available at each of several age ranges.)

Research on the possible interactive effects of age and experience on fluid or process aspects of cognitive functioning also has considerable theoretical importance. At least since the time of Thorndike (Thorndike, Bregman, Tilton, and Woodyard, 1928), a major class of explanation has attributed age-related declines in cognition to experiential deprivation or disuse. Examination of the relations between age and measures of cognition across different levels of experience can therefore be expected to be informative about one possible cause of the age-related differences frequently observed in measures of cognitive functioning.

The prevailing opinion among both lay people and researchers in the field seems to be that experience attenuates age differences in cognition, allowing overall effectiveness to be maintained either by preserving the original levels of basic abilities or through the development of compensatory skills. This attitude is reflected in the general culture by expressions such as "Use it or lose it" and "He who lives by his wits, dies with his wits." The following quotations, selected haphazardly from relevant articles and books published over a 50-year period, document the pervasiveness of this perspective in the professional literature.

> In general, then, abilities that are used throughout adult experience tend to increase with age, while abilities required by situations that do not come within the scope of adult experience show a definite decline over a range of adult years. (Sorenson, 1938, p. 736)

> Abilities which are exercised during our adult years, such as the maintenance of vocabulary, the capacity to understand and use different words, do not decline during our adult years. (Brozek, 1951, p. 224)

> The declines that are observed in abilities which are used frequently appear to begin at a later age and to be less drastic than are the declines in abilities which are exercised less frequently. (Denney, 1982, p. 824)

> Extended practice appears to reduce age differences in performance considerably . . . and when older individuals are highly experienced at the task they are performing, no age differences emerge. (Davies and Sparrow, 1985, p. 303)

Although this sample of quotations suggests a clear preference for the view that increased experience reduces the magnitude of age differences in cognitive functioning, the empirical bases for this preference are much less obvious. It is therefore desirable to conduct a thorough examination of the scientific foundation for conclusions about the role of experience on adult age differences in cognition. In the following sections three classes of evidence relevant to the influence of experience on age-related effects on fluid or process aspects of cognition are reviewed: research concerned with age differences in familiar activities, research investigating the effects of additional practice or training, and research involving select populations, such as members of particular occupational groups. Because the amount of data in each category is still quite limited, the discussion will focus as much on the methodological requirements needed to provide convincing evidence in future research as on summarizing the major empirical results from past research.

FAMILIAR ACTIVITIES

One hypothesis concerning age and experience is that the detrimental effects on cognitive functioning associated with increased age are restricted to novel and unfamiliar tasks and are not evident on frequently performed activities. Several different rationales have been offered to account for this predicted pattern of results; one involves the close association between young adulthood and formal schooling, during which there is considerable exposure to novel activities, and a presumed decrease with age in the willingness to perform what might be perceived to be meaningless or irrelevant tasks. The fundamental expectation from all versions of the hypothesis, however, is that age-related effects should be much smaller—and perhaps even nonexistent—on familiar tasks than on the presumably more abstract and novel tasks typically used in psychometric and laboratory investigations.

Unfortunately, two major problems make it difficult to reach a definitive conclusion concerning the possibility that adult age differences are smaller on familiar tasks than on unfamiliar tasks. (These problems are in addition to the statistical and logical difficulties associated with interpreting interactions [e.g., between age and familiarity] and with attempting to establish the nonexistence of differences between groups.) One problem is that the concept of familiarity has seldom been operationally defined or systematically investigated in adults of different ages. Ideally, claims that some tasks are performed more frequently than others should be documented with evidence concerning the relative amounts of time devoted to different activities among representative samples of adults. However, complete activity inventories of this type have apparently not yet been reported for any age group, much less for several different age groups. Furthermore, even if such data were available, they might be of limited value because the most relevant frequencies probably concern the basic components or processes involved in different activities, not the superficial activities themselves. For example, paired-associate tasks involving randomly selected words undoubtedly have a low frequency of occurrence in everyday life, but the same fundamental association processes may have an extremely high frequency when considered in the context of pairing cuisine or service with restaurants, athletes with sports teams, faces with names, shops with locations, appointments with days and times, and so on. Without accurate and detailed information concerning the frequencies with which particular processes or components are used in daily life, therefore, judgments about the relative familiarity of different tasks are necessarily subjective and of questionable validity.

A second problem complicating the issue of whether age-related differences are smaller with familiar tasks than with unfamiliar or novel tasks is that the two types of tasks may vary in dimensions other than familiarity. For example, there is an obvious confounding if so-called familiar tasks consist of measures of the products of prior processing, such as scores on a vocabulary test, whereas unfamiliar tasks involve assessments of the efficiency of current processing, such as the speed and accuracy of substituting symbols for digits or assembling blocks into novel patterns. Familiarity may also be confounded with amount of processing in that familiar tasks might involve fewer processing operations or lower levels of task complexity than might unfamiliar tasks. Matching familiar and unfamiliar tasks on dimensions such as the type of cognition being assessed and the amount of processing required will probably not be easy, but only if the tasks are equivalent in these respects could one be confident in attributing differences in observed age trends to the effects of familiarity.

Although documentation of the actual frequencies is lacking and novel tasks with processing requirements equivalent to those of familiar tasks have not yet been identified, age comparisons have been reported for a variety of tasks that can be argued to represent familiar activities. For example, young and old adults have been contrasted in the ability to remember and immediately dial a telephone number (e.g., Crook, Ferris, McCarthy, and Rae, 1980; Pollard and Cooper, 1978), to notice and report information from a street sign after driving or walking past it (Manstead and Lee, 1979), to remember a shopping list of grocery items (McCarthy, Ferris, Clark, and Crook, 1981), to remember information from a simulated news broadcast (Hill, Crook, Zadek, Sheikh, and Yesavage, 1989), to remember the source of factual information (McIntyre and Craik, 1987), and to comprehend and remember information on prescription medicine bottles (Morrell, Park, and Poon, 1989). In each of these cases, and in numerous others summarized in Salthouse (1987b), young adults have been found to perform significantly more accurately than have older adults.

Several psychometric tests have also been designed to evaluate the abilities required in daily activities. One such instrument is the Watson-Glaser Test of Critical Thinking, which has been described as follows:

> This test consists of 99 items almost all of which are of a realistic or practical nature involving problems, statements, arguments, and interpretation of data similar to those which a person might encounter in his daily life as he works, reads the newspaper, hears speeches, and participates in discussions on various topics. (Friend and Zubek, 1958, p. 407)

Apparently only two studies have investigated adult age differences on the Watson-Glaser test (Burton and Joel, 1945; Friend and Zubek, 1958), but both were consistent in finding significant age differences favoring young adults.

The most comprehensive study of age-related differences in a psychometric test designed to assess familiar activities was reported by Schaie and Willis (e.g., Schaie, 1988b; Willis and Schaie, 1986a), using the Educational Testing Service Basic Skills Test. This test was developed to assess real-life competencies and evaluates the examinees' ability to understand labels on household articles and medicine bottles, to interpret street maps, to obtain information from bus schedules and from telephone directory advertisements, and so on. Not only do these items appear to have face validity as measures of functioning in daily situations, but Willis and Schaie (1986a) also obtained estimates of the frequency with which representative activities within each of eight categories were performed. Within a sample of adults between 60 and 88 years of age, activities from five of the categories were reported to be performed weekly on average, with activities from an additional category performed at least monthly.

Data from 1500 adults on the ETS Basic Skills Test, as reported in Schaie (1988b), are illustrated in Figure 1. It can be seen that performance remains relatively stable until about the 50s or 60s, at which time a pronounced decline is evident. These results clearly indicate that young adults achieve higher scores than do older adults, but the exact nature of the age relationship in the relevant abilities is still somewhat equivocal. That is, it could be that actual ability to perform these types of tasks remains stable from the 20s through the 50s or 60s, but it is also possible that ability declines occur without concomitant reductions in measured performance because the performance of young and middle-aged adults is constrained by an absolute or functional measurement ceiling. The transformation of the scores from the original units of measurement into *T* scores obscures a possible absolute measurement ceiling because it is impossible to determine how far actual performance is from the maximum possible performance. Functional ceilings can also exist because performance can be less than the highest possible score for a variety of reasons, such as the presence of a few extremely difficult items or unrealistically short time allowances. If higher levels of performance were restricted by either an absolute or a functional measurement ceiling, therefore, the true relation between age and ability might be a monotonic decline rather than a period of stability followed by decline. Regardless of the precise nature of the age trends, however, the data in Figure 1 are unambiguous in indicating that, as with the studies cited earlier, young adults achieve substantially higher scores than do older

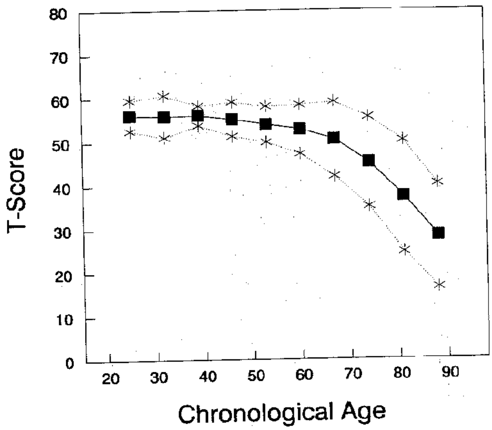

Figure 1. *Mean levels of performance on the ETS Basic Skills Test as a function of age. Values are represented in T-score units, with the asterisked, dotted lines representing plus and minus one standard deviation. Data from Schaie (1988b).*

adults on instruments designed to assess proficiency in familiar or everyday activities.

The studies just described are merely a limited—and not necessarily representative—sample of the research on familiar activities, but they are sufficient to indicate that there are convincing exceptions to the suggestion that age-related differences are small to nonexistent on familiar tasks or activities. Definitive research (with documented frequencies of relevant processes and comparable processing requirements across familiar and novel tasks) does not yet exist, but the research surveyed earlier clearly provides little support for the proposal that age differences are restricted to novel and unfamiliar activities.

PRACTICE AND TRAINING

A second issue relevant to the relations between age and experience concerns the effects of added experience on the magnitude of age differences in measures of cognitive functioning. The primary question in this context is whether age-related differences are invariant across different amounts of experience or are reduced in magnitude as a function of additional experience.

Considerable research has focused on the modifiability or plasticity of behavior during late adulthood, and consequently the effects of different amounts and types of instructional training on the cognitive functioning of older adults have been extensively investigated (e.g., see Baltes and Lindenberger, 1988, and Willis, 1987, for reviews). However, because the experiential interventions were administered to only a single age group, this research is not directly relevant to the issue of the effects of added experience on age-related differences in cognition. That is, the most important question for the purpose of determining the effects of experience on age differences in performance is *relative* rather than *absolute* modifiability, and it is simply impossible to draw conclusions about possible age-related differences in the benefits of experience without comparisons of two or more age groups.

Unfortunately, even the age-comparative practice or training studies that have been reported suffer from a number of limitations. For example, in several studies samples of young and old adults were compared after very small amounts of experience. It is difficult to specify the amount of experience sufficient to be considered realistic, but at a minimum the practice or training should extend across multiple sessions. Second, some studies have reported results from as few as one individual in each age group. Although virtually all available studies have employed small sample sizes (i.e., 20 or fewer individuals per age group), results based on extremely small numbers of adults in each age range provide a very limited basis for generalization.

Furthermore, apparently only two studies have attempted to examine the representativeness of the individuals who agree to participate for extended testing (i.e., Kliegl, Smith, and Baltes, 1989; Salthouse and Somberg, 1982). A final problem is that almost all of the available studies have focused on a single dependent variable from one particular task, thereby greatly restricting inferences beyond the measured variable and precluding distinctions among changes in the proficiency of the same construct as opposed to changes in the nature of the construct being assessed.

Although the preceding characteristics serve to qualify any conclusions, the existing research literature does provide some tentative information about the effects of manipulated experience on age differences in cognitive functioning. Table 1 summarizes the results from all relevant studies that could be located with a total of at least 12 individuals from two or more different age groups, and comparisons extending across a minimum of four separate sessions. These particular characteristics are somewhat arbitrary but were selected to maximize the meaningfulness of the results while not severely reducing the number of qualifying studies.

It should be noted that the outcomes in Table 1 should be interpreted cautiously because in some cases the patterns varied across different stages of practice (e.g., Salthouse and Somberg, 1982) and in others there was no distinction between effects attributable to instruction of a technique and practice with that technique (e.g., Kliegl et al., 1989). Furthermore, in several of the contrasts the entries in the "effect of practice" column are inferences based on the reported information because apparently there was no direct evaluation of the equivalence of young and old adults at different levels of practice, or of the effectiveness of practice, in the two groups. (This lack of quantitative information in many of the studies also precludes the use of more systematic meta-analytic procedures to integrate the results from different studies.)

The dominant pattern in Table 1 clearly seems to be that practice-related performance improvements are equivalent in magnitude for young and old adults. In a few cases older adults appear to have exhibited greater improvements than have young adults, primarily during the initial sessions of practice, but it is more frequently the case that young and old adults benefit nearly the same from practice or training. Young adults improved more than did older adults in a couple of studies, but it is not yet clear whether this particular outcome is restricted to situations requiring the acquisition of new skills or is also evident when the research subjects are increasing the proficiency of existing skills.

There are also a number of miscellaneous reports of age-related differences in more naturalistic learning situations. For example, Thorndike et al. (1928) reported that across 15 hours of practice, adults with a mean age of 22 improved their speed of writing with the wrong (i.e., nonpreferred) hand more than did adults with a mean age of 41. These same authors also reported that the benefits of 20 hr of study and instruction in oral comprehension of the artificial language Esperanto were greater in young adults than in middle-aged adults, though the two groups improved comparable amounts in other measures of language acquisition.

Several cases of age differences in the efficiency of retraining for bus drivers, electrical technicians, postal workers, oil production workers, and telephone operators have been described by Welford (1958, pp. 257–258) and Birren (1964, pp. 161–168). More recently, Egan and Gomez (1985), Elias, Elias, Robbins, and Gage (1987), and McAlister (1985)

TABLE 1

Studies of Practice Effects in Young and Old Adults

Measure	*# Sessions*	*# Trials/ Session*	*Young N/Age*	*Old N/Age*	*Effect of Practice*	*Source*
Perceptual discrimination						
1	7	500/600	8/18–28	9/62–72	Y = O	Ball and Sekuler (1986)
2	5	60+	12/19	12/67	Y = O	Hertzog et al. (1976)
3	50	200	8/23	8/69	Y = O	Salthouse and Somberg (1982)
4	50	50	8/23	8/69	Y = O	Salthouse and Somberg (1982)
Mean reaction time						
5	4	480	15/21	16/63	Y = O	Berg et al. (1982)
6	10	1000	6/18–27	18/50–58	Y = O	Leonard and Newman (1965)
7	4	492	10/20	10/69	Y = O	Madden (1983)
8	9	288	8/22	8/68	Y = O	Madden and Nebes (1980)
9	6	30	6/23	6/70	Y = O	McDowd (1986)
10	6	240	8/19	8/64	Y > O	Plude et al. (1983)
11	50	100	8/23	8/69	Y < O, Y = O	Salthouse and Somberg (1982)
Mental rotation slope						
12	4	480	16/21	16/63	Y = O	Berg et al. (1982)
Memory/visual search slope (varied mapping conditions)						
13	?	(Total trials = 4200)	7/20	7/70	Y = O	Fisk et al. (1988)
Memory/visual search slope (consistent mapping conditions)						
14	?	(Total trials = 4200)	7/20	7/70	Y > O	Fisk et al. (1988)
15	4	492	10/20	10/69	Y = O	Madden (1983)
16	9	288	8/22	8/68	Y = O	Madden and Nebes (1980)
17	50	100	8/23	8/69	Y < O	Salthouse and Somberg (1982)

Card sorting						
18	7	30/36	8/17–25	8/62–75	Y = O	Falduto and Baron (1986)
19	6	10	8/24	8/75	Y > O, Y = O	Plude and Hoyer (1981)
Digit symbol substitution						
20	5	20	12/23	12/69	Y = O	Beres and Baron (1981)
Recognition memory accuracy						
21	7	3	10/18–26	10/62–75	Y = O	LeBreck and Baron (1987)
Memory span						
22	5	20+	16/26	16/70	Y = O, Y > O	Taub (1973)
23	5	36+	14/25	12/71	Y = O	Taub and Long (1972)
24	Variable	Variable	4/23	20/72	Y > O	Kliegl et al. (1989)
25	20	Variable	18/24	19/72	Y > O	Kliegl et al. (1989)
Mental squaring						
26	6	Variable	16/24	16/67	Y = O	Charness and Campbell (1988)
Intellectual abilities						
27	4	Variable	25/17	25/72	Y > O	Kamin (1957)

reported that older adults have greater difficulty learning to operate a text editor or word processor than do young adults (but see Hartley, Hartley, and Johnson, 1984, for a possible exception). Studies investigating the acquisition of other computer-related skills have also found that older adults require more time than do young adults to achieve comparable levels of proficiency (e.g., Gist, Rosen, and Schwoerer, 1988; Zandri and Charness, 1989).

Detailed analyses of the success of air traffic control trainees as a function of age have been reported by Trites, Cobb, and their associates (e.g., Cobb, Lay, and Bourdet, 1971; Trites, 1963; Trites and Cobb, 1964a; 1964b). A consistent finding in all of these studies was that older trainees were much less likely than younger trainees to complete the training program and perform successfully as a controller. One illustration of this age relation is evident in the ratio of failures to successes at different ages. According to Trites (1963), the ratio of failures to successes was 1:1 for trainees under the age of 35 but increased to 4.7:1 for trainees age 35 or older and reached 7.4:1 for trainees age 39 or older.

Although the sample sizes have been small and the range of manipulated experience limited, two findings from research on manipulated experience appear to be fairly consistent. The first is the encouraging result that virtually all of the available research suggests that both young and old adults improve their performance with additional experience. If it is the absolute level of functioning that is important, therefore, then adults of nearly any age may eventually reach acceptable limits of performance. However, the second consistent finding is the complete absence of evidence that age differences in certain types of cognitive performance are eliminated after all individuals have received comparable amounts of practice or training. At the present time there are not even many convincing demonstrations of Age × Practice interactions in which the size of the age differences in performance was merely reduced with extended experience. A tentative conclusion from the available research on manipulated experience, therefore, is that it is unlikely that age differences in measures of cognitive functioning can be easily eliminated by the provision of additional experience.

In light of this relatively negative conclusion, it is perhaps appropriate to briefly describe a research project that is sometimes cited as indicating that age-related cognitive deficits can be reversed with small to moderate amounts of training. Schaie and Willis (e.g., Schaie and Willis, 1986; Willis and Schaie, 1986b) relied on longitudinal data to classify older adults as having remained stable or having declined in either spatial or reasoning ability, and then they administered one of two training interventions designed to improve performance in either the spatial or reasoning domain. The hypothesis that the declines were attributable to experiential deprivation predicts that the individuals who had declined in a given ability would have greater training-related benefits in that ability than would the individuals whose abilities had remained stable. Contrary to the prediction, however, the results of the studies indicated that the training benefits were virtually equivalent for the individuals whose abilities had declined and for those whose abilities had remained stable. (One of four Group × Training interactions was significant at the 0.05 level, but considering that it occurred in the context of 60 statistical tests, it can probably be dismissed as a chance occurrence.) Because the experientially mediated improvements were not selective, the results of the Schaie and Willis studies provide no evidence that the training altered the processes or mechanisms actually responsible for the longitudinal decline. Therefore, in the absence of evidence that additional experience is of greater benefit to older adults than to young adults, or to individuals whose abilities had declined relative to those whose abilities had remained stable, it seems premature to claim that experiential interventions can reverse or remediate age-related cognitive declines.

SELECT POPULATIONS

A third manner in which experience could influence the magnitude of age-related effects on cognitive functioning is if age effects are attenuated when the activities are highly overlearned and in continuous use. In other words, extensively performed activities might be maintained at high levels of proficiency even if there are age-related differences in the efficiency of performing the activities when first encountered or in the ease of acquiring high levels of proficiency. This possibility can be investigated by examining age-related trends among individuals within certain experientially homogeneous categories, such as members of particular occupations. The reasoning is that if a given set of activities is regularly performed by all members of a particular occupation, and if extensive use prevents or retards age-related decline, then small to nonexistent age differences might be expected in measures of the efficiency or effectiveness of those activities. This category of evidence is therefore similar to that involving familiar activities, but the critical variation in experience is postulated to exist across different groups of people for the same activities, rather than across different types of activities for virtually all people.

Perhaps the optimal means of determining whether there are age differences in activities related to one's occupation is simply to examine age trends in appropriate measures of job performance. Although potentially informative, occupational performance studies suffer from a number of weaknesses that limit their value in determining the joint effects of age and experience on cognitive functioning. A major problem concerns the issue of selective attrition. On one hand, the poorest workers are unlikely to continue on a job because their employers will either lay them off or shift them to less demanding positions if they are unproductive. On the other hand, some of the best workers may not stay on the job because they will be promoted to positions of greater responsibility. It is difficult to determine which of these factors predominates in any given situation, but the strong possibility that the surviving older members in a given occupation are less representative of their age peers than are the younger members should make one very cautious in interpreting results based on age comparisons involving measures of job performance.

A second complication of analyses of age differences in occupational performance is that workers of different ages may not have precisely equivalent job requirements. Even within the same job classification, older workers often have more seniority than do their younger counterparts, and such seniority may result in more desirable—and, possibly, less strenuous or demanding—job assignments. To the extent that workers of different ages are not performing under identical conditions, therefore, age comparisons in measures of job performance may not be very meaningful.

Finally, age comparisons of job performance are sometimes of limited usefulness because the analyses are based on coarse evaluations of overall effectiveness in relatively broad occupational categories. It would be much more informative for the purpose of examining interrelations of age and experience on cognitive functioning if the age comparisons were reported on specific dimensions of job performance with known involvements of different types of cognitive abilities. Moreover, it is probably not sufficient merely to restrict comparisons to individuals within what is ostensibly the same job classification. For example, the cognitive demands would probably be quite different for mechanics primarily responsible for diagnosing engine problems compared with mechanics who spend most of their time changing tires. Although measures of overall effectiveness are frequently useful for personnel evaluation in actual work situations, collapsing across cognitively diverse activities in performance evaluations makes it very difficult to identify potentially systematic effects of age and experience on aspects of cognitive functioning.

Various combinations of these three factors may be partially responsible for the generally small and inconsistent relations between age and job performance reported in recent reviews (e.g., Davies and Sparrow, 1985; McEvoy and Cascio, 1989; Rhodes, 1983; Waldman and Avolio, 1986). In keeping with this suggestion, it should be noted that more systematic age relations are sometimes reported within relatively narrow occupational categories reported to have high cognitive demands. Several studies, for example, have reported significant negative correlations between age and rated effectiveness as an air traffic controller (e.g., Trites, 1963; Trites and Cobb, 1964a, 1964b) with almost no attenuation of the age-related effects after controlling for amount of experience (e.g., Cobb, 1968; Matthews and Cobb, 1974).

Comparisons across adults of varying ages from select occupations have also been reported on measures of performance derived from specially designed experimental tasks or psychometric tests. Studies of this type generally provide more analytical information than do those based on overall evaluations of job effectiveness, but the performance measures are sometimes of questionable relevance to the occupation. An illustration of the confusion that can result from the lack of objective evidence concerning the relevance of measures to occupational activities is evident in a comparison of two studies in which age trends in the speed of handwriting were examined in samples of adults from different occupational groups. Smith and Greene (1962) reported very slight age effects "in professional and managerial groups, which use handwriting as a familiar daily task" (p. 161), but LaRiviere and Simonson (1965) claimed that there was a decline in handwriting speed among members of professional and managerial occupations "whose jobs did not require a great deal of writing" (p. 416). Regardless of the purported difference in outcomes (which should be considered tentative because apparently in neither case were the age trends evaluated statistically), one cannot hope to reach meaningful conclusions about the contributions of experience when there is so little agreement about the frequency of the target activity in different occupations.

Two of the most intriguing studies within the select population category were reported by Murrell and his colleagues. Murrell, Powesland, and Forsaith (1962) reported no performance differences between experienced young and experienced old operators of a drill press, but they found that novice older adults performed at lower levels than did novice young adults. A similar finding of no age differences among experienced workers and age differences favoring young adults among inexperienced individuals was reported by Murrell and Humphries (1978) with the task of speech shadowing among simultaneous language translators. Although these results are consistent with the interpretation that extensive experience prevents age-related declines that would otherwise occur, they are also consistent with a selective survival interpretation in that the experienced older adults may be a positively biased sample of their age group. It is unfortunate that additional information that might have allowed an assessment of the representativeness of each sample was not provided to allow these possibilities to be distinguished.

Most of the research involving targeted occupational groups has focused on pilots and air traffic controllers because of their importance to air transportation safety. Furthermore, because a key requirement in these jobs is effectiveness in high-speed decision making, the majority of the research has focused on various measures of speeded performance. For example, one project measured choice reaction time and digit symbol substitution performance in air traffic controllers and civil air pilots (Birren and Spieth, 1962; Spieth, 1964). Both reports (based on 161 and 560 adults, respectively) revealed that measures of perceptual-motor speed declined with increased age in these samples. Despite a restricted age range, with 83% of the individuals below the age of 50, correlations with age in the Birren and Spieth study were 0.59 with choice reaction time and 0.42 with digit symbol substitution performance. Both of these values are comparable in magnitude to those found in unselected samples of adults (see Salthouse, 1985a).

Another project involving the measurement of reaction time among airline, military, and test pilots of different ages was conducted by Szafran (1970). Szafran hypothesized that flying required making high-speed decisions and receiving and retaining information while carrying out routine operations. A choice reaction time task containing three, five, or eight alternatives was therefore administered either alone or in the presence of a concurrent memory task requiring the report of items presented two positions earlier in the sequence. The primary dependent variables were (1) the slope and intercept of the regression lines relating reaction time to number of alternatives in the single and concurrent conditions and (2) a measure of the amount of information transmitted in each condition. Interim reports of the project were published, with successively larger samples, in several articles appearing between 1965 and 1968. Results from what was apparently the final report, based on a total of 396 pilots, were described in a 1970 publication (Szafran, 1970). The major findings were that there were no significant correlations between age and measures from the reaction time task when it was performed alone, but that when the memory task was performed concurrently with the reaction time task, there were significant increases with age in the intercept of the regression equation relating number of stimulus-response alternatives to reaction time ($r = 0.26$) and in the number of errors in the memory task ($r = 0.16$), and a significant age-related decrease in the rate of information transmission ($r = -0.35$).

Although in his early reports Szafran suggested that these results were inconsistent with the findings from unselected adults, it is not clear that such a conclusion is justified because the individuals in his sample were unrepresentative of the general population in several respects. For example, his sample of pilots was probably healthier, of a higher socioeconomic level, and from a more restricted age range (i.e., 79% of the pilots were younger than 50 years of age) than participants in many other studies. Furthermore, because absolute levels of performance and, possibly, the relations between age and performance vary as a function of the particular apparatus and procedures employed, it is risky to make inferences about age trends in unselected adults without actual measurements using the same procedure and apparatus.

Perhaps the most comprehensive age-related project involving aircrew personnel was that of Glanzer and Glaser (e.g., Glanzer and Glaser, 1959; Glanzer, Glaser, and Richlin, 1958). These researchers based their selection of job-relevant tests of perceptual and intellectual functions on an earlier study of critical incidents and on a detailed job analysis of aircrew activities. A total of 544 aircrew personnel, 518 of whom were pilots in the Air National Guard or working for commercial airlines, were administered a battery of 14 psychometric tests. Significant age-related declines were reported on eight of the tests. Two of the tests with the largest age correlations were the orientation to new equipment ($r = -0.20$) and instrument comprehension ($r = -0.33$) tests. The former assessed comprehension and memory of information about new equipment of the type presented in oral briefings, and the latter required the integration of information from a compass and an artificial horizon to determine current position of an airplane. What is particularly striking about these correlations is that although they were small in absolute magnitude, they were still statistically significant when hours of flying experience was partialed out (i.e., -0.15 for orientation to new equipment and -0.24 for instrument comprehension), and the correlations were almost certainly attenuated by a restricted age range. That is, although pilots up to age 50 were tested, the mean age in the sample was only 31.8 years, and 80% of the participants were less than 35 years old.

One of the few studies in the select population category not focusing on aircraft pilots was recently reported by Salthouse, Babcock, Skovronek, Mitchell, and Palmon (1990), who measured spatial visualization abilities among practicing architects. The major assumption underlying this project was that architects are continuously involved in the production or interpretation of two-dimensional drawings of three-dimensional objects. It was therefore hypothesized that because they have received frequent experience using their spatial visualization abilities, architects might exhibit much smaller age-related declines in measures of spatial visualization performance than would unselected adults. This was not the case, however; significant age-related decrements were found in three separate measures of spatial visualization performance.

Figure 2 illustrates the regression equations summarizing the relations between age

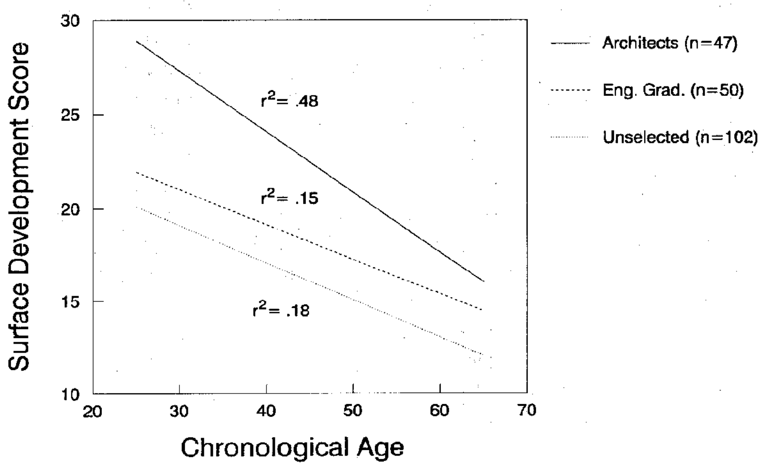

Figure 2. *Regression equations relating age to surface development performance for three groups of male college graduates. Data from Salthouse et al. (1990) and Salthouse and Mitchell (in press).*

and performance in three samples of adult males on one of the spatial visualization measures—that is, the score on the surface development test, which requires determination of the correspondence between edges on unassembled and assembled drawings of three-dimensional objects. Each sample consisted entirely of male college graduates with mean ages in the mid-40s, but the samples differed with respect to whether the individuals were practicing architects, graduates of a college with a predominantly engineering-oriented curriculum, or unselected adults responding to a newspaper advertisement for volunteers for behavioral research projects.

Although the regression line for the architects is above that of the engineering school graduates and unselected adults, the slopes—which indicate the amount of performance decline with each additional year of age—are very similar. If anything, the age relation, as indexed by both the slope and the percentage of variance accounted for by the linear equation, appears greater for the architects who presumably have the greatest experience with activities related to the performance measure.

This basic result has been replicated in a subsequent study (Salthouse and Mitchell, in press), in which unselected adults were categorized in terms of naturally occurring experience with activities presumed to require spatial visualization abilities. As in the architect study, the age trends were nearly identical for adults reporting different amounts of experience with the relevant activities.

Research with select populations offers the opportunity for investigating the effects of much more extensive amounts of experience than that generally possible in practice or training studies. However, it suffers from the problem that the young and old members of the target groups might not be equally representative of their age peers because of the possibility of selective attrition. Results from several studies seem to suggest that age-related declines may still be evident in measures of occupationally relevant activities, but the findings should be considered tentative until they are replicated with larger samples, with individuals from a broader range of ages, and with a greater number of performance measures of documented relevance to the occupation.

LIMITATIONS OF EXISTING RESEARCH

In addition to the specific methodological problems discussed in the context of each category of evidence, two broader objections can be raised against most of the research reviewed so far. These are that the analyses have generally ignored the contribution of knowledge factors and that most of the studies have been based on a rather narrow conceptualization of the consequences of experience.

One of the dominant distinguishing characteristics of experts in any given field is their possession of large amounts of structured knowledge. However, knowledge factors have largely been neglected in age-comparative studies focusing on fluid or process aspects of cognition. This is a potentially serious omission because effectiveness in many situations may depend more on factors related to one's knowledge than on the efficiency with which one can execute basic processing operations. In fact, Schmidt, Hunter, and Outerbridge (1986) reported that in some situations a sizable proportion of the influence of experience on job performance is mediated through greater job knowledge. Important goals of future research should therefore be to document relations between quantity or quality of knowledge and the variables of age and experience, and to identify the specific manner by which knowledge factors contribute to enhanced performance in particular cognitive activities.

Although seldom explicitly stated, most of the studies designed to investigate interrelations of age and experience seem to have implicitly adopted either a maintenance (i.e., experience preserves abilities that would otherwise decline) or a remediation (i.e., added experience reverses ability declines) interpretation of the role of experience. It is possible, however, that the most pronounced effects of experience are not evident at the level of basic abilities but instead are operative at more global or molar levels. Consistent with this suggestion are several reports of age invariances in the proficiency of a molar activity despite age-related declines in measures of presumably relevant molecular components. This general pattern has been reported in activities of bridge (Charness, 1979), chess (Charness, 1981; Pfau and Murphy, 1988), and transcription typing (Salthouse, 1984; Salthouse and Saults, 1987). The apparent implication of these findings is that the composition of competence may shift with increased age and experience.

Several mechanisms by which experience might result in the preservation of overall competence despite age-related declines in the efficiency of basic processes have been discussed by Salthouse (e.g., 1984, 1987a, 1987b, 1989a, 1989b). For example, effective functioning might be maintained by (a) *compensation,* in which losses in some processes are offset by gains in other processes; (b) *accommodation,* in which the nature of one's activities is altered to minimize deficit-revealing situations; (c) *elimination,* in which the impaired processes are gradually reduced in importance as proficiency in the relevant skills develops; and (d) *compilation,* whereby once the higher-order skills are assembled or compiled, they become independent of any subsequent declines in the efficiency of the constituent processes. Unfortunately, very little research with reasonably complex activities has been reported which would allow these speculations to be investigated and discriminated. This is regrettable because it is at least plausible that the greatest effects of experience are evident not in the efficiency of basic processes but rather at higher-order levels concerned with the optimal combinations of different abilities to maintain or increase competence in relatively complex activities.

CONCLUSION

Because the currently available evidence is equivocal, there is ample opportunity for one's biases and prejudices to influence the nature of the conclusion regarding the possibility that experience attenuates age-related differences in cognition. If the lack of strong evidence for an experientially mediated reduction of age differences is emphasized, then one could reasonably argue for a negative conclusion. However, if one focused on the methodological and conceptual limitations of previous studies, then it could be justifiably claimed that a positive conclusion might still be forthcoming after the appropriate studies have been conducted.

The most defensible conclusion at the present time is probably that it is too early to reach a conclusion. That is, the existing research is still too equivocal to allow firm decisions about whether age differences on familiar activities are smaller than those on novel activities, whether age differences can be reduced or eliminated with extensive experience, or whether age differences are absent on continuously practiced activities associated with one's occupation. Instead of trying to force a decision from currently inadequate data, therefore, it will be more productive to use the lessons learned from earlier studies to guide the design of future studies, which might eventually allow more definitive conclusions. Among the features that should be included in future research are (a) use of larger samples to provide a firmer foundation for generalizability; (b) inclusion of multiple indicators of the relevant abilities to allow inferences at the level of interesting theoretical constructs rather than single, potentially task-specific, variables; (c) exploration of the contribution of knowledge factors to different measures of performance; (d) examination of relatively complex activities that permit analyses of the manner in which a given level of proficiency is accomplished; and (e) better documentation of the extent and type of experience to ensure realism and relevance of the experience to the measured abilities.

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