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COGNITIVE TRAINING IN THE NORMAL ELDERLY

Sherry L. WILLIS and K. Warner SCHAIE *

Cognitive training research is one avenue to examining cerebral plasticity in old age. The term plasticity is used in this chapter to indicate the range of variability in cognitive behavior at the individual level (Perlmutter, 1990). There are at least three approaches to the study of cognitive plasticity in old age. First, one can chart the rate and the pattern of change in cognitive functioning that occurs as the individual progresses from young-old to old-old age; longitudinal designs afford the appropriate method for the study of age-related change (Schaie, 1983, 1990). A second approach makes use of naturally occuring events (head trauma, stroke) to examine the rate and range of recovery of functioning that occurs spontaneously or via a planned intervention after the event. The third approach involves an experimental manipulation in which the elderly are exposed to a medical or behavioral intervention and the magnitude of change in functioning associated with treatment is assessed by examining level of behavior prior to and after the intervention (Willis, 1987). This chapter describes a program of research involving this third approach to the study of cognitive plasticity.

Much of the focus in the study of cerebral plasticity has been on pathological or non-normative aging. This emphasis on pathological aging is understandable given the severe loss of cognitive functioning that is the hallmark of the dementias or that results from head injuries. However, epidemiological surveys indicate that most elderly do not suffer from pathological aging (Blazer, 1980; La Rue, Dessonville, & Jarvik, 1985). It is estimated, for example, that even in advanced old age (the decades of the 80s and 90s), at most 20% of US elderly suffer from Alzheimer's disease. Although most elderly may not suffer from neurological pathologies, there is increasing vulnerability with advancing age to normal age-related decline in certain mental abilities. The question therefore arises whether age-related, nonpathological decline in cognitive functioning is modifiable through educational interventions. Remediation of nonpathological cognitive loss is an important

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issue not only for the elderly themselves who fear loss of independence due to cognitive decline, but also for societies in general, since the elderly are expected to represent at least 20% of the population in most developed countries by 2030 or earlier (US Bureau of the Census, 1991).

In this chapter, we will review a program of research that examines the modifiability of cognitive behavior in normal elderly by employing educational intervention procedures. We will address five issues related to training effects.

1) **What ist the magnitude of training improvement?**
2) **What individual difference characteristics are related to the effectiveness of training?**
3) **How general or broad are the training effects?**
4) **Are the training effects durable over time? and,**
5) **What are the implications of interventions on basic mental abilities for tasks of daily living?**

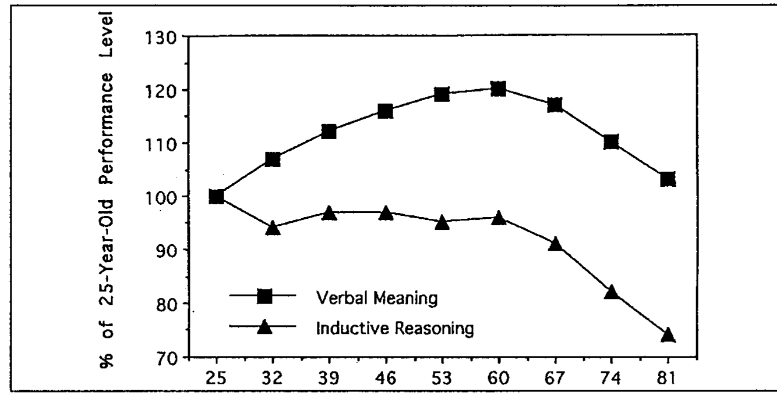
NORMAL AGE-RELATED CHANGE IN MENTAL ABILITIES

The presentation of findings from our training study needs to be placed in the context of prior longitudinal research on normal age-related change in cognitive behavior. Our approach to the study of intellectual aging has been **to focus on the changes that occur with age in a number of psychometric mental abilities.** The psychometric approach assumes that adult intelligence can be described in terms of a number of mental abilities; the adult's level of functioning on each ability is inferred from his/her performance on a number of tests known to represent that ability (Thurstone, 1962). The mental abilities perspective maintains that **adult intelligence needs to be studied as a multidimensional phenomena,** involving a number of different mental abilities; this approach is in contrast to a unidimensional, global perspective that focuses on a single composite test score that describes overall level of intellectual functioning, such as is obtained on the Wechsler Adult Intelligence Scale (Matarazzo, 1972; Wechsler, 1958, 1981).

• *Differential patterns of ability change*

The emphasis on the study of a number of different mental abilities is based on findings of longitudinal research, indicating that various abilities exhibit different patterns of change from young adulthood to old age (Schaie, 1983, 1990). *Figure 1* presents two contrasting patterns of age-related change for two different abilities, Verbal ability and Inductive reasoning. The pattern of age-related change for each ability is shown from age 25 years to 81 years; performance at different ages is calibrated in comparison to that of a 25-year olds, anchored at 100%. These data come from the *Seattle Longitudinal Study,* a major program of longitudinal research which has examined age-related change in mental abilities from young adulthood to old age over a thirty-five year period (Schaie, 1983, 1990, 1993, in press). Verbal ability is assessed by vocabulary measures examining the adult's ability to identify synonyms for a stimulus word. Inductive reasoning involves abstarct reasoning and is assessed by measures examining the adult's ability to identify patterns or rules in a series of letters or numbers and to utilize this rule in finding the next letter or number in the series.

FIGURE 1
Longitudinal age changes in ability performance level



The pattern of change from 25 to 81 years is quite different for the two abilities. For verbal ability, there is an increase in performance from young adulthood (age 25) with peak performance being reached in the 50's or 60's; reliable age-related decline does not occur until the mid 70's. In contrast, the pattern for inductive reasoning is stable across middle age with reliable decline occurring by the mid 60's. Two items are noteworthy. First, the age of peak performance varies by ability, occurring in young adulthood for inductive reasoning, but not until late middle age for verbal ability. Second, the age at which reliable decline is first noted varies by ability, occurring in the mid 60's for inductive reasoning, but not until the mid 70's for verbal ability.

• *Individual differences in rate and pattern of ability decline*

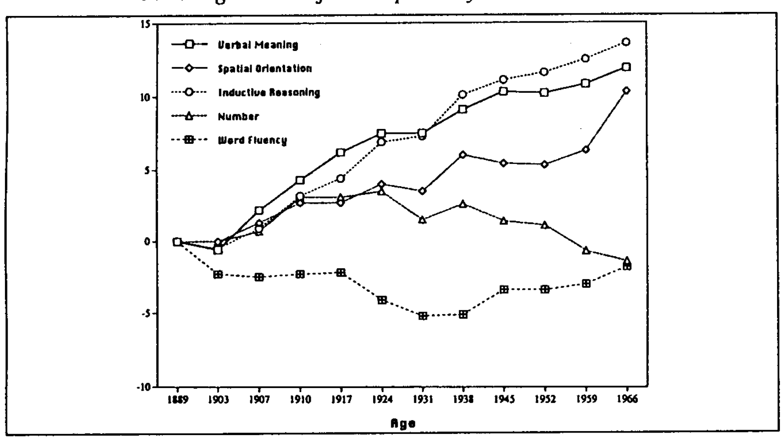
Figure 1 presents **normative data** on the pattern and rate of change in cognitive abilities. There are wide individual differences in the age of onset of reliable ability decline, and in the rate of decline. Older adults in the Seattle Longitudinal Study were classified as whether they had remained stable or declined for the preceding seven-year interval (60 to 70 years, 67 to 74 years, 74 to 81 years (Schaie, 1983, 1984). Although reliable age-related decline occurs, on average, in the mid 60's on inductive reasoning, considerable variability becomes evident when the pattern of change is examined at the individual level. For example, only 20% of adults exhibited reliable age-related decline from 60 to 67 years of age; 36% experienced decline between 67 and 74 years, and over 60% showed decline between 74 and

81 years. Thus, **age-related decline is a highly individualized phenomenon,** even when considering abilities that exhibit relatively early normative onset of decline.

• *Cohort differences in level of ability performance*

The study of individual variability in ability functioning is further complicated by the large cohort differences in level of performance (Schaie, 1983; Schaie & Hertzog, 1983). When the ability performance of successive birth cohorts is examined at the same chronological age, there are significant differences in level. *Figure 2* presents cohort differences in ability performance for eleven different cohorts; the 1889 birth cohort serves as the cohort base. Cohort differences are shown for five primary mental abilities (verbal meaning, spatial orientation, inductive reasoning, number, and word fluency). The cohort trends vary across different abilities. There is a strong linear positive cohort trend for inductive reasoning, with each successive cohort performing at a higher level; there are also positive linear trends for the earlier cohorts for space and verbal ability, with a plateauing of cohort differences for the more recent cohorts. In contrast, there is a curvilinear trend for number ability, and a negative trend, at least for the earlier cohorts, for word fluency.

FIGURE 2
Cohort gradients for the primary mental abilities



• *Implications of findings from longitudinal research for training*

At least three implications from the findings of longitudinal research need to be considered in the design of cognitive training. First, there are differences among abilities in the age of onset of reliably detected decline (Schaie, 1983, 1989a, 1990). If one of the objectives of intervention is to examine the remediation of cognitive decline, then the timing of the intervention needs to take into account average age of onset of decline for a given ability (Willis, 1990b). Since most adults do not experience reliably detectable decline in psychometric mental abilities until old age, interventions begun in middle age would need to target those rare individuals suffering unusually early decline. Even in old age, there is almost a ten-year span over which different abilities begin to show, on average, reliable decline. Intervention efforts could initially be targeted for abstract reasoning and speed-related abilities, since these abilities exhibit normative patterns of decline beginning in the mid 60's. On the other hand, interventions focused on acculturated skills, such as verbal abilities, should be targeted at older ages, since reliable decline on these abilities, on average, is not detected until the mid 70's.

Second, intervention efforts must consider the wide individual differences in age of onset of decline (Schaie & Willis, 1986). As noted above, many older adults have not experienced reliable decline even by age 70 in those abilities, such as inductive reasoning, that exhibit normative patterns of decline in the mid 60's. **Unless the developmental history of an individual is known, it is not possible to determine whether training improvement reflects the remediation of prior decline or enhancement of performance for an individual who has not experienced decline** (Willis, 1987, 1990b). If training researchers studied only subjects 80 years of age or older, then they could reasonably assume that most of their subjects had experienced some age-related decline. However, subjects seeking out training are generally the young-old, that age period in which there are the widest individual differences in patterns of decline. Third, one must take into account cohort differences in level of performance. This is particularly important when training efforts are focused on mental abilities showing positive cohort trends. In comparing the training outcomes, for example, of young old (60-74 year olds) versus old-old adults (75+ years), both age groups may have profited from training but the old-old group may be functioning at a lower level due to initial cohort differences in performance level.

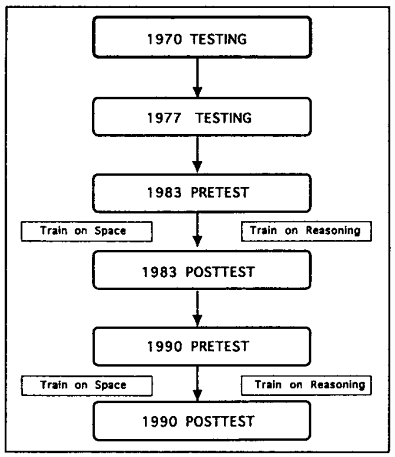
TRAINING RESEARCH WITHIN THE SEATTLE LONGITUDINAL STUDY

• *Design of the Seattle Training Study*

We now turn to the presentation of findings from the Seattle Training Study. All subjects were older adults drawn from the Seattle Longitudinal Study (SLS). The Seattle Longitudinal Study was begun in 1956 by K. Warner Schaie (1983, 1989a, 1990, 1993). The functioning of adults across the adult lifespan from age 22 to death has been examined in seven-year intervals on five primary mental abilities: Verbal Meaning, Spatial Orientation, Inductive Reasoning, Number and Word Fluency ability. Subjects in the Seattle Training Study had been participants in the SLS since 1970 or previously. The training study was begun in 1984 (Schaie & Willis, 1986; Willis, 1990a; Willis &

Schaie, 1988). *Figure 3* presents the design of the Seattle Training Study. Subjects' performance was examined on two primary mental abilities, Inductive Reasoning and Spatial Orientation, over the fourteen years (1970-1983) prior to training. Subjects were classified as having reliably declined over the fourteen year interval on one or both of the abilities, or as not having declined. Subjects were assigned to training on Inductive Reasoning or on Spatial Orientation on the basis of their decline status. Subjects who had declined on only one of abilities was assigned to training on the ability on which they had declined. Subjects who had declined on both abilities or who had remained stable on both abilities were randomly assigned to training on one of the abilities. Forty-seven percent of the subjects had not declined on either ability; approximately 15% had declined on one of the abilities but not on the other; only 22% of the subjects had declined on both abilities. All subjects were posttested following the training program.

FIGURE 3
Design of the Seatle Training Study



A follow-up study was conducted seven years later in 1990 (Willis & Schaie, 1992). Subjects were pretested to assess their current level of performance and to examine the question of the temporal durability of training effects. Subjects then took part in booster training on the same ability on which they were trained in 1983. The booster training was very similar in format to the training program used in 1983. Subjects were posttested following the booster training.

• *Description of the subjects*

Participants in the training study were 229 older adults (M = 97; F = 132). Mean age of the sample was 72.8 years (Range = 64-95). Mean educational level was 13.9 years (Range 6-20 years). There were no sex differences in age or educational level. All subjects were living independently in the community. Prior to initiation of the study, each subject's physician was contacted and asked to indicate whether the subject suffered any known physical or mental disabilities that would interfere with participation in the study; subjects so identified were not included in the study. Based on the assignment procedure described above, 118 subjects were trained on Spatial Orientation, and 111 subjects were trained on Inductive Reasoning.

• *Abilities trained*

Inductive Reasoning and Spatial Orientation abilities were the focus of the two training programs (Schaie, 1985; Thurstone, 1962). Of the five mental abilities examined within the Seattle Longitudinal Study, these two abilities were selected for training since many elderly were expected to be disadvantaged in their performance for two reasons. First, these abilities exhibit a relatively early age for onset of decline, in the mid 60's. Second, these abilities show positive cohort trends; thus, even elderly who had not experienced decline may function at a lower level on these abilities, compared with more recent cohorts, as a function of cohort differences.

Inductive Reasoning involves abstract thinking, often assessed under speeded conditions. Tests of Inductive Reasoning require the subject to identify the pattern or relational rule in a series of numbers of letters and to utilize the rule to determine the next letter or number in the series. **Spatial Orientation** also involves abstract thinking, but with regard to nonverbal material. The subject must be able to mentally rotate a two-dimensional figure in two-dimensional space. Tests of Spatial Orientation require the subject to identify which of six figures could be rotated in two-dimensional space to the same position as a stimulus figure.

• *Description of the two training programs*

The focus of the training was on facilitating the subject's use of effective cognitive strategies identified in previous research on the respective abilities (Schaie & Willis, 1986; Willis, 1990c).

• **For the Reasoning training program,** the pattern description rule(s) used in problem solution were identified. Four major types of pattern description rules (identity, next, skips, and backward next) were indentified, similar to those discussed previously in the literature (Holzman, Pellegrino, & Glaser, 1982; Kotovsky & Simon, 1973). Practice problems and exercises were developed, based on these pattern description rules. Practice problems often involved content other than letters so that the applicability of these rules to other content areas could be explored. For example, patterns of musical notes and travel schedules were devised, based on these rules, and subjects were to identify the next note or destination in the series. Subjects were taught through modeling, feedback, and practice procedures to identify these pattern description rules.

• **For the Space training program,** a content analysis of the PMA Spatial Orientation test was conducted to identify the angle of rotation for each answer choice. Practice problems were developed to represent the angle rotations identified in the task analysis (45°, 90°, 135°, 180°). Cognitive strategies to facilitate mental rotation that were focused on in training included:

a) development of concrete terms for various angles;
b) practice with manual rotation of figures prior to mental rotation;
c) practice with rotation of drawings of concrete, familiar objects prior to introduction of abstract figures;
d) subject-generated names for abstract figures; and
e) having the subject focus on two or more features of the figure during rotation.

These cognitive strategies had been identified in prior descriptive research on mental rotation ability (Cooper & Shepard, 1973; Egan, 1981; Kail, Pellegrino, & Carter, 1980).

FINDINGS FROM TRAINING RESEARCH WITHIN THE SEATTLE LONGITUDINAL STUDY

• *Training Effects for Stable and Decline Subjects*

Since most cognitive intervention studies have focused on mental abilities that exhibit early normative patterns of decline, there has often been the assumption that training improvement reflects primarily a remediation or reactivation of previous levels of cognitive functioning. However, the SLS data suggest that the assumption that training solely results in a reactivation of pre-existing skills is too simplistic and not completely accurate because not all older adults have suffered age-related decline. In our Seattle training research only 22% of the subjects had declined on both abilities; 47% had not declined on either of the abilities that were the focus of training (Schaie & Willis, 1986). Thus, one should expect qualitatively different outcomes for stable subjects who exhibit no prior decline when compared to subjects who have experienced decline.

Figure 4 presents the mean inductive reasoning scores for stable and decline subjects trained on reasoning at three occasions:

a) in 1970, fourteen years prior to training;
b) at the 1984 pretest, immediately before training;
c) at the 1984 posttest, following (Willis, 1990a).

Figure 5 similarly presents the mean scores for stable and decline subjects trained on spatial orientation (Schaie & Willis, 1986; Willis & Schaie, 1988). The pattern of training results is similar for the two abilities. In 1970, fourteen years prior to training, stable and decline subjects were performing at the same level on each target ability. At the 1984 pretest, decline subjects were performing at a significantly lower level. Training resulted in significant performance gain for both stable and decline subjects. However, the nature of the training effects is qualitatively different for the two groups.

For decliners, training was effective in returning their performance close to their 1970 score level. On the other hand, after training the stable group was performing, on average, above their 1970 level. For stable subjects then, the effect of training was to raise their performance level above that previously demonstrated, while for decliners there was partial remediation of age-related decline.

FIGURE 4
Training gain on the Inductive Reasoning ability

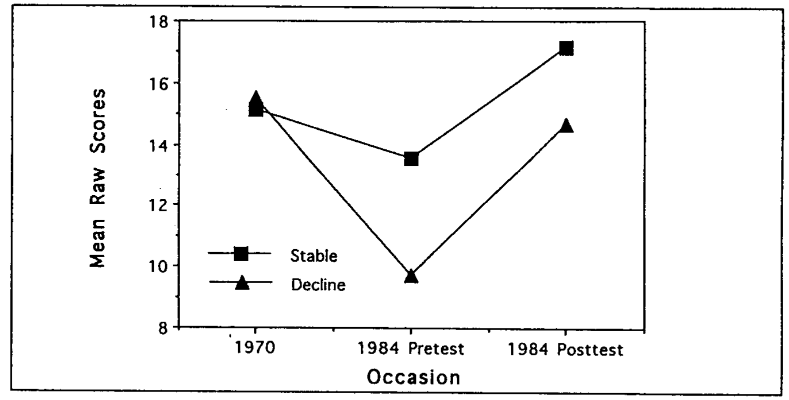
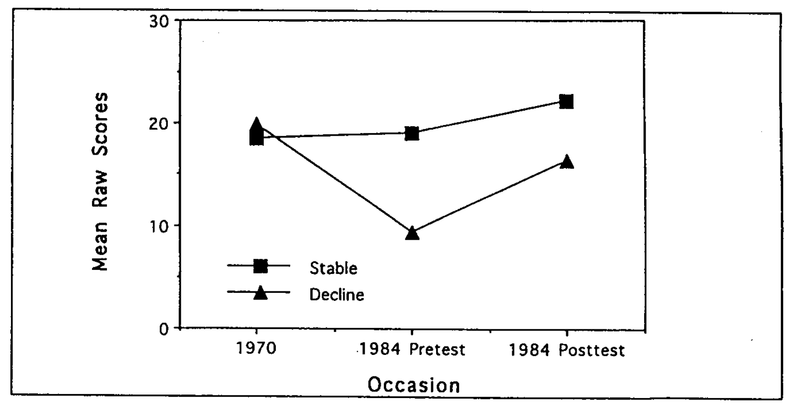


FIGURE 5
Training gain on the Spatial Orientation ability



The above figures provide information on training effects in terms of mean scores. Plasticity, however, is construed as an intraindividual phenomenon, and therefore assessment of training effects at the individual level is of particular interest (Schaie & Willis, 1986; Willis, 1990b). Two questions can be examined. First, what proportion of stable and decline subjects demonstrated significant training gain from pretest to posttest? Second, what proportion of decline subjects exhibited remediation to their 1970 score level? With regard to the first question, **approximately 50% of subjects in each training group showed significant improvement from pretest to posttest.** There was a trend for a greater proportion of decline subjects to show improvement in both training conditions. The second question deals with the proportion of decline subjects showing complete remediation of prior age-related decline. To assess remediation of decline, we examined the proportion of decline subjects whose performance at posttest was equal to or greater than their score fourteen years previously, in 1970. **Approximately 40% of decline subjects exhibited complete remediation.** There was no significant difference in the proportion of subjects for whom remediation occurred for reasoning versus space training. Thus, the data suggest that decline on both space and reasoning ability is responsive to training efforts.

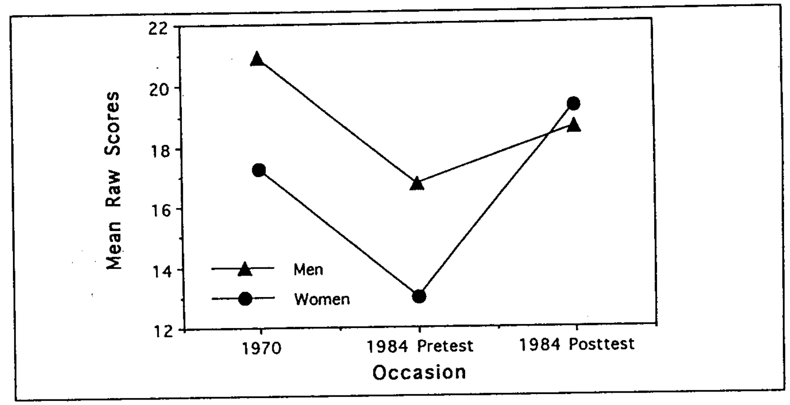
• *Individual Difference Variables Associated with Training Effects*

Not all individuals profit to the same degree from training intervention. What individual difference variables account for substantial variability in training effect? Two such variables are of particular note in our research: Gender and cohort.

• **Gender differences.** Gender differences in psychometric ability performance have been consistently noted at early stages in the lifespan (Linn & Petersen, 1985; McGee, 1979). For example, mean score differences in favor of males have been reported in spatial orientation ability, beginning in middle childhood, although there is considerable overlap in the distribution of scores for males and females. Likewise, gender differences in favor of women have been observed for the psychometric ability of inductive reasoning (Schaie, 1983). There has been, however, **relatively little research on gender differences in ability performance in midlife and old age.** Several questions with regard to gender differences in old age arise. First, there is the question of whether the magnitude of gender differences remains fairly constant as age-related decline occurs, or whether the gender gap becomes smaller. Second, there is the question of plasticity with regard to gender differences in old age? That is, would cognitive training in old age be effective in reducing the magnitude of the gender difference? These questions could be addressed within the SLS, given the longitudinal nature of the data and the targeting of intervention efforts on abilities exhibiting well established gender differences in mean level of performance.

Figure 6 presents findings with regard to gender differences in old age on spatial orientation ability; data is presented for those subjects experiencing reliable decline on spatial orientation (Willis & Schaie, 1988). Significant mean score differences in favor of men are show in 1970, fourteen years prior to the training intervention. Over these fourteen years prior to training (1970-1984 pretest), significant age-related decline occurs for men and women. Of interest is the finding that the magnitude of the gender difference remains relatively constant across this period of decline. Women exhibit greater training gain (1984 posttest) than do men. As a result of gender differences in training improvement, however. Women at posttest are performing, on average, at a level comparable to that of the men. The gender difference in mean level of performance has been eliminated as a function of training!

FIGURE 6
Gender differences in training gain on the Spatial Orientation ability

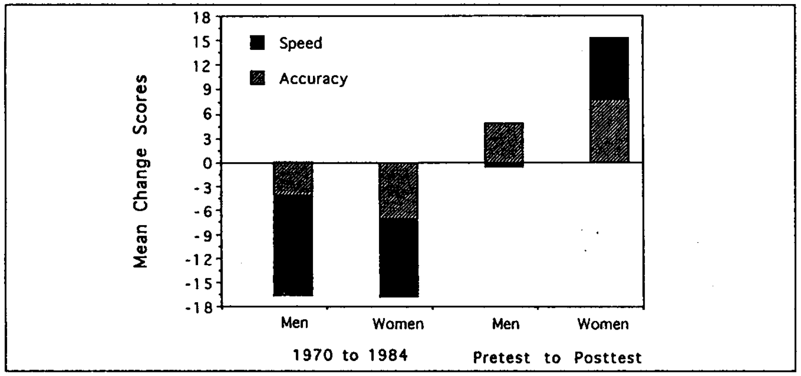


In order to understand more fully the nature of gender differences in spatial orientation, we decomposed the change scores into that portion of change associated with shifts in accuracy as contrasted to increase or decrease in problem solving speed, taking into account changes in the number of items attempted both across occasions and across gender (Willis & Schaie, 1988).

Figure 7 presents change scores on spatial orientation ability. The left side of this figure shows the magnitude of age-related decline for males and females; the part of the change score attributed to a decline in accuracy versus a decline in speed of problem solving is shown.

Whereas for women the portion of the change score associated with a decline in accuracy and speed is fairly equal, a greater portion of the change score for men is associated with a decline in speed (also see Schaie 1989b). The right side of the figure shows pre-posttest training gain scores for men and women. Note that women exhibit a mean gain score roughly equivalent to the magnitude of age-related decline. The mean gain score for men, however, is less than the mean age-related decline score. For women, training gain reflected improvement in both accuracy and speed of performance; almost a mirror image of their decline score. In contrast, the training gain for men was almost solely a function of improvement in accuracy; virtually none of the age-related decline associated with speed was remediated as a function of training. Thus, gender differences in training improvement reflect not only differences in the magnitude of training gain but also in the qualitative nature of the improvement associated with intervention.

FIGURE 7
Charge in speed and accuracy on the Spatial Orientation ability

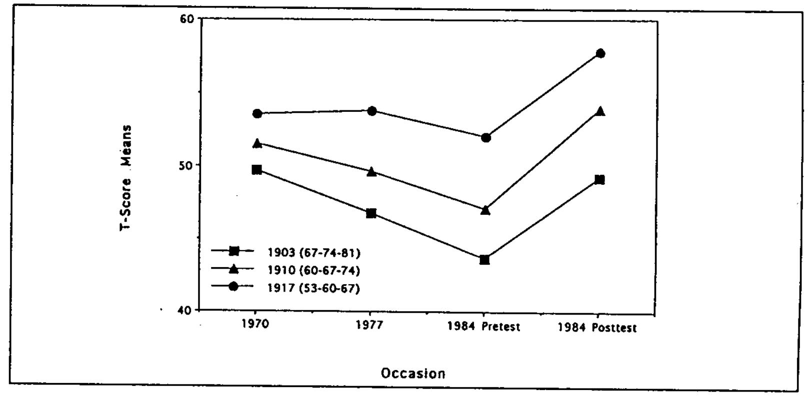


• **Cohort differences.** Positive cohort trends have been reported for inductive reasoning and to a lesser extent for spatial orientation in cohort-sequential research (Schaie, 1983, 1993; Schaie & Hertzog, 1983; Willis, 1989). Assuming cohort differences in level of performance, there is the question of whether training effects would differ by age/cohort.

Figure 8 shows mean scores on inductive reasoning at four occasions (1970, 1977, 1984 pretest, 1984 posttest) for three age/cohorts; the 1903 birth cohort shown at ages 67, 74, and 81; the 1910 birth cohort shown at ages 60, 67 and 74 years; and the 1917 birth cohort shown at ages 53, 60, 67 years (Willis, 1990a). Significant age-related decline on inductive reasoning has occured for the 1903 and 1910 cohorts (left side of figure) prior to training. The performance of the 1917 cohort was relatively stable over the 1970-1984 period; they were middle-aged during most of this interval. Note that after training the 1910 and 1917 cohorts were performing, on average, at a level above their 1970 base. In contrast, for the 1903 cohort, remediation of age-related decline was barely complete, on average.

Note also that age/cohort differences in level of performance are present at all points of measurement. While training was effective in remediating decline, on average for the two most recent age/cohorts, the magnitude of training effects was not sufficient to eliminate cohort differences (Willis, 1990a). Indeed, there is a slight fanning out of the cohorts' performances across measurement occasions. Given that age and cohort are confounded, it is not possible to determine whether this increasing variability is attributable to age or cohort. However, given data presented previously (Schaie, 1990), in which cohort differences were not evident for the oldest age group, it would appear that age may be the more significant factor in explaining the disparate performance of the oldest group.

FIGURE 8
Cohort differences in training gain on the Inductive Reasoning ability



In summary, **we have examined two sources of interindividual variability in training enhancement: Gender and cohort differences.** The training intervention was effective in reducing or eliminating gender differences in performance on measures of spatial orientation. Following training, women were on average performing at the same level as men. Training, however, was not as effective in reducing or eliminating individual differences associated with cohort. Cohort differences in mean performance level remain, or increased slightly, as a function of training. At the same time, **with respect to intraindividual change, training was uniformly effective.** That is, men and women and all three birth cohorts exhibited significant improvement.

• *The Breadth or Generality of Training Effects*

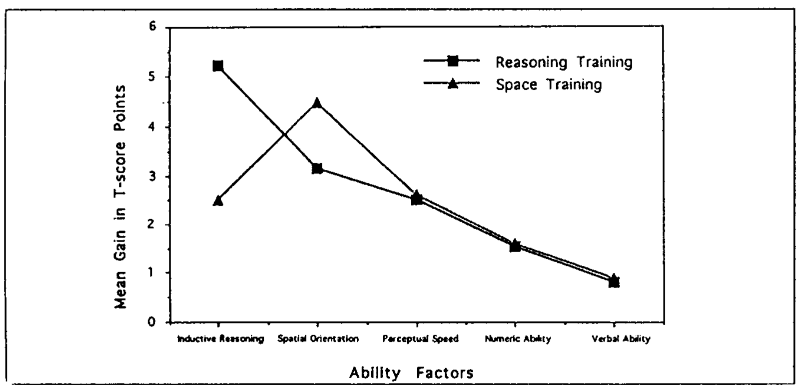
Perhaps one of the most debated issues in cognitive intervention research has been the issue of training transfer. How broad or general should training effects be expected to be? Our research indicates that **training effects occur at the latent construct level, and are ability-specific** (Willis & Schaie, 1986a).

• **Training effects at the latent construct level.** The focus of training effects is the cognitive construct or latent variable (e.g., the psychometric ability, for example, inductive reasoning), not improvement on a particular test (Willis & Schaie, 1986a; Willis, 1990a). Latent constructs, however, can only be indirectly assessed via observable behaviors, such as test scores on measures shown to represent the ability. Training gains, if assessed solely at the level of a single test score, represent a confound of variance common to the latent construct and variance that is unique to a specific measure. Il is change associated with common rather than unique variance that is of primary interest in training. If training effects reflected primarly change associated with unique variance, then the critique of "teaching the test" would be valid. When training studies rely on only one measure to evaluate training gain, it is impossible to disentangle change associated with common vs unique variance.

In order to examine change associated with common variance, subject's performance must be assessed on multiple measures, representing the latent construct. Factors scores, obtained via factor analytic procedures, are one index of the common variance associated with a latent construct. Subjects in our study were administered several measures of each ability to permit examination of the question of whether training improvement was exhibited in the variance common to several tests of an ability, or whether training improvement was only related to variance unique to a particular test. Special analyses were also conducted to assure us that the factor structure of our measures remained intact across the training intervention and that there had not been any qualitative change in the nature of the latent constructs (Schaie, Willis, Hertzog, & Schulenberg, 1987).

Figure 9 presents mean pre-posttest change in factor scores for the inductive reasoning training group and for the spatial orientation training group (Willis & Schaie, 1986a). For each training group change in factor scores is shown for five abilities. Subjects trained on inductive reasoning had significantly higher mean change scores on the inductive reasoning factor. Similarly, subjects trained on spatial orientation had significantly higher change scores on spatial orientation. These findings indicate that training improvement occurred at the level of the latent ability construct. Training enhancement was not limited to improvement on a single test; rather training effects were found for multiple measures of the ability that was the target of training.

FIGURE 9
Transfer of training: Training gain for five latent constructs



• **Ability-specific nature of training effects.** There is, however, a second aspect to considering the breadth or generality of training outcomes (Willis, 1987). Thus far we have argued that training effects are broad in that training improvement was demonstrated for several measures of the ability that was the focus of training. There is the further question of whether training improvement extends beyond the ability trained. That is, if training efforts focused on teaching the problem solving strategies associated with inductive reasoning, should one expect training improvement on other abilities, such as verbal ability or number ability? In order to examine this question, subjects must be assessed not only on measures that represent the ability to be trained, but also tests representing abilities (eg, verbal ability) that were not the focus of training. At pretest and posttest, subjects were administered measures of three abilities (verbal, number, speed) that were not the focus of training. Demonstration of ability-specific effects requires two conditions:

a) training effects must be shown for multiple measures of the ability trained,

b) no significant training effects should be shown for measures of abilities that were not the focus of training.

Because only one ability was the focus of each training program, it is important to demonstrate whether or not training effects were limited to measures of that ability. If transfer had occurred to verbal ability, for example, interpretation of the nature of the training (which focused on inductive reasoning) would have become much more difficult.

Training effects, therefore were broad in the sense that they were demonstrated for several measures of the ability trained. At the same time, training outcomes are specific in that enhancement occurs only for measures of the ability that was the focus of training. In order to assess the nature of training transfer, there is need for a well defined measurement system. One needs several relatively « pure » measures of the ability or skill that is the focus of training in order to demonstrate that training effects are not limited to a single test, but generalize across multiple measures of the ability. Subjects also need to be assessed on skills or abilities that were not the focus of training in order to determine the limits or boundaries of the training effects. It is only by simultaneously demonstrating that training effects were shown for the hypothesized ability, and that effects did not occur for other abilities or skills that the exact nature of the training program can be specified.

• *Temporal Durability of Training Outcomes*

The durability of training effects takes on added significance when intervention research is considered within a lifespan perspective. The concern is not only that significant improvement in cognitive performance be demonstrated immediately after training, but whether training has implications for patterns of cognitive development several years after the intervention (Willis & Nesselroade, 1990). The longitudinal design of the Seattle study permits examination of these issues. Subjects initially trained in 1984 were reassessed in 1991; thus, the maintenance of training effects over a seven-year interval could be examined. Subsequently, subjects were administered booster training on the same ability on which they were initially trained in 1984. The effects of the booster training were examined at 1991 posttest (Willis & Schaie, 1992).

Figures 10 and 11 present data on changes in ability performance that occurred over the seven-year interval (1983 pretest to 1991 posttest; Willis & Schaie, 1992). Age-related decline would have been expected to have occurred over the seven-year interval for many of our subjects, since by 1991 most had advanced into old-old age. We were interested in comparing subjects' performance subsequent to the 1991 booster training with their performance prior to training in 1984. That is, given the increasing likelihood of age-related decline, was training effective in boosting or maintaining earlier level of functioning?

FIGURE 10
Change from 1983 pretest to 1990 posttest of the Inductive Reasoning ability

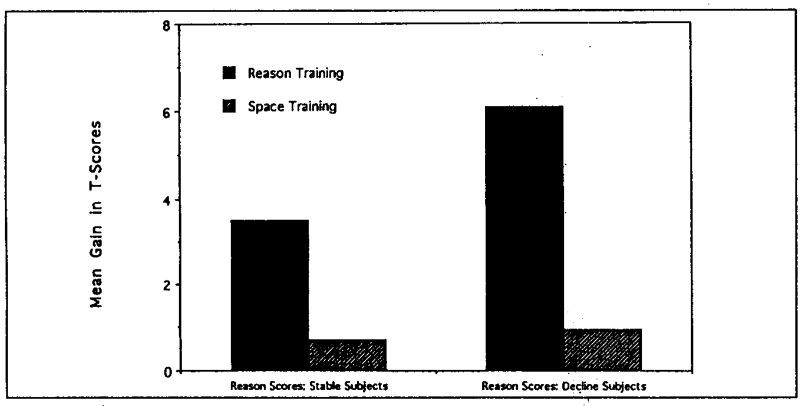
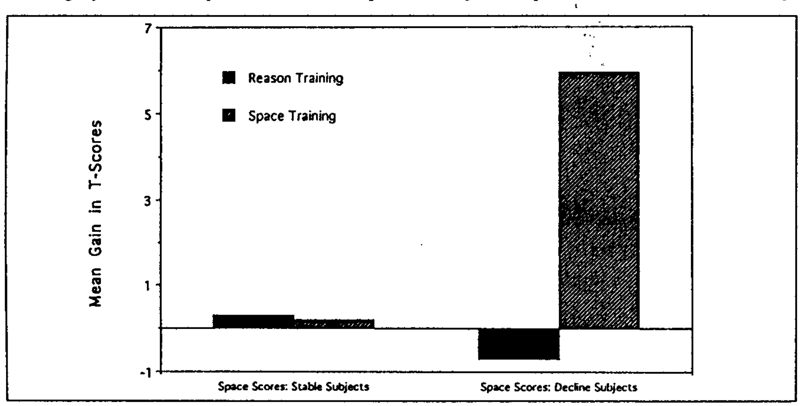


FIGURE 11
Change from 1983 pretest to 1990 posttest of the Spatial Orientation ability



• **Training durability on inductive reasoning.** The findings *(Figures 10 and 11)* vary somewhat between the two abilities and for subjects initially classified as having been stable or having decline on the ability trained. Subjects trained on inductive reasoning were performing, on average, at 1991 posttest at a level above their 1983 pretest scores. Thus, the combined effects of initial training and booster training were sufficient to overcome whatever age-related decline occurred during the seven-year interval. The durability of training effects is particularly evident for subjects initially classified as having declined on inductive reasonning.

• **Training durability on spatial orientation.** The durability of training effects on spatial orientation is somewhat weaker and more differential than those found for inductive reasoning. That is, only subjects initially classified as having decline on spatial ability were performing at a level above their 1983 pretest scores. Subjects initially classified as stable were on average functioning at the same level as they had prior to training in 1983.

Several conclusions regarding the durability of training effects and the potency of successive intervention efforts in 1983 and again in 1991 can be articulated (Willis & Schaie, 1992). First, the long terms effects of training were most evident for subjects who had been classified as having declined on the target ability. That is, decline subjects involved in each training program were performing at 1991 posttest at a level above their performance prior to training in 1983. There is suggestive evidence, therefore, that training may be particularly effective if it is begun after subjects begin to evidence decline. Second, training effects were somewhat more potent and more durable for inductive reasoning. Both stable and decline subjects trained on inductive reasoning were performing above the level of functioning exhibited prior to training in 1983. Third, with one exception, subjects trained on a specific ability were functioning at a higher level on that ability than comparison subjects trained on another ability. That is, except for stable subjects trained on spatial ability, subjects remained at an advantage on the ability trained in comparison with those not so trained.

• *Implications of Training on Mental Abilities for Everyday Task Performance*

The types of mental abilities and processes that have been the target of cognitive training research have been derived from psychometric, Piagetian, and information processing approaches to the study of intellectual aging (Denney, 1982; Hoyer, Labouvie, & Baltes, 1973; Willis, 1987). The training research literature cited above indicates that there is considerable plasticity in the elderly's functioning in these domains. There remains, however, the important question of the implications of cognitive training research for improving the competence of older adults in activities of daily living. What are the relationships between the types of cognitive domains examined in cognitive training research and competence in activities of daily living. Can performance on real-life tasks be improved? What types of training might be useful in improving performance on real-life tasks? Research related to such questions is very limited.

In this final section of the paper we will briefly outline one approach to considering these issues.

• **Practical intelligence.** The term practical intelligence has been used to differentiate between academic intelligence (eg, psychometric, Piagetian, information processing approaches) and the cognitive skills required to carry out tasks of daily living (Commons, Richards, & Armon, 1982; McClelland, 1973; Sternberg & Wagner, 1986). There is no commonly agreed-upon definition of practical intelligence. The term has been used to describe areas such as "practical know-how", professional competence, social judgment, and the layperson's conception of an intelligence person.

Our approach to the study of practical intelligence in later adulthood proceeds from thee assumption that there are classes of everyday activities that are critical for adaptive functioning in common life situations (Schaie, 1978; Willis & Schaie, 1986b). Because a major concern in old age is maintenance of independent living, this approach focuses on tasks associated with independent, effective functioning. For example, inability to perform tasks, such as comprehending medicine bottle labels or utilizing information in the phone directory, may lead to curtailment of independent living for many elderly (Willis, 1992; Willis & Schaie, 1994). There is no exhaustive taxonomy of real life tasks. Our research has focused on a subset of tasks that represents categories of common problems experienced by many elderly. At least two characteristics distinguish the types of tasks we have studied from other forms of practical intelligence. First, these tasks involve use of printed materials in solving everyday problems. Second, the tasks, for the most part, involve logical reasoning, and therefore, there are logically "correct " responses (Willis & Schaie, 1986b; Willis, 1992).

• **The relationship between traditional and practical intelligence: A hierarchical approach.** Are the abilities studied in cognitive training research related to practical intelligence as discussed above? For the types of practical intelligence tasks we are interested in, it has been useful to consider a hierarchical relationship between these forms of intelligence (Schaie, 1978; Willis, Jay, Diehl, & Marsiske, 1992; Willis & Marsiske, 1991; Willis & Schaie, 1986b). In this hierarchical scheme, the most elemental components are ability factors, such as the primary mental abilities represented within a psychometric approach to traditional intelligence (Thurstone, 1938). These include the abilities, such as inductive reasoning and spatial orientation, that have been the focus of cognitive training research.

Because behavior in real-world contexts is of necessity complex, we assume that no single ability factor can adequately predict performance in on a task of daily living (Willis & Marsiske, 1991; Willis & Schaie, 1993). Rather some combination of ability factors is required to best predict performance on real-life tasks. Thus, practical intelligence can be described as involving the expression of that combination of ability factors that, given minimally acceptable levels of motivation will permit adaptive behavior within a specific situation or class of situations. We do not wish to suggest that all of the variability in everyday tasks can be accounted for by a combination of ability factors, but we believe such factors represent an important first strata in a hierarchical approach to the study of practical intelligence.

A program of research in our laboratory has provided empirical findings to support this hierarchical approach (Willis, 1992; Willis, Jay, Diehl & Marsiske, 1992; Willis & Schaie, 1993). In studying performance on a variety of everyday tasks we have found that approximately two-thirds of the variance in performance of everyday tasks can be accounted for by a combination of basic mental ability factors. The ability factors accounting for the most variance include inductive reasoning and spatial orientation, the abilities that have been the focus of cognitive training studies. Verbal ability has been found to be another salient mental ability in accounting for individual differences in everyday task performance. Our research suggest several points regarding the relationship between traditional intelligence and tasks of practical intelligence. First, there are significant and reliable relationships between cognitive abilities studied in the laboratory and the cognitive skills involved in many tasks of daily living encountered by the elderly; traditional and practical intelligence are not totally unrelated spheres of competence. Second, tasks of practical intelligence are complex and involve the utilization of several basic mental abilities. Third, the particular combination of abilities involved will vary across different types of practical tasks.

• **Cognitive training and practical intelligence.** If substantial relationships exist between ability factors and some important tasks of daily living, what are the implications of findings from cognitive training research for the enhancement of everyday functioning in the elderly? First, it is encouraging to note that some of the abilities that have been the target of successful intervention efforts also account for considerable variability in performance of a number of essential tasks of daily living (Willis & Schaie, 1986b; 1993). Thus, the findings of cognitive training suggest that there is considerable plasticity in some of the rudimentary cognitive components underlying performance of complex tasks of daily living. The findings of prior training research then provide some encouragement for future intervention efforts focused on tasks of daily living. Second, the finding that practical intelligence tasks are complex and involve combinations of more basic abilities suggests that future training efforts targeted at everyday tasks may need to be combinatorial or multidimensional. Much of the prior cognitive training research has focused on single abilities. However, the complexity of practical intelligence tasks suggests that training may need to focus on strategies and skills associated several abilities, rather than a singular ability.

Why train on cognitive abilities, rather than on the practical tasks themselves? This is a question that deserves empirical investigation. However, the number of specific tasks of daily living on which training might be useful is very large. Training on cognitive abilities that underlie performance on these tasks may therefore be more efficient and result in broader transfer of training than training that is restricted to a specific practical tasks. This conclusion is subject to at least two conditions:

1) clusters of empirically related practical tasks must be identified,

2) a small subset of ability factors must be identified that share significant common variance with the practical task cluster.

SUMMARY AND CONCLUDING REMARKS

At the beginning of this chapter we stated that cognitive training research provides a useful approach for the study of plasticity in old age. In this final section, we will suggest three implications from the findings of cognitive training research for the study of plasticity.

• **Studying plasticity within a life-span context.** The longitudinal design of the Seattle study has permitted an examination of plasticity within a developmental context (Willis, 1990a; Schaie & Willis, 1986). A life-span perspective involves consideration of current level of functioning in the context of prior and future developmental trajectories. Findings from our training studies indicate considerable cognitive plasticity for older persons with two very different prior developmental profiles. Both subjects experiencing prior decline and those who had remained stable demonstrated significant training improvement. However, knowledge of the individual's prior developmental history had a major impact on our interpretation of the nature of training improvement. For decliners, training improvement represented a remediation. But for stable subjects, training improvement represented more advanced levels of performance than previously demonstrated. Likewise, examining the temporal durability of training effects and the individual's subsequent developmental trajectory provided a more complete understanding of the nature of plasticity. There is suggestive evidence, for example, that the durability of training effects and the potential for profiting from further intervention efforts may be related to the individual's prior developmental history. That is, long term plasticity may actually be somewhat greater for individuals suffering prior performance decline.

• **The multidimensional nature of plasticity: Growth, stability, and remediation.** A life-span approach suggests that even in old age, plasticity must be considered to be a multidimensional and multidirectional construct (Willis, 1990c). The stereotypic view of cognitive aging as one of unremitting, universal decrement has contributed to the assumption that plasticity in old age always involves remediation of lost skills rather than the acquisition of new responses. From the perspective of cognitive training research, we must conceptualize potential or plasticity along three directions: Potential for growth, potential for stability (maintenance), and potential for remediation.

Potential for growth involves the older adult's ability to demonstrate further quantitative or qualitative increases in knowledge base or skill beyond those shown at an earlier age. The capacity of the stable subjects in our training study to achieve significant training gain is evidence for potential for cognitive growth or gain, even in late life. Potential for maintenance involves the aging individual's capacity to maintain the same level of skill or performance as they progress from young old to old-old age. Indeed, maintaining their current level of functioning appears to be the major goal of many older adults! While much discussion of plasticity has tended to focus on gains or remediation, the elderly's potential to maintain their current level of functioning with advancing age needs further consideration. Finally, potential for remediation involves the opportunity for partial remediation or attainment of a skill or performance level that has shown previous age-related decline.

• **Study of plasticity in the context of individual differences.** The primary focus in the study of plasticity is on **intraindividual variability.** This involves examining the individual's current range of functioning in the light of his or her prior and future levels of functioning. The individual serves as their own baseline. However, plasticity or intraindividual variability needs to be examined in the context of sources of interindividual differences. For example, in our training research we have examined plasticity in relation to gender differences and in relation to age/cohort differences. Whereas the range of plasticity was sufficient to eliminate, on average, long standing gender differences in level of performance on spatial orientation tasks, age/cohort effects persisted in spite of considerable intraindividual plasticity within each cohort.

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