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29 Improvement with cognitive training: Which old dogs learn what tricks?

Sherry L. Willis

The term "cognitive training" conjures up the image of young students in a classroom, receiving instruction from a teacher. There is the implicit assumption that the young students did not possess cognitive abilities prior to cognitive training, so that the focus of training is on de novo learning. The critical question is whether or not, as a result of cognitive training, there is *acquisition* of specific knowledge and skills. However, cognitive training is being increasingly employed as a research paradigm across the life span. Questions regarding the purpose and effectiveness of cognitive training at later life stages often are quite different from those relating to the young students. Cognitive training in old age has recently been of particular interest, given the normative pattern of intellectual decline in this developmental period.

This chapter provides a selective review of recent research on cognitive training in later adulthood. The research literature will be reviewed with regard to five major questions: What cognitive abilities have been the targets of cognitive-training research? What is modified as a function of training? How large is the magnitude of the training effect? Who benefits from cognitive training? Are training effects maintained over time? The literature review will focus on the psychometric mental abilities and the cognitive problem-solving skills that have been studied via a training paradigm. The chapters in this volume by Bäckman (Chapter 28), West (Chapter 30), and Yesavage, Lapp, and Sheikh (Chapter 31) review the memory-training literature.

A perspective on cognitive-training research

For the past decade, my colleagues and I have been involved in several programs of cognitive-training research that have examined the modifiability of intellectual performance in later adulthood (Baltes & Willis, 1982; Willis, 1985; Willis & Schaie, 1986). It is our position that the descriptive study of normative

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trends in intellectual aging should be complemented with research on plasticity or variability in intellectual performance under various types of experimental conditions (Willis & Baltes, 1980). Comprehensive theories of intellectual aging must consider not only mean-level changes in performance but also the range of individual differences in performance and the conditions under which this variability is exhibited. There are three types of variability that are of interest in cognitive-training studies (Baltes & Willis, 1982).

Intraindividual variability

Intraindividual variability is of foremost concern: What is the range of variability in an individual's intellectual performance that can be exhibited as a function of training? Intraindividual change typically has been assessed in terms of pretest–posttest training gain and expressed in terms of standard-deviation units; see Nesselroade, Stigler, and Baltes (1980) and Nunnally (1982) for a discussion of the use of change scores in developmental research. For example, if the mean training-gain score (in *t*-score units) is 8, then the training gain is on the order of .8 of a standard deviation.

Ideally, pre–post training variability is examined in the context of other data on intraindividual variability available for the population studied. Experimentally induced intraindividual variability is compared with the range of intraindividual variability that has occurred ontogenetically. For example, the investigator can compare the range of intraindividual variability attributable to training with the range of intraindividual variability occurring normatively from middle age to old age; or training variability can be compared with variability from the peak level of performance at some earlier point in development. These types of analyses permit comparison of the range of variability attributable to ontogenetic change versus experimentally induced plasticity. These types of comparisons are useful in developing more complete models of intellectual aging, not only specifying the normative range of development but also providing some indication of the potential range of development. These comparisons are, of course, limited, because plasticity experimentally induced over a very brief time period (e.g., five 1-hour training sessions) is being compared with long-term ontogenetic change occurring over several decades.

If the investigator's goal is to utilize cognitive training as a paradigm for the study of developmental change, then intraindividual variability will be a central concern, and core comparisons will focus on comparing intraindividual variability due to training with longitudinal data on intraindividual variability. An alternative paradigm involves the use of extensive training procedures that make possible comparisons of intraindividual changes across the span of the intervention (Kliegl & Baltes, in press).

Interindividual differences in intraindividual change

The major source of variability examined in most cognitive-training studies has been interindividual differences in intraindividual change, because few

training studies have had samples with prior longitudinal data. Comparisons of training and control groups have been the most common types of interindividual differences examined. The range of pretest–posttest variability achieved by the training group is compared with the pretest–posttest changes exhibited by a control/comparison group. Within an experimental design, comparisons of treatment effects are based on the assumption that group differences on all variables expected to be related to the training have been eliminated through either random assignment or statistical control procedures (Campbell & Stanley, 1963). Unfortunately, with the limited sample sizes employed in many studies, adequate control through random assignment may be questionable, and many studies have not reported findings regarding the comparability of various groups.

Examination of other types of interindividual differences in intraindividual change has been seriously neglected (Krauss, 1980). There has been very limited investigation of the sources of individual differences that characterize older adults exhibiting differential training gains. Whereas the majority of training studies in the literature have reported statistically significant mean training improvement, there have been large individual differences in the magnitudes of training improvements. What are the sources of these individual differences? In addition, the majority of training studies have included only one type of training condition (e.g., trainer-directed instruction) and only a pretest–posttest control group. Individual differences in intraindividual variability across multiple training (e.g., practice, computer-assisted instruction, etc.) or control conditions merit further study.

Interability variability

A third type of variability of concern in training research deals with interability variability. Do abilities differ in their susceptibility to training modifiability? Are various training procedures differentially effective for different abilities? Does the nature of performance improvement following training vary by ability? For example, training improvement for some abilities may reflect largely an increase in response speed, whereas improved accuracy may characterize training gains for other abilities. Rarely has training research been conducted in a systematic manner that would permit examination of these types of issues. Although a number of cognitive abilities and processes have been studied via the training paradigm, a given investigator typically has studied only one or two abilities intensively. Comparisons of training effects across abilities have been limited by sampling differences and by lack of comparability of assessment batteries and training procedures.

Abilities and cognitive tasks as targets of training

What abilities and cognitive processes have been studied in training research? The selection of abilities as targets for training has been guided primarily by findings from descriptive, cross-sectional, and longitudinal research on intellectual aging. Abilities for which large and early age differences have been shown have most frequently been chosen as targets for training. Within the classic pattern of intellectual aging, these abilities have been characterized as involving abstract reasoning and speeded responding (Botwinick, 1977). The focus, then, has been on cognitive abilities and skills on which the average performance of the elderly has been shown to be deficient (Denney, 1982).

There have been several reviews of the training-research literature (Baltes & Barton, 1977; Baltes & Willis, 1982; Denney, 1979; Sterns & Sanders, 1980; Willis, 1985; Willis & Schaie, 1981). The training-research literature dealing with problem-solving skills and psychometric abilities is briefly summarized next.

Piagetian and problem-solving tasks

Piagetian tasks. The Piagetian tasks of conservation, classification, spatial egocentrism, and formal operations have been topics of training research. Denney (1974, 1979) has conducted several studies examining the effect of training on the classification criteria employed by the elderly. After observing another person (model) classify stimuli consistently according to dimensions such as shape, color, or size, the elderly were also able to classify consistently according to these criteria. In a spatial-egocentrism training study, Schultz and Hoyer (1976) allowed subjects to view stimuli from different spatial perspectives and gave verbal feedback regarding correctness of responses; training resulted in a significant increase in correct responses. Hornblum and Overton (1976) successfully trained subjects on several surface-area conservation tasks; at posttest, subjects showed improvement on other conservation tasks, suggesting a transfer-of-training phenomenon. These effects were maintained for a 6-week period for a subset of subjects given a delayed posttest. In a study by Tomlinson-Keasey (1972), middle-aged women showed significant improvement on several formal-operations tasks.

Problem-solving tasks. Concept formation has been the primary problem-solving skill studied. Crovitz (1966) found significant improvement on a card-sorting task after subjects observed a model sort the cards several times according to different dimensions. In a concept-formation training study conducted by Sanders, Sterns, Smith, and Sanders (1975), subjects were assigned to one of four conditions: reinforced (monetary) cognitive training, nonreinforced cognitive training, practice with feedback, and a no-treatment control group. At posttest, both the reinforced and nonreinforced training conditions demonstrated greater improvement than did the practice and control conditions. In one of the few studies of long-term maintenance, Sanders and Sanders (1978) found significant training effects 1 year following their study. Meichenbaum (1974) also was able to facilitate performance on a concept-formation task, employing modeling and verbal self-regulatory procedures.

In a series of studies, Denney and associates (Denney & Denney, 1974; Denney, Jones, & Krigel, 1979) studied the manipulation of concept-formation behaviors, using the 20-questions game. Modeling procedures were effective in improving the question-asking efficiency of older subjects. However, Denney (1980) found that other noncognitive treatments were not effective in improving performance on the 20-questions game; these noncognitive conditions included monetary reinforcement, manipulation of self-confidence, and additional time to plan a game strategy.

The modifiability of set induction and behavioral rigidity, which often are related to problem-solving proficiency, has been examined. Studies by Heglin (1956) and Lycette (1973) demonstrated that middle-aged and older adults' tendency to continue to use the same response strategies, even when inappropriate, can be modified with instruction. Levin and Overton (1979) reported that brief instruction on flexibility in thinking (i.e., breaking set) led to improved performance on a spatial-perspective-taking task.

Psychometric abilities

The four psychometric abilities of figural relations, inductive reasoning, spatial orientation, and perceptual speed have received the greatest attention in the training literature.

Figural relations. The fluid ability of figural relations was examined in a series of studies within the Adult Development and Enrichment Project (ADEPT) (Baltes & Willis, 1982; Plemons, Willis, & Baltes, 1978; Willis, Blieszner, & Baltes, 1981). The training involved five 1-hour sessions. Significant training effects were demonstrated for three measures of figural relations (Willis et al., 1981). These training effects were maintained at 1-week, 1-month, and 6-month posttests. Approximately 10 months after the initial training period, subjects were reassessed, and maintenance of the training effects was found. Subjects then participated in five additional training sessions. Additional training resulted in a higher mean level of performance on the figural-relations measures; however, the magnitude of the training gain resulting from additional training was less than that occurring in the first stage of training. At both stages of training, the effects were ability-specific.

Inductive reasoning. Labouvie-Vief and Gonda (1976) examined the manipulation of inductive-reasoning performance, in a study involving four conditions: cognitive-strategy training, a combined strategy training and anxiety-reduction condition, a no-feedback practice condition, and a no-treatment control condition. On the immediate posttest, both cognitive-strategy training conditions demonstrated superior performance to the no-treatment control condition, but did not differ significantly from the no-feedback practice condition. Training effects for the combined training condition were maintained at a 2-week posttest.

Inductive reasoning has also been examined in a series of studies conducted by ADEPT (Baltes & Willis, 1982; Blieszner, Willis, & Baltes, 1981). In an early

ADEPT training study, older adults participated in five 1-hour training sessions on inductive-reasoning problems involving letter-set, number-series, and letter-series tasks. Significant training effects were found on the nearest transfer measure of inductive reasoning at 1-week and 1-month following training. At a 6-month posttest, the no-treatment control group demonstrated significant retest effects such that the training–control-group difference was no longer significant. Because the mean performance of the training group at the 6-month posttest did not differ from their 1-week posttest level, the lack of a significant difference at 6 months appears to reflect a retest effect for the control group, rather than lack of maintenance of the initial training effect.

The effect of a no-feedback practice condition on inductive-reasoning performance was examined in two additional ADEPT studies. In the first study (Hofland, Willis, & Baltes, 1981), subjects participated in eight retest practice sessions. That is, subjects took inductive-reasoning tests under standard timed conditions during each of eight sessions; they received no information regarding their performance. A significant retest effect across trials was found. Examination of the performance pattern across retest sessions indicated that subjects exhibited small, steady gains across consecutive trials. In addition, there was considerable stability in the rank ordering of individuals across trials, suggesting that although there was significant intraindividual improvement, on average, across trials, interindividual differences in levels of performance were maintained across sessions.

An error analysis of trials scores was conducted to examine the nature of retest gains. There was a significant decrease in unattempted test items across trials, indicating that more items were attempted at each succeeding retest session. However, the mean number of commission errors was relatively stable across trials. Therefore, the improvement across trials appears to have been due primarily to an increase in total items attempted, rather than a reduction in commission errors.

Because no apparent performance asymptote appeared to have been reached across the eight trials in the Hofland and associates (1981) practice study, a replication and extension study (Hofland, 1981) was conducted involving 10 no-feedback retest trials. A number of findings from the first study were replicated: (1) A significant retest effect across trials was found. (2) Subjects showed small, steady gains across consecutive trials, with the greatest intertrial gain occurring early, between the pretest and the first retest trial. (3) Rank ordering of individuals' performances across trials was relatively stable. (4) Error analyses indicated a significant decrease in unattempted items across trials. There was a decrease in commission errors also; however, it did not reach statistical significance.

This study also provided additional findings regarding the modifiability of inductive-reasoning performance via practice. First, practice was found to result in significant transfer-of-training effects to a conceptually related measure of inductive reasoning. Second, at posttest, practice effects were examined under a relaxed time condition, as well as under a standard time condition; in the relaxed time condition, practice and no-treatment control groups were given additional

time to solve test problems. Mean performances of both practice and control groups improved significantly under the relaxed time condition. However, the practice group maintained a higher performance level. That is, when the groups were given sufficient time to attempt virtually every test item, the practice group answered a significantly greater mean number of items correctly and made significantly fewer commission errors, as compared with the control group.

Baltes and associates (Baltes, Dittmann-Kohli, & Kliegl, 1986) have recently reported a replication and extension of the ADEPT training research with a German sample of elderly. Subjects received five training sessions on inductive reasoning and five training sessions on figural relations in a counterbalanced design. Significant training effects were found for both abilities, and the effects were maintained across 1-month and 6-month posttests. Significant retest effects for the control group were also demonstrated across posttests. Transfer of training was demonstrated to conceptually related measures of inductive reasoning and figural relations. Task analyses also indicated that trained subjects correctly solved more items of various difficulty levels than did control subjects, indicating that the training effect was not restricted to items of low difficulty. Finally, error analyses indicated that although both training and control groups showed significant increases in numbers of items attempted and numbers of correct items, an increase in accuracy of performance (i.e., decrease in commission errors) occurred only for the training group.

Spatial orientation and inductive reasoning. In a recent project, we examined training effects within a longitudinal study design (Schaie & Willis, 1986; Willis & Schaie, 1986). A major purpose of the study was to examine the relative effectiveness of cognitive training in remediating the performances of subjects exhibiting cognitive decline on selected abilities versus improving the performances of subjects with stable levels of prior performance. Elderly participants in the Seattle Longitudinal Study (SLS) were classified as having remained stable or having declined over the previous 14-year period (1970–84) on two mental abilities: spatial orientation and inductive reasoning. Approximately 47% of the sample were classified as having remained stable on both abilities; approximately 31% had declined on only one of the two abilities; 22% had declined on both abilities. Subjects who had declined on only one of the abilities were assigned to a five-session training program focusing on that ability. Subjects who had remained stable on both abilities or who had declined on both abilities were randomly assigned to training on one of the abilities.

We believe that this was the first study to assess training effects at the level of ability factors, rather than at the level of individual test scores (Willis & Schaie, 1986). Significant training effects were found at the factor-score level for both inductive reasoning and spatial orientation. Training effects were ability-specific in that improvement was shown for the two ability factors that were the targets of training, but there were no training effects for any of the other ability factors included in the pretest–posttest battery. In terms of intraindividual change, approximately two-thirds of the sample showed significant pretest–posttest training improvement.

Were there differential training effects for subjects classified as having declined versus those having remained stable over the previous 14-year period? Analyses at the level of factor scores showed no significant differences in the magnitudes of training gains exhibited by stable versus decline subjects. When effects were examined at the level of individual measures, there was a trend for decliners to have gained somewhat more from training than had the stable subjects; this trend was most evident for subjects trained on spatial orientation. Whereas the magnitudes of training gains were roughly comparable for stables and decliners, the two groups did differ in their *levels* of performance at posttest. For the decliners, training improvement represented at least partial remediation to a prior level of performance, whereas for the stables, training improvement reflected a performance level above that previously demonstrated by the subjects over the prior 14-year period.

Of particular interest to us was the effectiveness of training in remediating the performances of decliners (Schaie & Willis, 1986). That is, for what proportion of the decliners was training effective in remediating performance to the level exhibited 14 years previously? The data indicate that at posttest, approximately 40% of the decliners were performing at a level equivalent to or above the level at which they had performed 14 years previously. The proportions of decliners exhibiting remediation were roughly equivalent for inductive reasoning and spatial orientation.

Response speed. Findings from several studies indicate that older adults' speed of responding on a variety of perceptual-discrimination tasks can be significantly increased. Hoyer, Labouvie, and Baltes (1973) examined the modifiability of perceptual speed performance under three conditions: reinforced practice with feedback regarding performance, nonreinforced practice with no feedback, and a no-treatment control. Significant improvement in performance on perceptual speed tasks occurred for both practice conditions; the reinforcement procedure itself appeared to have little effect. No transfer effects were obtained on a battery of psychometric measures administered after training. The lack of transfer from perceptual speed training to intellectual performance was replicated in a study by Hoyer, Hoyer, Treat, and Baltes (1978).

Coyne (1981) examined the effects of practice on forward visual masking for young and older adults. Practice resulted in a reduced susceptibility to forward masking for both age groups. Whereas there was an age effect for the length of the interstimulus interval, the interaction between age and practice was not significant, suggesting that the magnitudes of improvement associated with practice were comparable for the young and older adults.

Several studies (Beres & Baron, 1981; Erber, 1976; Grant, Storandt, & Botwinick, 1978) have examined the effects of practice on performance on the Digit Symbol Substitution subtest of the Wechsler Adult Intelligence Scale (WAIS). Significant improvement with practice has been exhibited for both young and older age groups. In the most extensive practice condition, Beres and Baron (1981) found that the scores of older women increased from the 25th to the 90th percentile relative to norms for young adults, and these scores were maintained during a follow-up test 10 days later.

Willis, Cornelius, and Baltes (1983) examined the effects of practice on several measures of attention/perceptual discrimination. In addition, transfer of training was examined with an assessment battery involving fluid/crystallized intelligence, perceptual speed, and memory span. Significant training effects occurred for three measures: the Stroop Color Interference task (Stroop, 1935), the Underwood Number Counting task (Underwood, 1975), and the Continuous Paired Associates Recall task (Atkinson & Shiffrin, 1968). These effects were maintained across 1-month and 6-month posttests. In addition to a no-treatment control, a social-contact control group was included to assess the effects of participation in an equivalent number of hours of social contact, but involving no training. No significant training effects occurred for the social-contact control condition. In addition, no transfer of training was found to measures of fluid/crystallized intelligence, perceptual speed, or memory span.

In summary, the training-research literature indicates that cognitive training is effective in significantly improving the performances of older adults on a variety of Piagetian tasks, problem-solving tasks, and psychometric abilities. Although the specific training procedures employed have varied across studies, common elements in training have included behavioral modeling by a trainer, instruction in the use of relevant cognitive strategies, practice with prototypical tasks, and feedback regarding correctness of responses. Training has been found to be effective in both remediating cognitive decline and improving performances of subjects exhibiting no prior decline.

Nature of training effects

Although a review of the training literature strongly supports the notion of plasticity in older adults' intellectual performances, there has been considerable debate and discussion regarding the nature of the training improvement. How are training gains to be interpreted? Reviewers of the literature have tended to focus on three issues: the breadth of training effects, the directionality of these effects, and what specific behaviors are modified as a function of training.

Breadth of training effects

Alternative views have been taken regarding both the expected breadth and the actual breadth of training gains demonstrated. Some have interpreted training effects to be narrow and to reflect little more than "teaching the test." In contrast, others have suggested that training may result in significant alterations in the structural relationships among abilities. For example, Donaldson (1981) has suggested that as a result of training, fluid-ability measures (e.g., figural-relations tasks) may become more characteristic of crystallized intelligence. Findings from several recent studies indicate that neither of these extreme positions is supported by the data.

Latent variables and training

Discussion of the breadth of training effects must begin with recognition that it is a cognitive construct or latent variable (e.g., classification, inductive reasoning) that is the target of intervention research. The primary concern in training research is not a change in performance on a letter-series test or the 20-questions task per se, but rather change in the latent construct that task is said to represent. Latent constructs can be assessed only indirectly via observable tests that have been shown empirically to represent those constructs. Training gains, as measured by these observable tests, however, represent confounding of the variance common to the latent construct and the variance that is unique to that specific measurement instrument. It is change in the common variance that is of primary interest in training. If training improvement reflected primarily change in unique variance, then the critique of "teaching the test" would be valid. When training studies rely on only one test to assess training gains, it is impossible to disentangle changes attributable to common versus unique variance. Subjects' performances on multiple measures representing the latent construct are required to assess change in common variance.

How can training gains attributable to change in the common variance be assessed? One method is to assess training effects at the factorial level, rather than at the level of individual test scores. Ability-factor scores representing variance common to a given latent construct are the dependent variables in these analyses of training effects. Whereas factor-analytic procedures have most commonly been employed in research within psychometric models of intelligence, this method could be usefully employed in research on memory processes or problem-solving abilities and would permit the researchers to examine their findings more precisely at the latent-construct level.

In our recent training studies (Willis & Schaie, 1986) we have found significant training effects at the factorial level for the abilities of inductive reasoning and spatial orientation. These findings are evidence of training gains at the latent-construct level.

Ability-specific training effects

We have found across a number of studies that training effects were specific to the ability that was the focus of training. Demonstration of ability-specific effects requires two conditions: (1) Training effects must be shown for multiple measures of the ability that is the focus of training. Ideally, data will be analyzed at the factorial level, so that training effects at the latent-construct level can be examined. (2) No training effects should occur for measures of other abilities that are not the focus of training. Both conditions must be met for an ability-specific interpretation of training effects. If effects occur for measures of abilities other than that trained, then specification of the nature of training effects at the construct level and in terms of variance common to a particular construct will be more difficult.

Should ability-specific effects, when demonstrated at the construct level, be interpreted narrowly or broadly? We believe that such effects occur at the level that would be expected, given that training procedures typically have been designed to focus on cognitive strategies and behaviors associated with a specific ability or cognitive process. Indeed, the current state of the field of cognitive psychology is such that it would be difficult to develop training procedures aimed for broader effects. In mainstream cognitive psychology, it has proved exceedingly difficult to specify and operationalize executive processes or metacognitive components that are truly generalizable across multiple abilities. Componential analyses typically have been limited to a particular ability construct (Detterman, 1980; Sternberg, 1982). Discussion of metacomponents remains at a theoretical level.

Targeting training effects at an ability-specific level makes sense from the perspective of findings from longitudinal research on intraindividual change in cognitive functioning (Schaie, 1983). There are wide individual differences not only in the timing of the onset of cognitive decline but also in terms of which particular abilities or skills exhibit early change. In young-old age, changes in cognitive functioning tend to be highly specific and individualized. For example, our classification of the change status of elderly participants from the SLS indicated large individual differences, even when two abilities (inductive reasoning, spatial orientation) were considered that should exhibit early decline within the classic pattern of intellectual aging. Almost one-half (46%) of the subjects showed no statistically reliable decline on either ability over the previous 14-year period. Almost a third (31%) of the subjects showed decline on one of the abilities, but not on the other. Because for many older individuals, early ontogenetic changes in cognitive functioning appear to be ability-specific, such an approach to intervention in many cases seems reasonable. A prescriptive, individualized approach to training that will result in ability-specific effects is also compatible with the notion of selective optimization in later adulthood (Baltes, Dittmann-Kohli, & Dixon, 1984). Given older individuals' need and desire to set priorities and selectively utilize their cognitive resources, an ability-specific approach will be useful.

Structural invariance and training effects

Thus far, our discussion of the breadth of training effects has focused on pretest–posttest quantitative change, whether examined at the test-score level or at the latent-construct level. Analyses of training effects have been almost solely concerned with issues of quantitative change. However, our interpretations of findings regarding quantitative change are based on assumptions regarding the structural stability of the measurement framework from pretest to posttest (Donaldson, 1981; Schaie, Willis, Hertzog, & Schulenberg, 1985; Willis & Schaie, 1986). Structural invariance addresses questions such as the following: Are the same latent constructs represented in the assessment battery at pretest and posttest? Are the observable measures still representative of the same latent constructs following intervention? Have the relationships among these constructs remained constant across intervention?

If assumptions regarding structural stability are not met, then interpretation of exactly what was modified as a function of training becomes ambiguous. For example, if Donaldson's suggestion (1981) is correct that educational training procedures resulted in fluid-ability measures becoming more crystallized in character, then our interpretation of the nature of training effects needs to be seriously altered. The existing literature offers strong support for assumptions of structural invariance (Baltes, Cornelius, Spiro, Nesselroade, & Willis, 1980). However, the issue merits empirical investigation.

In recent training research, we examined the pretest–posttest structural stability of a measurement battery representing the five primary mental abilities of verbal meaning, inductive reasoning, spatial orientation, number, and perceptual speed (Schaie et al., 1985). Would training on either inductive reasoning or spatial orientation significantly alter the relationships among these abilities, or the representativeness of tests as "markers" of specific ability factors? We found virtually complete structural stability for the abilities (verbal, number, speed) that were not the targets of training. There were some slight pretest–posttest shifts in the regression weights for measures representing the trained abilities. However, all measures were still representative of the constructs they were selected to mark at pretest, and the shifts in regression weights did not alter interpretation of the ability-specific nature of training effects. These findings are supportive of earlier correlational research on the stability of interability relationships across retest trials (Hofland et al., 1981).

To our knowledge, the study of Schaie and associates (1985) was the first stringent test of structural stability within the context of training intervention. These findings of structural stability were to be expected, given that the psychometric measures employed are highly reliable and have evidenced strong saturations on the particular ability constructs. However, there is need for further examination of structural stability in a training context, particularly with regard to less reliable (i.e., more state-like) constructs. For example, there is some suggestive evidence of changes in the relationship between memory span and other abilities at various stages in the learning curve (Hofland et al., 1981; Labouvie, Frohring, Baltes, & Goulet, 1973).

Directionality of training improvement

Because gerontological training research has focused almost exclusively on those abilities exhibiting early age differences or age-related decline, there has been the implicit assumption that training effects reflect the modifiability/reversibility of cognitive decline. However, longitudinal research findings regarding individual differences in the timing of decline and what abilities show decline suggest that training effects may be multidirectional. That is, training effects may reflect remediation, incrementation, or compensation, depending on a given individual's prior performance history on a specific ability. In our research with SLS participants, approximately 55% of the subjects had exhibited declines over the prior 14 years on one or both of the abilities studied, and thus training effects focused on remediation (Schaie & Willis, 1986). However, approximately 45% of the sample showed no significant decline on either of the abilities studied, and thus training effects represented new performance levels.

Remediating cognitive decline

Are training procedures effective in remediating cognitive decline and in improving the performances of subjects showing no previous decline? To answer this question, training studies must be conducted with subjects with prior longitudinal data, and thus far, very little such research has been conducted. Our training research with SLS subjects examined this question for the abilities of inductive reasoning and spatial orientation (Willis & Schaie, 1986). Findings from this research indicate that there were significant training gains for both stable and decline subjects. When results were examined at the factorial level, there was no significant difference in the mean training gains for stables and decliners.

We have been particularly interested in the effectiveness of training for subjects experiencing significant cognitive decline. To what extent is training effective in remediating decliners' performances to prior performance levels? For 40% of the decliners, training resulted in remediation to the subject's performance level 14 years previously (Schaie & Willis, 1986). These reversal effects were demonstrated for both of the primary abilities (inductive reasoning and spatial orientation) that were the targets of training. We interpret these findings as lending support to the notion of the plasticity of behavior into late adulthood and suggesting that for at least a substantial proportion of the community-dwelling elderly, observed cognitive decline is not irreversible. Part of what has been termed "decline" is likely attributable to disuse and can be subjected to environmental manipulations involving relatively simple educational training techniques.

Although the magnitudes of pretest–posttest training gains were equivalent for stable and decline subjects, training effects have qualitatively different implications for the two groups. Stables and decliners obviously differed on baseline performance at pretest. Consequently, the effects of training resulted in moving the decliners closer to their previous performance levels, whereas training resulted in raising the performances of the stables beyond previously exhibited performance levels. Thus, the mean levels of performance at posttest differed significantly for the two groups.

Without prior longitudinal data, it is not possible to address issues regarding the directionality (i.e., remediation, incrementation) of training effects. Given current cohort differences in ability performance levels, many older adults may be disadvantaged when compared with younger age cohorts, even though showing no significant ability decline. Because most studies have not had subject samples with prior longitudinal data, the more appropriate focus for training research is on the magnitude or range of training gains, rather than on the directionality of the training effects.

Specific behaviors and skills modified via training procedures

The most commonly used dependent variables in gerontological training research have been the number of correct responses and/or the speed of responding. However, these indices provide only limited insight into what specifically is modified as a function of training. An increase in correct responses may occur in several ways. For example, as a result of training, the subject may respond more quickly, therefore attempting more problems and answering a greater number of items correctly. However, the number of commission errors may also increase, such that there will be no change in level of accuracy. On the other hand, training may result in little increase in the number of items attempted, but there may be a significant decrease in commission errors, so that accuracy as well as the number of correct responses will increase.

Error analyses

More microlevel assessments, particularly componential and error analyses, have proved useful in examining the qualitative nature of training improvement. For example, in their study on spatial egocentrism, Schultz and Hoyer (1976) found that training improvement occurred as a result of a significant reduction in perceptual judgment errors (wrong responses), but not in egocentric responses per se. In fact, this sample of elderly people made relatively few egocentric judgments, even prior to training.

Error analyses conducted in conjunction with a series of training studies focusing on the fluid abilities of inductive reasoning and figural relations suggest that various treatment procedures may be differentially effective in increasing performance accuracy. Baltes and associates (1986) found a significant increase in number of correct responses for both a cognitive-training group and a pretest–posttest control group; thus, both cognitive training and simple retest exposures are effective in increasing correct responding. However, ability-specific cognitive training was also effective in decreasing the proportion of commission errors, thus increasing the level of accuracy. In contrast, the pretest–posttest control group exhibited an increase in commission errors. These findings are supported by results from two studies examining extensive retest experience (Hofland, 1981; Hofland et al., 1981). Older subjects experiencing multiple retest sessions with no feedback regarding performance exhibited significant increases in total number of items attempted and in the number of correct responses. However, the proportion of commission errors did not significantly decrease. When the pretest–posttest control group was given additional time to solve test items, there was a significant increase in number of correct responses, but also an increase in commission errors, a finding similar to that for the control group in the study of Baltes and associates (1986). Thus, whereas an increase in correct responses can be elicited by simple retest procedures, improvement in accuracy of performance appears to be related to specific cognitive-training procedures.

Our recent research suggests that the qualitative nature of training improvement may vary with the particular ability that is the target of training. Performance on fluid abilities, such as figural relations and inductive reasoning, typically is characterized by a sizable number of commission errors. Therefore, an important aspect of fluid-ability training is a reduction in the proportion of commission errors. In contrast, descriptive research on spatial orientation indicates that the rate of commission errors is relatively low. The major source of individual differences (including age differences) is in the speed of mental rotation (Cerella, Poon, & Fozard, 1981; Cooper & Shepard, 1973). Thus, one would predict that effective training on spatial orientation would result in a significant increase in the number of items attempted, reflecting increased speed of mental rotation, but that there would be relatively little change in error rate. Error analyses of our study of spatial-orientation training support this prediction. Significant performance improvement is associated primarily with an increase in the number of items attempted (Willis, 1985).

In summary, this section on the nature of training effects has addressed three issues: breadth of training effects, directionality of training effects, and specific behaviors modified via training. Recent training research indicates that training effects are broad, in that they can be demonstrated at the level of the latent construct (e.g., ability factor); however, effects are specific (limited) to the ability trained. Training effects at the construct level have been demonstrated in the context of structural invariance in the measurement framework. With regard to the second issue, training has been found effective both for subjects exhibiting prior decline on the ability trained and for subjects showing no prior decline. Finally, the specific behaviors modified as a function of training appear to vary with the particular ability being trained. That is, for abilities characterized by high rates of commission errors, training may reflect largely a decrease in errors, whereas for other abilities (e.g., spatial orientation) in which speed of mental rotation is the critical component, training improvement may reflect change in this component.

Magnitude of training effects

How large are the training effects reported in the literature? Assessment of the magnitudes of training effects requires the specification of a criterion against which effects can be compared. Training effectiveness may be assessed in terms of the criterion of intraindividual change or in terms of the magnitude of interindividual differences in intraindividual change.

Intraindividual change

If intraindividual change is the primary concern, as we argue it should be, then training improvement needs to be compared with the individual's performance at some earlier time, prior to training. Ideally, if longitudinal data are available, then the individual's posttest performance can be compared with his or her performance at some earlier point in development. In our recent training research with SLS participants, we conducted a number of analyses to determine the training effects on the abilities of inductive reasoning and spatial orientation, using subjects' performances on these abilities 14 years prior to training. The effects of training on average performance levels were examined separately for three age cohorts (Schaie & Willis, 1985). The average ages for these cohorts at the time of training (in 1984) were 67, 74, and 81 years. For all of these age cohorts, statistically significant average declines had been noted by age 67 for the two abilities studied. A cohort's average level of performance 14 years prior to training was first compared with the average performance level for subjects receiving only pretest–posttest assessment (i.e., retest effects) and second compared with that for subjects receiving cognitive training, in addition to pretest–posttest assessment. For *spatial orientation*, retest experience alone was sufficient to remediate the 14-year average decline for the younger (67 years) and middle (74 years) age cohorts. For the oldest cohort (81 years), cognitive training resulted in remediation of average decline. For the younger cohort (67 years), cognitive training raised the average performance level significantly above that observed 14 years previously.

Similar findings occurred for *inductive reasoning*. Retest effects alone were sufficient to remediate the youngest cohort (67 years) to the average performance level 14 years previously. Cognitive training remediated the 14-year average decline for the oldest cohort (81 years) and raised the average performance levels of the youngest and middle cohorts significantly above their average performance levels 14 years previously. Thus, for the young-old, simple retest experience appears to be an effective remediation procedure. For the old-old, more length and structured cognitive-training procedures appear to be required for remediation.

The power of a longitudinal approach to training research, however, lies in the potential for assessing training effectiveness at the individual level, as well as at the group (average) level. When intraindividual change is examined for particular individuals, what proportion of subjects exhibit significant training effects? In our research, we found that approximately 40% of subjects exhibiting prior decline could be remediated to or above their performance levels 14 years previously (Schaie & Willis, 1986). The proportions of subjects showing remediation were comparable for the inductive-reasoning and spatial-orientation abilities.

When the criterion was shifted to pretest–posttest training gain, we found that over half of decliners exhibited significant training improvement. Prior level of performance was a less useful criterion for assessing training improvement for subjects showing no cognitive decline on the ability trained. However, when pretest–posttest training gain was used as the criterion, we found that over half of the stable subjects trained on inductive reasoning showed significant improvement, whereas 40% of stable subjects trained on spatial orientation showed significant pretest–posttest gain.

Interindividual differences in intraindividual change

In the majority of training studies lacking prior longitudinal data, the magnitudes of training effects have been assessed in terms of interindividual differences in intraindividual change: The pretest–posttest training gain of the training group has been compared with that of a control group. When the magnitude of training improvement was examined in terms of standard-deviation units, several studies reported effect magnitudes on the order of .50 to 1.00 standard deviations (Baltes et al., 1986; Hornblum & Overton, 1976; Willis et al., 1981; Willis & Schaie, 1986).

How do these estimates of training gains compare with the magnitudes of age-related declines, as estimated from longitudinal data sets? Recent estimates of the magnitude of age-related declines derived from Schaie's longitudinal study (Schaie & Willis, 1985) indicate that from the age where decline can first be reliably demonstrated to age 74, the magnitude of decline is on the order of one-half of a standard deviation for fluid abilities, such as spatial orientation and inductive reasoning. The cumulative decrement to age 81 amounts to approximately .75 of a population standard deviation. Thus, the magnitude of training improvement reported in several studies compares favorably with the effect size for age-related decline.

If analyses of training effects are to focus primarily on interindividual differences in intraindividual change, the selection of appropriate comparison/control groups becomes critical. The researcher must consider questions such as these: What types of comparisons are of interest? What variables are (are not) controlled for by selection of a particular control group? When training and control groups are randomly selected from the same population, there is the assumption that the effects of all variables expected to be related to the treatment effects have been eliminated (Campbell & Stanley, 1963; Krauss, 1980). Thus, group differences may be attributed to treatment effects.

Age-comparative studies

We find interpretation of training effects involving younger-age comparison groups particularly troublesome. Age-comparative research, whether descriptive or interventive in focus, typically has violated critical assumptions of quasi-experimental design, in that age, of course, cannot be randomly assigned. Rarely have age-comparative studies given careful consideration to comparability of age groups on variables such as education, testing experience, health, and sensory impairment, all of which have been shown to be related to intellectual performance.

In many age-comparative studies, younger and older groups have been compared in terms of their *levels* of performance at posttest. When a significant age difference in performance levels has been found, the authors have concluded that such age differences have not been due primarily to environmental variables, because training intervention (often involving less than an hour) has not eliminated average performance differences. However, for many of the cognitive variables that have been the focus of training research, cohort differences have been reported that have been as large as or larger than the magnitude of age-related change (Schaie, 1983). Even if training is effective in remediating age-related decline for a significant proportion of subjects, it is to be expected that age differences attributable to cohort differences will remain. Age comparisons of levels of performance are, then, particularly vulnerable to multiple confounds. Age comparisons of pretest–posttest change scores probably are the most defensible units of comparison; see Nunnally (1982) for a discussion of change scores. The absence of a significant interaction between age and treatment (assuming a treatment main effect), as reported in several studies, suggests considerable plasticity of intellectual functioning in later adulthood, in that the training gain for the older group was as great as the training gain for the younger group.

In summary, the magnitude of training effects must be assessed with regard to a criterion. We have argued that the individual's performance at some earlier time, prior to training, is the most appropriate criterion, because intraindividual change is the primary concern in the study of behavior plasticity. However, most training research has employed a control group as the criterion, and thus the focus is on interindividual differences in intraindividual change. Several studies have reported effect magnitudes on the order of .50 to 1.00 standard deviation (SD).

Individual differences in training effectiveness

We come now to the issue that is of greatest concern to the older adult, and often to the clinician. Who benefits from training procedures? That is, what are the individual-difference variables associated with training improvement? Ironically, this is an issue that has received little attention in the training literature; see Yesavage, Lapp, and Sheikh (Chapter 31, this volume).

Given the current propensity toward age-comparative designs in research on intellectual aging, chronological age has been one of the common individual-difference variables examined. Researchers have hypothesized that if age differences reflect primarily experiential/environmental differences, then the elderly should exhibit greater training effects than younger age groups. There appears to be the implicit assumption that younger age groups are nearer their maximal potential levels of performance than are older adults and therefore should show smaller training gains. However, longitudinal research indicates that peak levels of performance on many abilities are not attained until the thirties (Schaie, 1983); thus, the typical college-age comparison group may be a full decade from their peak performance levels. Moreover, the limited trials involved in most training

studies have not provided an adequate test of maximal performance levels for either age group (Kliegl & Baltes, in press).

The findings are limited and mixed regarding chronological age as a predictor of training improvement within the period of later adulthood. In their training research on the fluid abilities of figural relations and inductive reasoning, Baltes and associates (1986) reported that subjects under 70 years of age exhibited a larger training gain (.1 SD) than did subjects over the age of 70. However, those authors considered these age effects to be rather small, compared with the magnitude of the main effect of training. In our training research on inductive reasoning and spatial orientation, we found that covarying on age, education, and income did not significantly alter the training outcomes (Schaie & Willis, 1986). However, as reported earlier, we found that more intensive and more lengthy training procedures were needed to remediate age-related declines for older cohorts (average age 81) than for younger cohorts (average age 67).

There is some evidence that training may be particularly effective for subjects who have experienced decline on the target ability. Although there was no significant difference between stables and decliners in the magnitude of training gain at the factorial level for either inductive reasoning or spatial orientation, we did find greater training improvement for decliners when training effects were examined at the level of individual tests (Schaie & Willis, 1986; Willis & Schaie, 1986). In particular, subjects who had declined on spatial orientation showed greater training gains. Likewise, training improvement on spatial orientation was greater for females, specifically females who had declined (Schaie & Willis, 1986; Willis, 1985). However, greater training improvement by decliners was not a function of regression toward the mean effects (Schaie & Willis, 1986). Nor did subjects suffering decline function at a lower baseline performance level than stable subjects; stable and decline subjects did not differ in performance level 14 years prior to training (Schaie & Willis, 1986). Baltes and associates (1986) reported that there was a trend for subjects with lower initial levels of performance to exhibit greater training improvement. Lower initial performance levels may reflect decline at some point prior to training.

It should be noted that the training studies cited in this literature review involved community-dwelling elderly who were in fair to excellent health. We do not wish to imply that the cognitive-training procedures utilized in these studies would necessarily be effective with elderly suffering from neuropathologies or severe chronic illnesses. Findings were not as positive from the limited research examining the effectiveness with clinical populations of the brief training procedures employed in the literature cited earlier. However, more intensive intervention procedures have been used effectively to modify more limited areas of behavioral functioning in clinical populations (Wilson & Moffat, 1984; Wilson, Chapter 32, this volume).

In summary, examination of the individual-difference variables associated with training outcomes is one of the most neglected areas in training research and merits further study. Key variables examined have included age, prior decline status, gender, and health. The relative importances of these variables as predictors of responsiveness to training are not well documented at present.

Maintenance of training effects

The temporal durability of training effects is an important issue for both theoretical and practical reasons. The utility of training efforts is greatly diminished unless behavioral proficiency is maintained over time. However, the designs of most training studies have not included delayed posttests. Several studies have reported maintenance of training effects several weeks after training (Beres & Baron, 1981; Blieszner et al., 1981; Hornblum & Overton, 1976; Labouvie-Vief & Gonda, 1976). Maintenance of effects 6 months after training on several fluid abilities has been reported by Baltes and associates (1986) and Willis and associates (1981, 1983). Finally, sustained effects have been reported at 10 months and 1 year following training by Baltes and Willis (1982) and Sanders and Sanders (1978), respectively.

A number of methodological issues are involved in assessing the durability of effects. Delayed posttests provide additional practice on the target measures and thus often serve as a minor form of intervention. In our ADEPT training research involving 1-week, 1-month, and 6-month posttests, we observed increases in levels of performance for both the training and control groups from the 1-week to the 1-month posttest. These retest effects may be particularly sizable for the control group. In the study of Blieszner and associates (1981), the mean performance level of the training group was stable from 1 week to 6 months after training; however, the control group exhibited a significant retest effect across delayed posttests, such that the training–control-group difference was no longer significant at 6 months. Simple retest practice can be a powerful procedure for boosting performance of no-treatment controls at delayed posttests.

When treatment–control-group differences diminish across time, it is important to examine the extent to which the effect reflects decay of training or potent retest gains. One procedure for disentangling treatment maintenance and retest effects is to include multiple control groups, staggering the timing of the initial posttest across groups.

Maintenance of training effects typically has been assessed in terms of mean number of correct responses. However, error analyses have suggest that although both cognitive training and retest experiences result in increases in total number of items attempted and number of correct responses, cognitive training also has the effect of increasing the accuracy level (i.e., decreasing commission errors), whereas the commission-error rate may actually increase under simple retest procedures (Baltes et al., 1986; Hofland et al., 1981). Therefore, analyses of maintenance effects need to include procedures such as error analyses to examine more closely what behaviors are maintained across time.

Although we consider maintenance an extremely important concern, it is important to recognize that the question of the range of behavioral plasticity is a separate issue from that of maintenance. Demonstration of the reversibility of performance decline does not require that these effects be maintained over time. The question of reversibility is addressed most pointedly at the initial posttest. Should we expect training effects to be infinitely durable? No. Research on life-style antecedents of cognitive change indicates that in the natural environment, different types of life styles are associated with maintenance and decline of cognitive functioning (Gribbin, Schaie, & Parham, 1980; Stone, 1980). Maintenance of intellectual performance in healthy older adults is associated with an active life style involving high levels of environmental stimulation. In contrast, decline in intellectual functioning is associated with a restrictive life style, often involving the loss of family supports. If, following training, the individual returns to a life style associated with deleterious cognitive effects, should maintenance of training gain be expected?

Maintenance of cognitive gain following training would seem to require the incorporation of certain critical experiential variables into the life space of the older adult. We, as scientists, know relatively little about the person and environmental variables associated with maintenance of intervention effects. Examination of the more applications-oriented intervention literature on topics such as weight reduction, drug addiction, and cigarette smoking indicates relatively meager success with regard to maintenance of effects. The procedures required to maintain effects may be in many ways qualitatively different from the intervention strategies employed to induce the initial change in behavior. For example, we would not suggest that older adults continue to take periodic cognitive-training booster sessions for the remainder of their lives.

Research on which activities of daily living are related to maintenance of high levels of performance on specific abilities or cognitive processes may prove useful. Just as has been argued with regard to the life-event literature (Hultsch & Plemons, 1979), it probably will be the salient dimensions characterizing these activities, rather than the specific activities per se, that are important. Intervention research in the natural environment can then explore whether or not inclusion of these experiential dimensions in daily living results in maintenance of performance on those abilities associated with these dimensions.

In summary, the few studies that have examined the temporal durability of training effects indicate maintenance at 6-month and 1-year intervals following training. Maintenance of intervention effects for lengthy periods following training would seem to require modifications in the subject's life space that would foster and facilitate utilization of the effective cognitive behaviors acquired during training.

Future perspectives and conclusions

A well-documented finding in descriptive research on intellectual aging is the increasing range of individual differences with age. We believe that one of the most critical next steps in cognitive-training research is movement from a normative to a differential approach to training. The need for a differential approach to the study of aging (in general) was described some years ago (Thomae, 1976), and though often discussed and lauded, it is still the exception when it is adequately reflected in empirical research. Cognitive-training research offers a microcosm for examining some of the more salient individual-difference variables as they interact with training outcomes.

Examination of the interactions between individual differences and training improvements is important in at least two respects. First, it extends our understanding of the nature of training improvement. In our own research, we have been examining the differentiation of training improvement due to remediation of cognitive decline versus training gain reflecting new performance levels in subjects experiencing no prior decline.

Second, examination of individual-difference variables may prove useful in targeting those populations most likely to benefit from training. The fact that a sizable proportion of subjects who had shown prior decline exhibited significant training gains provides empirical support for educational programs for the elderly. Further research is needed on those individual-difference characteristics that distinguish those decliners who showed significant training improvement and those who did not.

Thus, findings from a differential approach to training not only have potential for contributing to basic knowledge on cognitive aging but also should have utility for more applied concerns with regard to clinical and public-policy issues. In order to facilitate optimal functioning and care for the growing proportion of the elderly, we must proceed to ask, Which old dogs can learn what tricks?

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