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Long-Term Effects of Fluid Ability Training in Old-Old Age

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This study examined the effects of multiple phases of cognitive training on older adults' intellectual performance over a 7-year period as Ss advanced from young-old to old-old age. The study involved a pretest–posttest/no-treatment control-group design. At each of 3 training phases, conducted in 1979, 1981, and 1986, Ss received 5 training sessions on the fluid ability of figural relations. Participants ($N = 38$) had a mean age of 69 years (range = 63–80) at the onset of the study. Results showed that (a) significant training effects occurred at each of the 3 study phases, when Ss had mean ages of 69, 71, and 77 years; (b) the largest training gains were made in the first training phase; and (c) as a function of multiple phases of training, Ss in their 70s and early 80s performed significantly above their baseline level of figural relations performance 7 years previously.

A number of studies have reported significant improvement in the elderly's cognitive performance immediately after a brief cognitive intervention (Bachman, 1989; Baltes, Dittman-Kohli, & Kliegl, 1986; Willis, 1987; Yesavage, Lapp, & Sheikh, 1989). The present study extended prior research by examining the impact of multiple phases of training on cognitive performance and the long-term effects of training. Although findings from previous training studies have been important in highlighting the range of variability or plasticity in cognitive performance that can be experimentally manipulated in the elderly, the developmental issue of the relation of training improvement to subsequent cognitive functioning in advancing old age has received little attention. Elderly subjects participating in cognitive training studies have been, on average, in their mid- to late sixties, the period during which age-related decline begins to occur (Cunningham, White, & Smook, 1985; Schaie, 1989). The question arises of the long-term impact of brief cognitive interventions for subjects in their seventies and eighties, when there is an increasing probability of cognitive decline.

This study examined the long-term effects of training for elderly subjects who participated in a cognitive training study from 1979 to 1986 (Baltes & Willis, 1982; Willis, Blieszner, & Baltes, 1981). Experimental subjects participated in three phases of training: in 1979, when subjects were on average in their late sixties; in 1981, when subjects were in their early seventies; and in 1986, when subjects were in their late seventies. At each of the three training phases, subjects received training on the fluid ability of figural relations. Figural relations ability involves abstract reasoning with figural stimuli (Cattell, 1971); previous longitudinal research on other fluid abilities has indicated that reliable age-related decline begins to occur, on average, in the mid- to late sixties (Schaie, 1983). At each training phase, the performance of subjects was compared to a no-treatment control group that participated only in pretest and posttest sessions.

Two major questions were addressed in the present study. The first question focused on a comparison of the magnitude of training improvement across the three phases of training. In the first phase of this study, subjects exhibited a pre–posttraining gain of approximately 1 *SD* (Willis et al., 1981). In the present study, gain at the subsequent two phases of training was compared. Training improvement might be expected to be cumulative across intervention phases such that larger gains (rate of improvement) are achieved at successive training phases. However, previous cognitive training research with both young and old-older adults has suggested that the greatest gains are made in the initial phase of training and that the subsequent rate of improvement is somewhat slower (Beres & Baron, 1981; Hofland, Willis, & Baltes, 1981). Moreover, in the present study, the advancing age of subjects across the study phases made them more vulnerable to the onset of health problems and to age-related cognitive decline, thus possibly reducing their responsiveness to training intervention.

The second major question focused on change in the subjects' performance from baseline (1979 pretest). We examined whether trained subjects could function at a level significantly above their baseline performance across the period from young-old to old-old age if they continued to receive brief cognitive interventions. Findings from previous longitudinal research has indicated that, on average, reliable cognitive decline begins to occur from young-old to old-old age (Cunningham, 1987). There are wide individual differences, and some older adults do not experience reliable decline on some abilities until the late seventies. However, even among the elderly who experience no decline until advanced old age, significant improve-

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ment above previous performance levels is rare (Schaie, 1983). The present study examined whether cognitive training across the transition from young-old to old-old age would be effective in sustaining performance levels above those observed in young-old age, prior to training.

Method

Subjects

Subjects were 37 (9 male, 28 female) older adults who participated in the Adult Development and Enrichment Project (ADEPT) Figural Relations training study from 1979 to 1986. Mean age of subjects in 1979 was 69.6 years (SD = 4.8; range = 63–80). Mean educational level was 11.7 years (SD = 3.8; range = 6–22). Subjects lived in small rural communities in central Pennsylvania and rated their general health, eyesight, and hearing as good at all occasions of measurement. At the final assessment, (1986), training (N = 25; 5 men, 20 women) and control (N = 12; 4 men, 8 women) groups did not differ in age, educational level, or ratings of general health, eyesight, or hearing. Training and control subjects did not differ on 1979 mean pretest scores on the ADEPT Figural Relations Test (Plemons, Willis, & Baltes, 1978).

Attrition effects for total group. Attrition effects were examined for the total sample and separately for training and control groups. Ninety-two subjects (23 men, 69 women) began the study in 1979. Returning and nonreturning subjects did not differ significantly on their 1979 ADEPT Figural Relations pretest scores. Returning and nonreturning subjects also did not differ significantly in educational level or in 1979 self-ratings of general health, eyesight, or hearing. Attrition effects were found for age; returning subjects were younger than nonreturning subjects, $t(91) = 3.0$, $p < .01$. Reasons for nonreturn in 1986 were examined: 20.7% of the original sample had died; 23.9% were ill or in nursing homes; 8.7% had moved; and 6.5% were not interested in continuing participation. It should be noted that the drop-out rate associated with illness/institutionalization is consistent with national demographic data for 75–84-year-olds. Survey findings indicate that 15 to 25% of the old-old are disabled and require assistance with one or more activities of daily living (Cornoni-Huntley et al., 1985; Longino, 1986; Soldo & Manton, 1985).

Attrition effects for training and control groups. Attrition effects were also examined separately for training and control groups. Because the study was planned to examine long-term effects of training and because subject attrition was expected, twice as many training (N = 60) as control (N = 32) subjects were recruited in 1979. Attrition effects were not found for the 1979 ADEPT Figural Relations pretest for either training or control groups. Returning training subjects were significantly ($p < .05$) younger and had more years of education than nonreturning training subjects; however, the groups did not differ in self-ratings of general health, eyesight, or hearing. No attrition effects were found for the control group on age, educational level, or self-ratings of health, eyesight, or hearing. Reasons for drop-out were similar for training and control groups, respectively: deceased, 20% and 22%; illness, 25% and 22%; moved, 8% and 9%; and not interested, 5% and 9%. In sum, although the returning group was somewhat positively biased in age, performance of returning and nonreturning subjects did not differ at the first occasion of measurement for the primary dependent variable in the present study, the ADEPT Figural Relations Test.

Design and Procedure

This study comprised three phases. Each phase involved a pretest–treatment–posttest/no-treatment control-group design. The first study phase occurred in 1979–80 and examined improvement in mental ability performance as a function of training. The second study phase (1981) began approximately one year after the initial phase and was designed to examine whether further training would result in greater training gain. The third study phase occurred in 1986 and was designed to assess the long-term maintenance of training effects and to examine whether additional training in old-old age would be beneficial. In the first phase, subjects were randomly assigned to training and control groups. In Phases 1 and 2, training subjects participated in five 1-hr training sessions. In Phase 3, training subjects received only two training sessions because of advanced age and increasing visual limitations. Subjects were trained in groups of 4 to 8 persons by a middle-aged female trainer. The no-treatment control group received pretests and posttests but no training.

Training Program

The training program focused on the fluid ability of figural relations. Figural relations ability is defined by tasks involving the identification of rules or patterns in figural material. The content of the training program was based on a task analysis of Scale 2 of the Culture Fair Test (Cattell & Cattell, 1957), which had been previously shown to be a strong marker of figural relations ability. The Culture Fair Test has four subtests (Figure Series, Figure Classify, Matrices, and Topology), each involving a different type of figural relations problem. The task analysis identified relational rules (e.g., size, shape, position) utilized in solving items in each subtest. Training problems were then developed for the most frequently occurring relational rules associated with each subtest. None of the training items were identical to test items on the Culture Fair Test.

The training sessions focused on each of the four types of figural relations problems. The sessions involved the trainer modeling the use of relational rules in solving the task, individual practice by subjects on training items, feedback regarding correct solutions of practice problems, and group discussion. The training program was very similar across the three study phases, and all sessions were conducted by the same trainer.

Measures

The same pre–posttest battery was administered during each of the three study phases. The battery included measures of fluid and crystallized intelligence. The most direct measure of training effects was the ADEPT Figural Relations Test, developed in early pilot research (Plemons, Willis, & Baltes, 1978); test items were based on the relational rules identified in the task analysis described for the training program. The ADEPT Figural Relations Test is the dependent measure of interest in the present study. This test was the only figural relations measure administered at pretest at each of the three phases, thus permitting the analysis of change across occasions and study phases.

Results

Findings are presented with regard to two questions. First, the relative magnitude of training gains achieved at each of the three study phases is compared. Second, change in performance from baseline (1979 pretest) is assessed across the three study phases.

Derivation of Scores

To examine change in level of performance across occasions, the entire data matrix for the ADEPT Figural Relations Test was scaled to the total group's 1979 pretest score (M = 50; SD = 10). Scores were then adjusted for attrition effects.

Table 1
Adult Development and Enrichment Project Figural Relations Test: Mean T Scores and Standard Deviations

Group	Phase 1		Phase 2		Phase 3	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Training						
M	49.78	61.90	59.10	66.14	54.10	60.62
SD	12.15	10.32	10.44	11.35	13.16	10.97
Control						
M	51.41	52.82	52.99	56.57	51.49	53.41
SD	10.25	10.56	10.02	9.83	9.78	11.29

Note. Mean scores are adjusted for attrition effects.

Although the performance of the returning and nonreturning subjects on the 1979 ADEPT Figural Relations pretest score did not differ significantly ($p < .17$), we decided to adjust returning subjects' score level across occasions for the slight positive bias that was found, because attrition effects are a major concern in the study of longitudinal change (Campbell & Stanley, 1963; Schaie, 1989). The magnitude of the attrition effect on the ADEPT Figural Relations Test was computed as the difference between the returning (1986) subjects' 1979 pretest score and the total group's score. Because the magnitude of attrition effects on the ADEPT Figural Relations Test differed somewhat for training and control groups, adjustments were computed separately by group. The mean attrition effect for training and control groups was 1.66 and 2.01 *T* score points, respectively. This attrition effect was subtracted from the returning training and control groups' scores at all measurement occasions. The mean scores, adjusted for attrition effects, are shown in Table 1 for training and control groups at pre- and posttest occasions for each study phase.

Comparison of Magnitude of Pretest–Posttest Gains Across Study Phases

The magnitude of the training gains achieved in the three study phases was compared by means of a 2 (group: training, control) × 3 (occasion: 1979 posttest − 1979 pretest; 1981 posttest − 1981 pretest; 1986 posttest − 1986 pretest) multivariate analysis of variance (MANOVA) with repeated measures, with change scores as the dependent variables. A significant main effect for group was found, $F(1, 35) = 20.54$, $p < .001$, indicating that the gains for the training group were greater than those for the control group across all study phases. The main effect for occasion was not significant, indicating that the magnitude of change did not differ significantly across the three study phases when averaged across groups. Also, the Group × Occasion interaction was not significant, indicating that group differences in pretest–posttest gains did not vary significantly among the three study phases. Figure 1 shows the mean change scores for the training and control groups at each study phase.

Relation of Pretest–Posttest Gains to Score Level, Age, and Education

The relationship between level of performance and magnitude of pretest–posttest gain was examined next. For each of the three training phases, the pretest score for that phase was correlated with the posttest–pretest change score. At the first training phase (1979), subjects with lower pretest scores exhibited greater training gain ($r = -.47$, $p < .01$). However, the relationship between score level and pretest–posttest gain was not significant at Phase 2 or Phase 3 of training. Thus, although lower performing subjects initially exhibited greater training improvement, this relationship was not manifested at subsequent training phases. Later training effects thus cannot be explained in terms of a regression toward the mean (Nesselroade, Stigler, & Baltes, 1980). Moreover, baseline performance level (1979 pretest) was not significantly related to pretest–posttest change at Phase 2 or at Phase 3. The relationships between pretest–posttest change scores at each training phase and age and educational level were also examined; no significant correlations were found.

Performance Improvement Above Baseline

Group differences in magnitude of change from baseline performance (1979 pretest) were examined across study occasions. The difference between each subject's 1979 pretest score and his or her score at each subsequent occasion was computed, resulting in five change scores (1979 posttest − 1979 pretest;

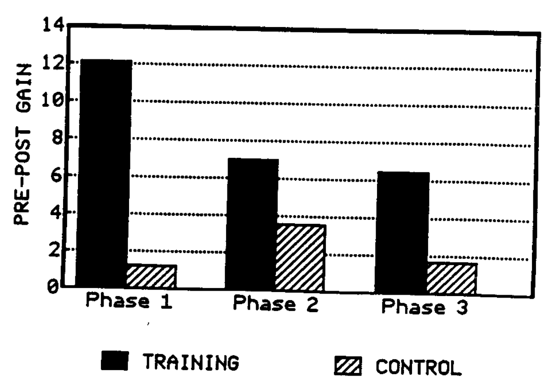

Figure 1. Mean pretest–posttest change scores on the Adult Development and Enrichment Project Figural Relations Test for training and control groups at three study phases.

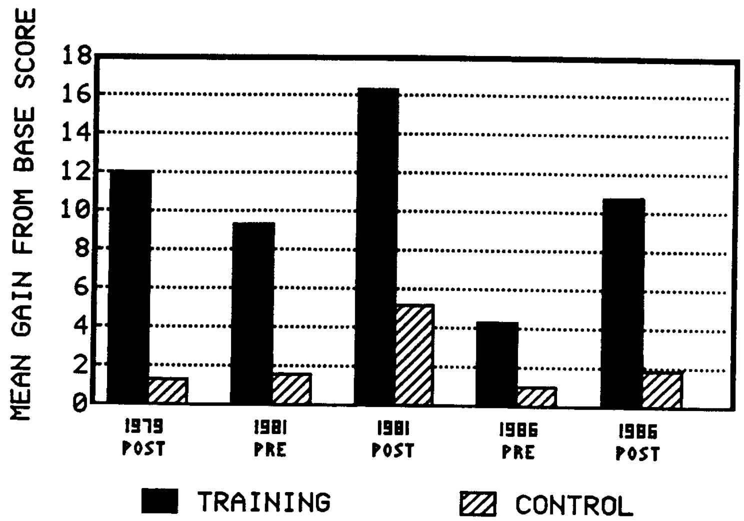

Figure 2. Mean change score from baseline (1979 pretest) on the Adult Development and Enrichment Project Figural Relations Test for training and control groups. (The five change scores are 1979 posttest − 1979 pretest; 1981 pretest − 1979 pretest; 1981 posttest − 1979 pretest; 1986 pretest − 1979 pretest; and 1986 posttest − 1979 pretest.)

1981 pretest − 1979 pretest; 1981 posttest − 1979 pretest; 1986 pretest − 1979 pretest; and 1986 posttest − 1979 pretest). Figure 2 presents the five mean change scores separately for training and control groups.

A 2 (group: training, control) × 5 (occasion) MANOVA with repeated measures was conducted with the five change scores described above as the dependent variables. A significant main effect for group, $F(1, 35) = 7.91$, $p < .001$, was found, indicating that the training group exhibited greater change from baseline performance than did the control group, averaging across occasions. A significant main effect for occasion was found, Rao's $R(4, 32) = 14.68$, $p < .001$, indicating that change from baseline varied across occasions when averaged across groups. Post hoc analyses indicated that the change from baseline to the 1981 posttest was significantly ($p < .05$) greater than all other change scores. The Group × Occasion interaction failed to reach significance, indicating that the ratio of change in the training group compared with change in the control group did not significantly differ across study phases.

Subjects' change from their baseline performance was also examined at the individual level. The proportion of subjects performing at or above their baseline score on all subsequent occasions was assessed. Of the training subjects, 64% scored at or above their baseline on the five subsequent measurement occasions, compared with 33% of the control group.

Finally, accuracy of subjects' performance in 1986 was compared with accuracy at baseline. Accuracy was defined as the proportion of correct responses to total number of items attempted. At baseline, the accuracy rates for training and control groups were 51% and 53%, respectively. At 1986 pre- and posttest, training and control subjects were functioning at a higher rate of accuracy than at baseline. Accuracy rate at 1986 pre- and posttest for the training group was 63% and 75%, respectively, compared with 56% and 60% for the control group.

Discussion

This study examined the long-term effects of cognitive training over a 7-year period as subjects advanced from young-old age (mean age = 69 years) to old-old age (mean age = 77 years). Experimental subjects received three phases of cognitive training on the fluid ability of figural relations. The design of the study, involving multiple training phases and the follow-up of subjects over an extended time period, permitted the examination of two questions that have received little attention in the training literature.

Relative Gain Across Multiple Training Phases

The first question focused on a comparison of the magnitude of training gain at each intervention phase. Three findings are of interest with regard to this question. First, the largest pre–posttest training improvement occurred at the first phase of training (Figure 1), although the Group × Occasion interaction only showed a trend toward statistical significance. The magnitude of improvement at Phase 1 amounted to 1.2 *SD*, compared with 0.6 *SD* at Phase 2 and at Phase 3. The finding of greater gain associated with an early phase of training confirms earlier work with both young and older adults (Beres & Baron, 1981; Hofland et al., 1981). Moreover, findings from the present study support previous research (Schaie & Willis, 1986) in that the cognitively disadvantaged, those performing at a lower level, profited the most at early training phases.

Second, cumulative training gain appears most likely to occur when phases of training are closely spaced temporally. The training group reached its highest performance level after the second phase of training, which occurred approximately 1 year after the first phase; because there was little change in performance from Phase 1 posttest to Phase 2 pretest, the gain achieved in Phase 2 appears to be cumulative to the gain achieved in Phase 1. The largest retest effects for the control group also occurred at the second phase of training.

The third finding focuses on the significant pre–posttest gain made in Phase 3, which indicates that there is considerable potential for modifiability of cognitive performance even in old-old age for reasonably healthy subjects. The same magnitude of training gain (0.6 *SD*) was achieved at Phases 2 and at Phase 3, although all subjects were 5 years older at Phase 3, and training subjects received only two training sessions at Phase 3. Moreover, at Phase 3 posttest, subjects performed at the same level that they had attained at the Phase 1 posttest but somewhat below their Phase 2 performance level.

Change From Baseline Performance Level

The second issue involved a comparison of subjects' baseline performance with subsequent performance levels. An important finding of the study was that training subjects performed, on average, above their baseline score across all later measurement occasions. The improvement in cognitive functioning over this age period is of importance because longitudinal data has reported an average age-related decline of approximately 3 *T* score points over the age range of 67 to 74 years (Schaie, 1983). In contrast, training subjects in the present study functioned, on average, 10 *T* score points above their baseline score immediately after training in 1979 and again in 1986, when subjects were in their mid-seventies.

Long-term effects of training were demonstrated in the finding that 5 years (1986 pretest) after Phase 2 training, subjects performed, on average, 5 *T*-score points above their baseline. Significant improvement above baseline was not found for the control group (except at Phase 2 posttest); however, retest effects associated with pre- and posttesting appear to have contributed to the control group's maintaining their baseline level of performance across a period in which some age-related decline would have been expected on average.

Because significant changes in mean scores can be due to a few extreme cases, change from baseline was also examined at the individual level. The proportion of subjects performing above their baseline score at all occasions over the 7-year study period was examined. Sixty-four percent of the training group's performance was consistently above baseline, compared with 33% of the control group's. Improvement above baseline, as a function of training or retest effects, was also reflected in changes in accuracy of performance. At baseline, training and control groups answered correctly only half of the items attempted; accuracy rates for the groups were 51% and 53%, respectively. At the 1986 posttest, training subjects answered, on average, 75% of the attempted items correctly, compared with 60% for the control group.

Conclusions

The major objectives of this study were to examine the effects of multiple phases of training on the elderly's cognitive functioning as they advanced into old-old age and to assess the long-term effects of training. To examine these issues, experimental and control subjects were studied over a 7-year period, with experimental subjects receiving three phases of cognitive intervention. The magnitude of training gain associated with each of the study phases was assessed, and subjects' performance at baseline was compared with their level of performance at later occasions in the study.

The results of the study show the following: (a) As a function of multiphase cognitive training, many adults in old-old age can perform at a higher ability level than that demonstrated in young-old age at baseline. (b) There is considerable plasticity in cognitive functioning into old-old age. Older adults in their late seventies can show significant training improvement. (c) The magnitude of training improvement is greater at earlier phases of training, but higher performance levels are attained at later phases of intervention because of cumulative effects. (d) Magnitude of training improvement is unrelated to age or education.

In interpreting these findings, it is important to keep in mind that our subjects were community-dwelling adults who reported themselves to be in good health. We do not wish to claim that cognitive training procedures such as those used in this study would be effective with older adults suffering cognitive changes associated with neuropathologies.

In summary, our findings support prior work on the plasticity of cognitive performance in late adulthood. For a substantial proportion of community-dwelling older adults, lower levels of cognitive performance may be associated with limited cognitive stimulation in their everyday environment and with disuse. Training research indicates that for these older adults, ability performance can be enhanced through brief educational exercises. However, training gain would be expected to dissipate if, after training, subjects returned to a nonstimulating environment or failed to exercise the skills emphasized in training. Findings from this study suggest that multiphased training efforts are effective in sustaining higher levels of cognitive performance even into old-old age. Although the training procedures used in the present study were experimental, the challenge for future research is to explore naturalistic types of activities that would be effective in enhancing and maintaining cognitive functioning.

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