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# Training Research in Aging: Attentional Processes

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This training study examined the modifiability of older adults' ($N = 73$; $M$ age = 70.5 years) performance on measures of attentional processes and training transfer to the psychometric ability domains of perceptual speed, memory span, and fluid-crystallized intelligence. Significant training effects occurred for attention measures, and these effects were maintained at 6-month posttest. However, no far training transfer was found to the ability factors of fluid-crystallized intelligence or memory span. This lack of far transfer is supported by prior structural analyses of attention-ability relationships, which showed the present attention measures to load primarily on a perceptual speed factor, not on fluid (GF) or crystallized (GC) intelligence dimensions. It is argued that examination of process-ability relationships within a transfer of training paradigm is of particular relevance for the educational researcher.

Our prior training research (Baltes & Willis, 1982) has examined the modifiability of older adults' performance on several dimensions of fluid intelligence. This research indicated significant training effects related to the two fluid abilities of figural relations (Willis, Blieszner, & Baltes, 1981) and induction (Blieszner, Willis, & Baltes, 1981). Transfer of training effects was shown to several measures of the target ability. These effects were maintained over a 6-month period. Similar training improvement in later adulthood has been shown for a variety of other intellectual dimensions (see Sterns & Sanders, 1980; Willis & Schaie, 1981, for reviews).

The present study extends this training paradigm to attentional processes. Specifically, the study focuses on training attentional processes that have been linked in the information processing and gerontological literatures with psychometric ability performance. The study, thus, contributes to clarifying the relationship between cognitive processes (such as attention) and certain psychometric mental ability factors, using a training transfer paradigm.

In recent years, increasing emphasis has been given to an information processing analysis of intellectual functioning. This trend has occurred both within the mainstream of cognitive research and specific to intellectual aging (Hunt, 1978; Poon, Fozard, Cermak, Arenberg, & Thompson, 1980; Sternberg, 1977). The role of attention processes in intellectual performance of older adults has been of particular interest. Older adults have been found to perform at lower levels on several attention processes: selective attention (Hoyer & Plude, 1980; Rabbitt, 1977), divided attention or attention switching (Craik, 1977), and concentration-vigilance (Talland, 1968). Of special

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relevance to our own research has been recent consideration of attentional processes associated with the theory of fluid (Gf) and crystallized (Gc) intelligence. Horn has suggested that attentional processes may be associated with age differences shown in fluid intelligence performance (Horn, 1982; Horn, Donaldson, & Engstrom, 1981). Specifically, Horn suggests that attentional processes may operate in the aging decline of Gf, as implicated in short-term memory and perceptual speed performance. In discussing these attentional processes, Horn et al. (1981) state

> The results suggested that Gf decline is associated mainly with defects in processes of organizing information; becoming alert to new information; ignoring irrelevancies; concentrating, maintaining, and dividing attention; and holding information in working memory.

Within the information-processing literature, Hunt (1978) has noted the possible parallel between information-processing deficits and Gf decline.

Given these emerging perspectives, we wished to examine the modifiability of older adults' performance on tasks representing four attention dimensions derived from prior research within both the information-processing and psychometric fields. The four attention dimensions were labeled discrimination, selective attention, attention switching, and concentration-viligance. Transfer-of-training effects were assessed to the psychometric ability domains of memory span, perceptual speed, and Gf-Gc intelligence. It was predicted that training improvement on attention should result in training transfer to the extent such attention processes are implicated in older adults' performance on these psychometric abilities. Finally, maintenance of training and transfer effects was assessed over a 6-month period.

## Method

### Design and Procedure

The study involved a pretest–treatment–posttest design. Following a pretest session, subjects were assigned randomly to one of the following three conditions: attention training, social contact control, and no-contact control. Attention training subjects participated in five 1-hour training sessions on attention tasks. Social-contact control subjects participated in five 1-hour discussion sessions dealing with friendship relationships in old age. The purpose of the social-contact control group was to examine whether posttest performance on attention and intelligence measures would be affected by participation in an equivalent number of hours of social contact that involved no training. The no-contact control group received only pre- and posttests. Subjects in the attention training and social-contact conditions met in groups of four to eight persons. Attention training sessions were conducted by a middle-aged female trainer; social-contact discussion groups were conducted by a female graduate student.

To examine maintenance of training, three posttests were administered approximately 1 week, 1 month, and 6 months after training. The pretest session (1.5 hours) involved seven near-transfer attention measures and two memory span tests (described below). At each posttest occasion, the pretest measures plus a battery of Gf-Gc and perceptual speed measures, representing far transfer, were administered (2 sessions/1.5 hours each). Order of test administration was constant across testing occasions. Subjects in the three conditions were pre- and posttested together in groups of no more than 12 persons. Pre- and posttesting was conducted by a middle-aged female tester with a graduate student proctor. Multiple rest breaks were given during pre- and posttest sessions.

### Subjects

Subjects were community residents in rural central Pennsylvania. They were recruited from local organizations and were paid for their participation individually ($2.00/hour), or an equivalent contribution was made to their organizations. Subjects reported themselves to be in good health with no major auditory or visual deficits.

Seventy-three persons ($M = 16$; $F = 57$) completed the 6-month posttest (attention training = 23; social-contact = 28; no-contact control = 22). Subjects' mean age was 70.5 years ($SD = 5.4$; Range = 62–84 years). Mean educational level was 11.9 years ($SD = 3.2$; Range = 5–22 years). Subjects completing the study in the three conditions did not differ in mean age or educational level. Treatment conditions also did not differ significantly in mean pretest performance on the seven attention measures; however, there was a systematic trend across all seven measures for the training group's mean scores to be lower than those for one or both of the control groups. Since the study extended approximately over a 9-month period, some attrition occurred. Data on possible dropout effects are presented in the Results section.

### Attention Dimensions

The research focused on four attention process dimensions, identified within the information processing and Gf-Gc intelligence literatures. These four dimensions are described briefly below.

*Discrimination* involves differentiating similarities and differences in perceptual stimuli quickly (e.g., discriminating letters, numbers, and figures). Discrimination is probably the most elementary of these four attention dimensions. *Selective attention* requires focusing on (selectively attending to) specific task stimuli while ignoring other irrelevant stimuli. Selective attention involves response competition—focusing on relevant features while inhibiting attending and responding to irrelevant aspects of the task. *Attention switching* requires shifting attention from one task or stimulus dimension to another and then shifting attention back again. Study of attention switching has often involved dual task measures. The subject must hold in memory material related to the first task while processing additional information related to the second task, and then switch attention again to the first task. Many psychometric tests (such as Gf measures) may involve complex combinations of cognitive demands that require attention switching. *Concentration-vigilance* involves sustained attention over a lengthy time period to simple tasks that are within the subject's repertoire. The emphasis is on persistence in attending to the task.

## Attention Measures

Seven measures identified from the information processing literature to represent these four attention dimensions are shown in the top of Table 1. A brief description of the measures representing each dimension is given below.

### Discrimination

*Letter Matching Test.* This task was originally devised by Posner (Posner & Mitchell, 1967). A paper-and-pencil version of this task was developed by Lansman (Lansman, Donaldson, Hunt, & Yantis, in press) and has been shown to tap the same cognitive processes as conventional process measures involving a reaction-time paradigm. The task involves determining whether pairs of letters are the same or different in each of two conditions. In the physical-identity condition, letter pairs must be physically identical (e.g., AA). In the name-identity condition, only the letter name is the same (e.g., Aa). The total items correct in the name-identity condition was the score used.

### Selective Attention

*Stroop Color Interference.* This task, originally developed by Stroop (1935), has four parts. In Parts 1 and 3, subjects were shown color swatches (red, orange,

Table 1
*Attention Training Study: Posttest Battery*

| General dimension | Primary ability | Measure | Transfer level | Source |
|---|---|---|---|---|
| Attention | | Letter Matching Test | Near | Lansman, et al., in press; adapted from Posner & Mitchell, 1967 |
| | | Stroop Color Interference[a] | | adapted from Stroop, 1935 |
| | | Underwood Number Counting[a] | | adapted from Underwood, 1975 |
| | | Continuous Paired Associate Recall[a] | | adapted from Atkinson & Shiffrin, 1968 |
| | | Semantic Recall[a] | | adapted from Wickens, 1971 |
| | | Concentration[a] | | Düker & Lienert, 1959 |
| | | Word Recognition[a] | | ADEPT, Note 1 |
| Perceptual speed (PS) | PS | Number Comparison | Far | Ekstrom, French, Harman, & Derman, 1976 |
| Memory span (MS) | MS | Auditory Memory Span Backward[a] | Far | after Ekstrom et al., 1976 |
| | | Visual Memory Span Forward[a] | | Ekstrom et al., 1976 |
| Fluid | CFR | ADEPT Figural Relations | Far | Plemons, Willis, & Baltes, 1978 |
| | | Culture Fair | | Cattell & Cattell, 1957, 1961, 1963 |
| | | Raven's Advanced Progressive Matrices (Set II, odd-numbered items) | | Raven, 1962 |
| | I | ADEPT Induction | | Blieszner, Willis, & Baltes, 1981 |
| | | Induction Composite | | Ekstrom et al., 1976; Thurstone, 1962 |
| Crystallized | V | Vocabulary (V-2) | Far-Far | Ekstrom et al., 1976 |

*Note.* The attention tasks were selected to represent four dimensions of attention functioning: discrimination (Letter Matching); selective attention (Stroop, Underwood Counting); attention switching (Continuous Paired Associate, Semantic Recall); and vigilance (Concentration, Word Recognition). ADEPT = Adult Development and Enrichment Project.
[a] Also given at pretest.



blue, yellow) and wrote the first letter of the color (R, O, B, Y) quickly. In Parts 2 and 4, color names were printed in a competing ink color (i.e., RED printed in blue ink); subjects wrote quickly the first letter of the ink color. The score was the total items correct on Parts 2 and 4.

*Underwood Number Counting.* This test, originally developed by Underwood (1975), has four parts. In Parts 1 and 3, stimuli are rows of Q's ranging from 1 to 9 Q's. Subjects counted quickly the number of Q's in a row. In Parts 2 and 4, stimuli are rows of identical numerals with variable spans (e.g., eight 2's, five 4's). Subjects counted the number of digits in a row. The score used was the total correct items in Parts 2 and 4.

### Attention Switching

*Continuous Paired Associate Recall.* This task, developed by Atkinson and Shiffrin (1968), involves 8 practice trials followed by 30 test trials. Subjects were shown two cards (e.g., A = 3; B = 7), with the letters (A or B) each paired with a single number. A test trial followed (A = ?, or B = ?). Then the letter (A or B) was repaired with a different number (A = 9). The score used was the total test trials correct.

*Semantic Recall.* This measure (Wickens, 1972) involves five blocks with four trials per block. Subjects were shown the first trial card with three semantically related words (e.g., apple, orange, peach) and asked to remember the items while performing a distraction task (writing numbers forwards by threes). Subjects then recalled the three items on the first trial card. The second trial card was then shown, followed by the distraction task, and recall. Prior research suggested increasing proactive interference in recall of semantically related items, with the greatest difficulty on Card 4. The score was items correct for Card 4, summed across the five trial blocks.

### Concentration

*Concentration.* This task, adapted from a German measure by Düker and Lienert (1959), involves sustained concentration on mental arithmetic tasks. Subjects first computed the sum for two addition problems (7 − 2 + 8 = ?; 10 + 4 − 6 = ?), and then computed the difference between the sums (13 − 8 = ?). Concentration was assessed over a 15-minute time period. Score was the total problems correct.

*Word Recognition.* This test was developed by the authors (ADEPT, Note 1). Subjects examined lists of three-letter (consonant-vowel-consonant) syllables (e.g., POD, BEL), and circled syllables that were English words. The score was the total number of items correct.

Accuracy scores were used as the dependent variable for all measures. The tests were adapted to be administerable to small groups rather than individually. Time limits were established for different sections of a test, based on previous research and a pilot study with an older sample. Size of type and figures were enlarged to accommodate older adults' visual needs.

## Attention Training Program

The training program involved five 1-hour sessions. Each of the first four sessions focused on one of the attention dimensions. Each session was divided into three parts. The first and third parts involved training on problems related to that attention dimension. The second part involved a group exercise, providing further practice on the relevant attention dimension. The fifth session was a review session, involving practice on all four attention dimensions.

Training problems were developed to focus on the cognitive process demands specified for each of the four attention dimensions. Content of practice and test items differed. For example, in the training session on selective attention, subjects were shown rows of colored stars and dots and were asked to count quickly the items of a given color (ignoring shape), or the items of a given shape (ignoring color). The task is similar in cognitive demands but not in content to the Underwood Number Counting task. The cognitive demand in both tasks was to count the number of objects of a specified stimulus dimension while ignoring a competing stimulus dimension. The trainer also related these attention dimensions to activities in the subjects daily life. For example, selective attention was related to the subject's trying to carry on a phone conversation while the other people in the room were talking. Instructional strategies focused on a particular attention dimension. In selective-attention training, for example, subjects rehearsed the relevant dimension as they worked problems as a strategy aid to ignoring irrelevant dimensions.

## Assessment of Training Effects

Two major criteria used in assessing training effects were transfer of training and maintenance of training across three posttests, spanning 6 months.

*Training transfer: Near- and far-transfer levels.* Training and transfer effects were assessed with a broad battery of attention, memory span, perceptual speed, and Gf-Gc ability measures, shown in Table 1. Transfer effects were predicted to follow a hierarchical pattern, based on theory and research in the information processing and Gf-Gc intelligence literatures, and on the similarity of transfer measures to the training program.

Three levels of training transfer were examined. The first level focused on near transfer to the attention measures. The largest training effects were predicted for the attention measures, since attention dimensions were the training focus. No predictions were made regarding differential training effects among the seven attention measures, since each of the attention dimensions represented by these measures was emphasized in training.

The second level of transfer focused on far transfer to memory span, perceptual speed, and two Gf abilities. Recent theory and research suggest that attentional processes may be operating in aging decline in memory span, perceptual speed, and Gf intelligence. Specifically, such attentional processes were hypothesized to be evidenced most directly in memory and perceptual speed tasks, and in turn in Gf performance. Memory span was represented by two measures: Visual Memory Span Forward and Auditory Memory Span Backwards. Perceptual speed was marked by the Number Comparison Test. Fluid intelligence was represented by the primary abilities of Figural Relations (CFR) and Induction (I). Figural Relations was marked by three tests: ADEPT Figural Relations (Form B), Culture Fair (Scale 2, and Power Matrices from Scale 3), and Raven's Advanced Progressive Matrices. Induction ability was represented by two measures: ADEPT Induction (Form B), and Induction Composite. Each of the Induction measures involved three subtests: Letter Sets, Letter Series, and Number Series.

The third transfer level focused on far-far transfer to Gc intelligence, represented by Vocabulary. No far-far transfer to Gc intelligence was predicted. The Gf-Gc portion of the battery had been used in prior training research on Gf abilities (Plemons, Willis, & Baltes, 1978; Willis et al., 1981).

*Maintenance of training effects.* Maintenance of effects across 1-week, 1-month, and 6-month posttests was the second major criterion for assessing training. Temporal maintenance is critical, if training effects are to be interpreted to represent modification of level of functioning on the attention processes. The immediate posttest, used in most prior studies, was considered inadequate to assess the stability of training effects.

*Retest effects.* Repeated posttesting involved in the assessment of training maintenance may result in retest (practice) effects in a test-naive population such as the elderly. Such practice effects have been demonstrated in prior training research with the elderly (Willis et al., (1981) and in research on retesting (Hofland, Willis, & Baltes, 1981). Retest effects due to practice in test taking were hypothesized to be more general than training effects and were expected for *both* training and control groups. Moreover, practice effects should occur for all or most of the posttest measures without regard to a differential pattern of training transfer. Differentiation of training and retest effects is important for an ability-specific interpretation of training.

*Structural relationship of transfer measures.* In an earlier study with a different sample ($N = 83$) of elderly from the same geographical region (Cornelius, Willis, & Baltes, Note 2), we examined the measurement properties of the attention tasks and their structural relation to psychometric intelligence. Several findings from this previous study are relevant to interpretation of the present data. First, all attention measures exhibited good split-half or internal consistency reliability (.81 to .97). The attention measures were found to be highly interrelated. Confirmatory and comparative factor analyses examining four-, two, and one-factor models for the attention measures indicated that only the one-factor solution was acceptable.

Finally, the structural convergence between the attention measures and the psychometric dimensions of Gf-Gc intelligence, memory span, and perceptual speed was examined, via confirmatory factor analysis, employing an adaptation of extension analysis. A previously identified four-factor structural solution for the psychometric intelligence variables (Factors: Broad Gf Reasoning, Gc Knowledge, Memory Span, and Perceptual Speed; Baltes, Cornelius, Spiro, Nesselroade, & Willis, 1980) was extended, allowing attention tasks to load freely on each of the four psychometric factors. Unique variances, factor variances, and covariances were estimated. The overall statistical fit of the model was acceptable, $\chi^2$ (221) = 309.16, $p$ = .0001. The outcome of this analysis examining the interface between attention and psychometric intelligence is shown in Table 2. Six of the seven attention measures loaded significantly on the Perceptual Speed dimension. The exception was the Continuous Paired Associate measure, which loaded on the Broad Gf Reasoning factor. In summary, these analyses suggest that the attention tasks (a) have acceptable measurement properties (reliability); (b) are highly related to each other; and (c) have most of their measurement variance associated with the Perceptual Speed factor.

## Results

Results of this study are reported in three sections. First, training, transfer, and maintenance effects across posttest occasions are examined. Second, retest effects are reported. Third, possible dropout effects are discussed.

All test data were standardized. A standardization procedure was employed for the following two reasons: (a) It provided a common baseline of performance on each measure to which all other data points for that measure were compared; and (b) it eliminated scale-level differences among measures, facilitating examination of transfer effects. The entire data matrix for each measure (across occasions and treatments) was standardized using the no-contact control group's first posttest score as the standardization metric ($M = 50$; $SD = 10$).

### *Training and Transfer Effects*

Training effects across posttest occasions were examined using repeated measures analysis of variance (ANOVA) procedures with follow-up univariate tests. Where pretest scores were available, gain scores were used as the dependent variable for two reasons: Gain score analyses permit assessment of training effects at the level of intraindividual change, and gain scores do not reflect possible pretest differences among treatment groups in level of performance. There has been considerable controversy over the use of gain scores (Cronbach & Furby, 1970; Harris, 1963). However, several methodologists (Campbell &



Table 2
*Extension of Four-Factor Model of Psychometric Abilities to Attention Variables*

| Variable | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Unique variance |
|---|---|---|---|---|---|
| | **Loadings** | | | | |
| **Variable** | | | | | |
| Culture Fair | .81 | | | | .35 |
| ADEPT Figural Relations | .84 | | | | .30 |
| Raven's Progressive Matrices | .80 | | | | .36 |
| ADEPT Induction | .79 | | | .02 | .35 |
| Induction Composite | .84 | | | | .29 |
| Verbal Analogies | .72 | | | | .48 |
| Word Matrix | .66 | | | | .57 |
| Social Translations | .61 | | | | .63 |
| Social Situations | .32 | .42 | | | .50 |
| Verbal Meaning | | .98 | | | .03 |
| Vocabulary | | .91 | | | .17 |
| Visual Number Span | | .42 | .33 | | .57 |
| Auditory Number Span | | | .67 | | .55 |
| Number Span—Delayed Recall | | | .97 | | .07 |
| Finding A's | | | | .63 | .61 |
| Number Comparison | | | | .74 | .45 |
| Identical Pictures | | | −.03 | .87 | .28 |
| Letter Matching: Name Identity | −.06 | −.03 | .07 | .93 | .20 |
| Stroop Color Interference: Word | .23 | .02 | .01 | .57 | .37 |
| Underwood Number Counting | .19 | .05 | .07 | .66 | .20 |
| Concentration Performance | .29 | .12 | −.01 | .38 | .48 |
| Word Recognition | −.24 | .27 | −.03 | .91 | .20 |
| Semantic Recall: Trial 4 | −.35 | .46 | .28 | .43 | .52 |
| Continuous Paired Associate Recall | .73 | −.16 | .04 | .15 | .42 |
| | **Intercorrelations** | | | | |
| **Factor** | | | | | |
| 1. Broad Reasoning (Gf) | — | | | | |
| 2. Crystallized Knowledge (Gc) | .78 | — | | | |
| 3. Memory span | .61 | .49 | — | | |
| 4. Perceptual Speed | .81 | .67 | .44 | — | |

*Note.* Factor loadings underlined are significantly different from zero. ADEPT = Adult Development and Enrichment Project.

Stanley, 1963; Nesselroade, Stigler, & Baltes, 1980; Nunnally, 1973, 1982) have strongly supported the use of gain scores in developmental and experimental studies of change. The critical question in training studies is the range of change associated with training, and gain scores are the most direct measure of change. Gain scores have often been criticized for their unreliability. However, the reliability of gain scores is a function of the reliability of the measures from which they were derived. The reliabilities of pre-posttest measures in this study are good (.81 to .97), and thus error of measurement problems (e.g., regression toward the mean) would be expected to affect interpretation of results only minimally.

Where pretest scores were not available (Perceptual Speed, Gf-Gc measures), covariance analyses were performed. The covariate was the pretest score on the Continuous Paired Associate Recall task, since this was the only attention measure to show a clear relationship to the Gf factor in the structural analysis (see Table 2).

*Training effects on attention and memory-span measures.* Since pretest data are available for the attention and memory span measures, three gain scores per measure (difference between each posttest and pretest) were computed from the stanardized scores. To obtain an initial assessment of training effects, a 3 (Treatment: Training, Social Contact, No-Contact) × 3 (Occasion: Posttests 1, 2, 3) multivariate analysis of variance (MANOVA) with repeated measures was conducted (see Table 3). This analysis resulted in significant treatment and occasion main effects. Since the Treatment × Occasion interaction was not significant, the treatment main effect suggests that training was maintained across posttest occasions. The occasion main effect is interpreted to reflect primarily retest effects common to both training and control groups.

Univariate 3 (Treatment) × 3 (Occasion) repeated measures ANOVAs were conducted to examine training effects separately for each measure (see Table 4). Significant treatment main effects were found for three attention measures: Stroop Color Interference ($p < .02$), Underwood Number Counting ($p < .001$), and Continuous Paired Associate Recall ($p < .03$). Follow-up analyses of these treatment main effects via the Behren's-Fisher test were conducted to compare training effects between pairs of conditions. For the Stroop and Underwood Counting measures, a significant ($p < .05$) training effect was found in comparison to both the Social Contact and no-contact control groups. For the Continuous Paired Associate Task, the training group differed significantly ($p < .05$) from the no-contact control.

A significant ($p < .03$) Treatment × Occasion interaction was found for the Concentration measure. Follow-up analyses via the Satterthwaite test indicated a significant difference ($p < .05$) between training and both the social contact and the no-contact control at Pretest 1. Training effects were also examined at the level of individual

Table 3
*Summary of Multivariate Analysis of Variance for Attention and Memory Gain Scores*

| Source | *df* | *F* | *p* |
|---|---|---|---|
| Treatment (T) | 18, 122 | 2.75 | .001 |
| Occasion (O) | 18, 262 | 4.59 | .001 |
| T × O | 36, 522 | 1.09 | .333 |

subjects. Reliable training gain (defined as greater than 1 Standard Error of Measurement) from Pretest to Posttest 1 was found for the following percentage of training subjects for each measure: Stroop (83%), Underwood Counting (100%), Continuous Paired Associate (70%), and Concentration (83%). No treatment effects were found for the Memory Span measures.

In response to a reviewer's concern regarding use of gain scores, training effects were also examined using posttest scores as dependent measures in the MANOVAs and univariate ANOVAs. Results of these analyses showed the same pattern of significant effects found when using gain scores.

Table 5 presents the mean gain scores and standard deviations for attention and memory span measures, computed from standardized scores. A graphic summary of these scores for each condition, averaged across posttest occasions, is shown in Figure 1.

*Training effects on perceptual speed and Gf-Gc measures.* A 3 (Treatment) × 3 (Occasion) multivariate analysis of covariance (MANCOVA) with repeated measures was conducted on the perceptual speed and Gf-Gc standardized posttest measures. The covariate was the pretest score for the Continuous Paired Associate task. A significant occasion main effect was found, $F(14, 226) = 9.22$, $p < .001$. Neither the treatment main effect nor the Treatment × Occasion interaction was significant. Univariate 3 (Treatment) × 3 (Occasion) repeated measures ANCOVAs were conducted separately for each test. Significant occasion main effects occurred for each of the seven measures; Number Comparison, $F(2, 140) = 4.36$, $p < .015$; ADEPT CFR, $F(2, 140) = 17.22$, $p < .001$; Culture Fair, $F(2, 140) = 13.10$, $p < .001$; Raven, $F(2, 140) = 6.33$, $p < .002$; ADEPT Induction, $F(2, 140) = 16.81$, $p < .001$; Induction Composite, $F(2, 140) = 7.64$, $p < .001$; Vocabulary, $F(2, 140) = 3.29$, $p < .04$. No treatment main effects nor Treatment × Occasion interactions were significant.

## Retest Effects

Sizeable retest effects were predicted across posttest occasions due to the test na-



ivete of elderly subjects. Two criteria should differentiate retest and training effects: Retest effects should occur for both treatment and control groups but should not reflect the pattern of near-to-far training transfer. This prediction was supported by the significant occasion main effect in the MANOVA for the attention and memory span measures and in the MANCOVA for the perceptual speed and Gf-Gc measures. Univariate ANOVAs conducted separately for each of the 16 tests (attention, memory span, perceptual speed, and Gf-Gc) indicated significant occasion main effects for every

Table 4
*Summary of Univariate Analyses of Variance for Attention and Memory Gain Scores*

| Measure | Source | *SS* | *df* | *F* | *p* |
|---|---|---|---|---|---|
| | Attention measures | | | | |
| Letter Matching Test | Treatment (T) | 237.24 | 2 | 2.62 | .079 |
| | Error between | 3169.41 | 70 | | |
| | Occasion (O) | 50.12 | 2 | 3.23 | .043 |
| | T × O | 16.86 | 4 | 0.54 | .704 |
| | Error within | 1086.35 | 140 | | |
| Stroop Color Interference: Word | Treatment (T) | 384.13 | 2 | 4.48 | .015 |
| | Error between | 3003.17 | 70 | | |
| | Occasion (O) | 120.88 | 2 | 5.91 | .003 |
| | T × O | 72.61 | 4 | 1.77 | .137 |
| | Error within | 1431.84 | 140 | | |
| Underwood Number Counting | Treatment (T) | 3202.61 | 2 | 9.01 | .000 |
| | Error between | 12434.02 | 70 | | |
| | Occasion (O) | 177.78 | 2 | 4.36 | .015 |
| | T × O | 173.38 | 4 | 2.13 | .081 |
| | Error within | 2853.49 | 140 | | |
| Continuous Paired Associates | Treatment (T) | 1023.98 | 2 | 3.81 | .027 |
| | Error between | 9399.37 | 70 | | |
| | Occasion (O) | 263.12 | 2 | 5.75 | .004 |
| | T × O | 70.31 | 4 | .77 | .548 |
| | Error within | 3203.90 | 140 | | |
| Semantic Recall | Treatment (T) | 569.03 | 2 | 1.97 | .147 |
| | Error between | 10117.01 | 70 | | |
| | Occasion (O) | 67.64 | 2 | 3.38 | .037 |
| | T × O | 40.46 | 4 | 1.01 | .403 |
| | Error within | 1399.23 | 140 | | |
| Concentration | Treatment (T) | 48.39 | 2 | .42 | .661 |
| | Error between | 4068.36 | 70 | | |
| | Occasion (O) | 188.89 | 2 | 14.41 | .000 |
| | T × O | 75.71 | 4 | 2.89 | .025 |
| | Error within | 917.40 | 140 | | |
| Word Recognition | Treatment (T) | 128.86 | 2 | 2.56 | .085 |
| | Error between | 1764.23 | 70 | | |
| | Occasion (O) | 126.91 | 2 | 8.37 | .000 |
| | T × O | 9.62 | 4 | .32 | .866 |
| | Error within | 1060.79 | 140 | | |
| | Memory span measures | | | | |
| Visual Span Memory | Treatment (T) | 51.41 | 2 | .21 | .810 |
| | Error between | 8525.25 | 70 | | |
| | Occasion (O) | 89.75 | 2 | 1.28 | .283 |
| | T × O | 33.30 | 4 | .24 | .917 |
| | Error within | 4924.95 | 140 | | |
| Auditory Memory Span Backwards | Treatment (T) | 365.76 | 2 | .88 | .418 |
| | Error between | 14473.12 | 70 | | |
| | Occasion (O) | 302.86 | 2 | 3.38 | .037 |
| | T × O | 92.07 | 4 | .51 | .725 |
| | Error within | 6263.74 | 140 | | |

*Note.* Gain scores computed from standardized scores were the unit of analysis.

Table 5
*Mean Gain Scores and Standard Deviations for Attention and Memory Span Measures for Three Conditions at Three Posttests*

| | Posttest 1 | | | Posttest 2 | | | Posttest 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| Measure | Training | Social contact | No contact | Training | Social contact | No contact | Training | Social contact | No contact |
| Letter Matching | | | | | | | | | |
| *M* | 5.4 | 3.9 | 2.7 | 6.7 | 4.1 | 4.5 | 6.5 | 4.3 | 4.3 |
| *SD* | 5.5 | 4.3 | 3.2 | 4.6 | 4.3 | 3.7 | 4.8 | 5.5 | 3.8 |
| Stroop Color Interference | | | | | | | | | |
| *M* | 6.4 | 2.1 | 2.3 | 6.3 | 2.9 | 3.9 | 3.3 | 1.7 | 2.5 |
| *SD* | 5.6 | 4.5 | 4.9 | 3.8 | 4.2 | 3.7 | 5.7 | 5.2 | 2.9 |
| Underwood Counting | | | | | | | | | |
| *M* | 11.9 | 2.2 | 6.9 | 15.0 | 3.6 | 8.4 | 10.0 | 3.5 | 7.7 |
| *SD* | 8.1 | 7.1 | 8.9 | 10.4 | 6.9 | 10.8 | 9.2 | 7.7 | 7.7 |
| Continuous Paired Associates | | | | | | | | | |
| *M* | 5.9 | 3.0 | −1.0 | 7.4 | 4.8 | 2.1 | 6.6 | 6.2 | 2.5 |
| *SD* | 7.6 | 7.9 | 8.6 | 8.6 | 6.6 | 6.3 | 8.8 | 7.5 | 7.6 |
| Semantic Recall | | | | | | | | | |
| *M* | 5.3 | 1.9 | 2.6 | 7.6 | 2.8 | 3.5 | 5.7 | 2.4 | 4.1 |
| *SD* | 8.2 | 3.5 | 7.9 | 8.9 | 4.0 | 9.9 | 9.2 | 5.3 | 8.5 |
| Concentration | | | | | | | | | |
| *M* | 4.1 | 2.5 | 1.7 | 4.1 | 4.5 | 3.2 | 1.0 | 2.6 | 1.4 |
| *SD* | 3.5 | 5.6 | 3.3 | 4.1 | 5.3 | 3.5 | 5.8 | 6.1 | 4.9 |
| Word Recognition | | | | | | | | | |
| *M* | 4.8 | 3.4 | 4.7 | 6.1 | 5.1 | 6.8 | 5.2 | 3.1 | 5.2 |
| *SD* | 4.0 | 2.8 | 2.8 | 4.2 | 3.1 | 4.8 | 3.9 | 3.6 | 3.5 |
| Visual Memory Span | | | | | | | | | |
| *M* | 3.5 | 3.0 | 1.6 | 3.8 | 4.9 | 4.0 | 2.9 | 4.1 | 2.9 |
| *SD* | 7.5 | 9.8 | 7.6 | 8.3 | 8.0 | 8.5 | 7.6 | 6.8 | 7.5 |
| Auditory Memory Span Backwards | | | | | | | | | |
| *M* | 2.6 | 3.7 | 2.1 | 2.8 | 6.5 | 5.4 | .0 | 4.4 | 1.9 |
| *SD* | 9.2 | 10.3 | 4.9 | 7.1 | 12.2 | 13.9 | 8.4 | 9.9 | 9.8 |

*Note.* Gain scores (posttest minus pretest) were derived from standardized scale scores, with entire data matrix for each measure standardized to no-contact control's Posttest 1 score ($M = 50$; $SD = 10$).

measure except Visual Number Span Forward. Follow-up analyses on these occasion effects via the Tukey WSD method indicated the following pattern of retest effects averaged across occasions: Posttest 1 < Posttest 2—Underwood Counting, Continuous Paired Associate, Semantic Recall, Concentration, Word Recognition, ADEPT Figural Relations, Culture Fair, Raven's Advanced Progressive Matrices, ADEPT Induction, and Induction Composite; Posttest 2 < 3—Culture Fair and Vocabulary; Posttest 1 < 3—Letter Matching, Continuous Paired Associate, ADEPT Figural Relations, Raven's, and Vocabulary; Posttest 2 > 3—Stroop, Underwood Counting, Concentration, Word Recognition, and Auditory Number Span; Posttest 1 > 3—Concentration and Number Comparison. The magnitude of retest effects for social-contact and no-contact controls (relative to a 0 gain baseline) is illustrated in Figure 1.

### Dropout Effects

Since the study involves subject participation over a lengthy time period, some subject attrition occurred. Table 6 presents a summary of attrition at various study intervals. Several dropout issues were addressed. First, we examined whether subjects completing the study through the 6-month posttest ($N = 73$) differed from the total sample pretested ($N = 103$). Subjects completing the study and total dropouts ($N = 30$) did not differ on mean age; dropouts had a somewhat lower educational level ($M = 10.5$ years, $SD = 3.9$; $F(1, 101) = 3.70$, $p < .06$). These two groups also differed significantly on five of the seven pretest attention measures: Letter Matching, $F(1, 101) = 8.23$, $p < .01$, Underwood Counting, $F(1, 101) = 6.67$, $p < .01$, Continuous Paired Associate, $F(1, 101) = 5.71$, $p < .02$, and Word Recognition, $F(1, 101) = 7.06$, $p < .01$, with the dropouts scoring lower on each measure. One significant Dropout × Treatment Condition × Measure interaction was noted: Pretest performance of dropouts in the social-contact control group was significantly lower on the Letter Matching test than remaining subjects' mean score in that condition, $F(1, 35) = 3.61$, $p < .01$.



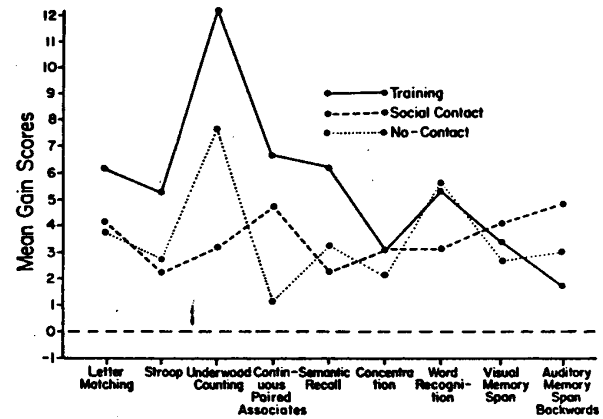


*Figure 1.* Mean gain scores for attention and memory span measures averaged across posttest occasions for three conditions. (Stroop = the Stroop Color Interference task.)

Table 6
*Number and Percentage of Subjects Participating at Each Occasion by Group*

| | Training | | Social contact | | No-contact control | |
|---|---|---|---|---|---|---|
| Occasion | No. | % | No. | % | No. | % |
| Pretest | 34 | 100 | 37 | 100 | 32 | 100 |
| Training | | | | | | |
| Session 1 | 33 | 97 | 35 | 95 | | |
| Session 2 | 33 | 97 | 34 | 92 | | |
| Session 3 | 33 | 97 | 34 | 92 | | |
| Session 4 | 33 | 97 | 34 | 92 | | |
| Session 5 | 33 | 97 | 34 | 92 | | |
| Posttest 1 (1 week) | 32 | 94 | 32 | 87 | 29 | 91 |
| Posttest 2 (1 month) | 30 | 88 | 32 | 87 | 26 | 81 |
| Posttest 3 (6 months) | 23 | 73.5 | 28 | 78.4 | 22 | 68.8 |

Second, since several subjects in each condition dropped out after Posttest 1, characteristics of those completing the study and those ($N = 20$) dropping out after Posttest 1 were compared. The groups did not differ significantly on mean age or educational level. Mean pretest scores of the total completing sample and dropouts after Posttest 1 differed significantly on Concentration, $F(1, 91) = 4.24$, $p < .05$. The two groups did not differ significantly on attention mean scores at Posttest 1. In summary, then, significant dropout effects occurred early in the study, with dropouts having both a lower eductional level and lower pretest scores on several attention measures. However, there is little evidence to suggest that dropout effects were differential across the treatment conditions. Thus, results obtained for subjects completing the study appear to be internally valid.

## Discussion

### Training and Practice Effects

This study examined the modifiability of older adults' performance on attention measures and possible transfer of training to the intellectual ability domains of fluid-crystallized intelligence, perceptual speed, and memory span. A significant treatment main effect on the attention measures was found and maintained across three posttests, spanning a 6-month period. Univariate analyses indicated significant training effects maintained across a 6-month period for the Stroop Color Interference, Underwood Number Counting, and Continuous Paired Associate tasks. In addition, a significant training effect at the 1-week posttest was found for the Concentration task. Note that the training effect found for the Continuous Paired Associate task was for the only measure showing a strong relationship with the General Reasoning (Gf) factor. Although few studies have examined stability of training improvement, the effects in this study were generally maintained over a 6-month period.

No significant training transfer effects were found for several levels of far transfer, representing the intellectual ability domains of fluid-crystallized intelligence, perceptual speed, and memory span. The absence of far transfer is consistent with findings from our previous factor analytic study (Cornelius et al., Note 2) in which six of the seven attention measures had significant loadings on the Perceptual Speed factor. In a college-age population, Lansman et al. (in press) also found several cognitive process measures (including the Letter Matching task) to load primarily on perceptual speed and visualization factors, but not on Gf-Gc dimensions. Such a structural pattern of relationships would then suggest little or no transfer from training on perceptual speed-type tasks to Gf-Gc dimensions. The findings of our study also collaborate prior gerontological invervention research by Hoyer, Labouvie, and Baltes (1973), in which practice on perceptual speed tasks resulted in significant improvement in responding but no transfer to a variety of ability measures. In the present study, some transfer might have been expected to the Perceptual Speed measure. However, there is a slight problem with the power of the statistical tests used to assess far transfer. The analyses of far-transfer effects, using standardized posttest scores as the dependent variable, are less sensitive to intraindividual change than the gain-scores analyses conducted for the attention measures. Since far-transfer measures were not given at pretest, gain scores could not be computed.

Similar patterns of effects were found for both control groups—social and no-contact control. The social-contact control examined whether posttest performance on attention measures would be affected positively by this group receiving social contact in an equivalent number of hours to those spent in the training sessions. Prior training research typically has included only a no-contact control group receiving just pre- and posttests. Training effects in such studies could have been attributable partially to the greater number of hours of social contact given the training subjects. However, in this study, social-contact treatment without specific attention-training procedures did not result in significant group differences on attention measures.

The retest effects represented in the analyses as occasion effects are of interest in two respects. First, significant occasion effects were found for all measures except the Visual Number Span test. Practice effects are most evident in initial, closely spaced retest sessions (e.g., 1-week and 1-month posttests). Retest effects occurred for measures of a wide variety of abilities, including not only novel tests but also more common tests, such as vocabulary. The magnitude of such retest effects and their occurrence over a wide variety of ability measures suggests that considerable caution is required in interpreting single-occasion assessment of test-naive populations, such as the elderly. Initial test performance of such populations may be particularly vulnerable to performance factors (e.g., test sophistication, anxiety, response speed), which affect test behavior but are not intrinsically related to the ability assessed (Sarnacki, 1979).

Second, the relative magnitude of training effects to size of retest effects on attention measures merits some discussion. We suggest that the large retest effects for the control groups on the near-transfer measures are a function of the nature of the tasks—namely, perceptual-speed-type measures. Prior research (Hoyer et al., 1973) has indicated that significant improvement on such



tasks can occur with practice, employing no specific cognitive training strategies. In contrast, in our prior training research focusing on fluid abilities, specific cognitive strategies were trained, and large retest effects for the control group on fluid measures did not occur (Willis et al., 1981).

### *The Role of Training Research in the Study of Process-Ability Relationships and Educational Implications*

Training research would appear useful in the study of process-ability relationships in two respects. First, training research can be useful in examining the nature of process-ability relationships. The transfer-of-training paradigm examines the extent to which performance modification in one domain results in behavioral change in a theoretically related domain. In the present research, it was predicted that if the attention dimensions trained were associated with the aged's performance on specific psychometric abilities, then transfer effects to these ability domains should occur. The lack of training transfer to measures of memory span, perceptual speed, or Gf-Gc intelligence can lead to several different interpretations. Some will interpret our results to support their contentions that attention measures such as those used in this study are not sufficiently complex to represent the type of processes underlying psychometric ability functioning. Both the recent research by Lansman et al. (in press) and our structural analyses (Cornelius et al., Note 2) indicate that most of the measurement variance of those measures examined is associated with the performance factors of perceptual speed and visualization.

Alternatively, it is possible that the attention dimensions (and representative measures) focused on in the present study are not the most critical attention factors underlying intellectual performance in aging; thus, modification of performance on these dimensions would not be reflected in far-transfer assessment. For example, examination of our measures suggests a notable distinction between the attention and fluid tasks. In the attention tasks, the salient dimension is defined a priori for the subject, and a relatively simple response is required, whereas in the fluid tasks the subject must first identify the salient dimension (relational rule) and then use that information in solving the problem. It is this complex sequence of steps in problem solution that characterizes ability test items.

Second, we argue that in educational research a training paradigm is critical in the study of cognitive processes. Thus far, information-processing research has focused primarily on *describing* the processes and strategies used by individuals in problem-solving tasks. However, the educational researcher is concerned not only with description but also with the questions of the range of modifiability and the conditions under which such processes and strategies can be trained or optimized. Recent limited research by Sternberg and Weil (1980), Holtzman, Glaser, and Pellegrino (1976), and others (Belmont & Butterfield, 1977; Brown & French, 1979) suggests that short-term training efforts are useful not only in improving younger subjects' performance on specific strategies but also in training subjects to use more optimal processes or strategies. Training research in later adulthood provides a unique contribution; it examines the modifiability of assumed deficits in cognitive processing with age. In developing comprehensive models of information processing, descriptive, normative data must be complemented with an experimental, manipulative perspective. Such a dual approach is critical in educational research and application.

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