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Training the Elderly on the Ability Factors of Spatial Orientation and Inductive Reasoning

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We examined the effects of cognitive training with elderly participants from the Seattle Longitudinal Study. Subjects were classified as having remained stable or having declined over the previous 14-year interval on each of two primary abilities, spatial orientation and inductive reasoning. Subjects who had declined on one of these abilities received training on that ability; subjects who had declined on both abilities or who had remained stable on both were randomly assigned to the spatial orientation or inductive reasoning training programs. Training outcomes were examined within an ability-measurement framework with empirically determined factorial structure. Significant training effects, at the level of the latent ability constructs, occurred for both spatial orientation and inductive reasoning. These effects were general, in that no significant interactions with decline status or gender were found. Thus, training interventions were effective both in remediating cognitive decline on the target abilities and in improving the performance of stable subjects.

A consistent finding of longitudinal studies is that there are wide individual differences in the patterns of intellectual ability change in later adulthood (Schaie, 1983; Willis & Baltes, 1980). Although findings from a number of longitudinal studies indicate that the onset of ability decline occurs normatively in the middle to late 60s, there is considerable variability in timing and breadth of decline (Jarvik & Bank, 1983; Siegler, 1983). The more common pattern is that decline is selective, rather than pervasive, particularly in early old age (Schaie, 1984). Individuals typically show statistically reliable decrement on a particular subset of abilities, although their performance remains stable on other abilities. Although selective decline is the more common change pattern for the young–old, there are a number of individuals who show no statistically reliable ability decline—a few exhibiting a pattern of stability even into their 80s. Conversely, there are individuals for whom, even in their 60s, there is pervasive rather than differential decline, typically associated with health-related problems.

Given these wide individual differences in ability changes, cognitive training effects may indicate either remediation of decrement or improved performance for stable individuals, beyond that previously demonstrated. Both types of training outcome (i.e., remediation, new performance levels) are of theoretical and practical interest in the study of cognitive aging. However, longitudinal data on subjects' ability functioning is required to differentiate the two types of effects.

The purpose of this study is to examine the effectiveness of cognitive training with participants from a longitudinal research program. Individual profiles of ability change were defined for the primary abilities of spatial orientation and inductive reasoning. These abilities were chosen as the focus of training because they had been identified in previous research to exhibit early patterns of normative decline (Schaie, 1983).

Our study was guided by a number of methodological considerations: First, training effects were examined at the latent construct level (i.e., ability factors). Normative decline in intellectual functioning is construed to have occurred at the construct level (Schaie & Hertzog, 1985); thus, it becomes critical to demonstrate that training effects are not test specific but have occurred at the construct level (Birren, Cunningham, & Yamamoto, 1983).

To show that training effects have indeed occurred for an ability construct, it is necessary to examine those effects in the context of a measurement framework for which the structural relationships have been empirically defined. The convergent and divergent validity of the training paradigm, moreover, must be demonstrated by showing that training effects occurred exclusively for the targeted abilities, and did not result from a generalized training phenomenon that extended to the entire measurement system. Finally, it is important to ascertain that there was stability in the measurement framework across pre- and posttest occasions. Training could affect the structural relationships among the abilities in the measurement framework, as well as result in quantitative change. Interpretation of the nature of the training effects would be somewhat ambiguous if structural change had occurred from pre- to posttest.

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Method

Subjects

Subjects were 229 older adults (132 women, 97 men) from the Seattle metropolitan area, who had been participants in the Seattle Longitudinal Study (SLS) since 1970 or earlier (Schaie, 1983). All of the subjects were members, or had been members, of the Group Health Cooperative of Puget Sound, a health maintenance organization. Mean age of the total sample was 72.8 years (range = 64–95; SD = 6.41). Mean educational level was 13.9 years (range = 6–20; SD = 2.98). There were no sex differences in age or educational level. Mean income level was $19,879 (range = $1,000–$33,000; SD = $8,520). All of the subjects were community dwelling, and most of the subjects were Caucasian. Prior to initiation of the study, each subject's physician was contacted and asked to indicate whether the subject suffered any known physical or mental disabilities that would interfere with participation in the study; subjects so identified were not included in the study.

Design and Procedure

Classification of subjects. Subjects' test performances on the Thurstone (1948) Primary Mental Abilities (PMA) reasoning and space measures were classified as having remained stable, or as having declined, over the prior 14-year interval involving three data points (1970, 1977, and 1984–pretest). The statistical criterion for the definition of decline was one standard error of measurement or greater over the entire 14-year period (reasoning = 4 points, space = 6 points). Subjects were first classified by defining a 1 standard error of measurement (SEM) confidence interval about their observed 1970 score (cf. Dudek, 1979). If their 1977 score fell below this interval, they were provisionally considered to have declined, otherwise, to be stable. Next, their 1984–pretest score was considered. Decline subjects who in 1984 returned to within the confidence interval about their 1970 score were then reclassified as stables. Stable subjects whose 1984–pretest score dropped to a 1-SEM interval below their 1977 score were reclassified as *decliners.*

There were 107 subjects (46.7% of the sample) classified as having remained stable on both ability measures; 35 (15%) had declined on reasoning, but not on space; 37 (16%) had declined on space, but not on reasoning; and 50 (21.8%) had declined on both measures. As would be expected, stable subjects (M = 70.9 years; SD = 5.35) were somewhat younger than decline subjects (M = 74.4 years; SD = 6.84; $p < .001$). Although the mean age differed, note that a wide age range occurred for both stables (range = 64–85 years) and decliners (64–95 years). Decline and stable subjects did not differ significantly on educational level or income.

Given the classification procedure already described, there was the possibility of statistical regression effects occuring, such that 1970 high scorers would have been erroneously classified to the decline group, and the low scorers to the stable group. To examine for possible regression effects, a time-reversed control analysis was performed (cf. Baltes, Nesselroade, Schaie, & Labouvie, 1972; Campbell & Stanley, 1966). This analysis did not support the presence of substantial regression effects that would increase the classification error rate above that specified by the chosen confidence interval (Schaie & Willis, 1986).

Procedure. Subjects were assigned to either inductive reasoning or spatial orientation training programs, based on their performance status (1970–1984). Subjects who had declined on reasoning, but not on space, or vice versa, were assigned to the training program for the ability exhibiting decline. Subjects who had remained stable on both abilities or had shown decline on both abilities were randomly assigned to one of the training programs. Spatial orientation training subjects included 51 stables (28 women; 23 men) and 67 decliners (38 women; 29 men). The average 14-year change for the spatial orientation training group was 0.60 for stables and 11.36 for decliners. Inductive reasoning training subjects included 56 stables (31 women; 25 men) and 55 decliners (35 women; 20 men). The average 14-year change for the inductive reasoning training group was 0.23 for stables and 6.78 for decliners.

Stable subjects in spatial orientation training were significantly younger ($p < .03$) and better educated ($p < .05$) than were decliners. Stable subjects in inductive reasoning training were also significantly younger ($p < .001$) than decliners, but decliners were significantly better educated ($p < .01$) than stables. There was no difference in income for subjects assigned to either training program.

All of the subjects had previously participated in the Seattle Longitudinal Study and were informed via a series of letters that a new phase of the study was beginning. Subjects who indicated an interest in participating were visited in their homes by a staff member. The purpose of the home visit was to discuss details of the study and to answer questions, to assess sensory handicaps that might interfere with participation, and to determine whether the home was a suitable place for conducting the training sessions.

The study involved a pretest–treatment–posttest control group design. The inductive reasoning training group served as a treatment control for the spatial orientation training group, and vice versa. Subjects were administered a broad psychometric ability battery in two pretest sessions (2 ½ hr per session). Based on their prior longitudinal performance plus their pretest scores, subjects were assigned to either the inductive reasoning or the spatial orientation training program. Training began within 1 week of pretest and involved five 1-hour individually conducted training sessions. The training sessions were conducted within a 2-week period. The majority of subjects were trained in their homes. Two middle-aged trainers, with prior educational experience in working with adults, served as trainers. Subjects were randomly assigned to the trainers within pragmatic constraints, such that each trainer trained approximately equal numbers of stable and decline subjects in each training program. Subjects were assessed within 1 week of training on a posttest battery that involved the same measures that were administered at pretest. They were paid $100 for participating in the study.

Measures

The pre–posttest battery involved psychometric measures representing five primary mental abilities, including the PMA measures (Thurstone, 1948), administered at previous SLS assessments. Each ability was represented by three to four marker measures. The pre–posttest ability battery is shown in Table 1. Marker measures for spatial orientation and inductive reasoning abilities are discussed in more detail later in the article, inasmuch as these abilities were the target of training, and training effects were predicted for these abilities.

Spatial orientation. Spacial orientation was assessed by four measures. Three of the tests (PMA Space, Object Rotation, and Alphanumeric Rotation) are multiple response measures of two-dimensional mental rotation ability. The subject is shown a model line drawing and asked to identify which of six choices shows the model drawn in different spatial orientations. There are two or three correct responses possible for each test item. The Object Rotation test (Schaie, 1985) and the Alphanumeric test (Willis & Schaie, 1983) were constructed so that the angle of rotation in each answer choice is identical with the angle used in the PMA Space test (Thurstone, 1948). The three tests vary in item content. Stimuli for the PMA test are abstract figures; the Object Rotation test involves drawings of familiar objects; and the Alphanumeric test contains letters and numbers. The fourth test, Cube Comparisons (Ekstrom, French, Harman, & Derman, 1976), assesses mental rotation in three-dimensional space.

Inductive reasoning. Inductive reasoning ability was assessed by

Table 1
Mental Abilities Measurement Battery

Primary ability	Test	Source
Inductive reasoning	PMA Reasoning	Thurstone (1948)
	ADEPT Letter Series (Form A)	Blieszner, Willis, & Baltes (1981)
	Word Series	Schaie (1985)
	Number Series	Ekstrom, French, Harman, & Derman (1976)
Spatial orientation	PMA Space	Thurstone (1948)
	Object Rotation	Schaie (1985)
	Alphanumeric Rotation	Willis & Schaie (1983)
	Cube Comparison	Ekstrom et al. (1976)
Perceptual speed	Finding A's	Ekstrom et al. (1976)
	Number Comparison	Ekstrom et al. (1976)
	Identical Pictures	Ekstrom et al. (1976)
Numeric	PMA Number	Thurstone (1948)
	Addition	Ekstrom et al. (1976)
	Subtraction & Multiplication	Ekstrom et al. (1976)
Verbal	PMA Verbal	Thurstone (1948)
	Vocabulary II	Ekstrom et al. (1976)
	Vocabulary IV	Ekstrom et al. (1976)

Note. PMA = Primary Mental Abilities; ADEPT = Adult Development and Enrichment Project.

four measures. The PMA reasoning measure (Thurstone, 1948) assesses inductive reasoning ability via letter series problems. The subject is shown a series of letters and must select the next letter in the series from five letter choices. The Adult Development and Enrichment Project (ADEPT) Letter Series test (Blieszner, Willis, & Baltes, 1981) also contains letter series problems; however, some of the problems involve pattern-description rules other than those found on the PMA measure (see Kotovsky & Simon, 1973, for discussion of pattern description rules). The Word Series test (Schaie, 1985) parallels the PMA measure in that the same pattern-description rule is used for each item; however, the test stimuli are days of the week or months of the year, rather than letters. The Number Series test (Ekstrom et al., 1976) involves series of numbers rather than letters, and involves different types of pattern-description rules involving mathematical computations. The PMA Spatial Orientation and Reasoning tests were administered at previous SLS measurement points, and thus provide the most direct assessment of training improvement and remediation.

Training Programs

The focus of the training was on facilitating the subject's use of effective cognitive strategies identified in previous research on the respective abilities. A content task analysis was conducted on the two PMA measures representing these abilities, to identify relevant cognitive strategies.

Inductive reasoning. For each item of the PMA Reasoning test, the pattern-description rule(s) used in problem solution were identified. Four major types of pattern-description rules (identity, next, skips, and backward next) were identified and focused on in training. These pattern-description rules are similar to those discussed previously in the literature (Holzman, Pellegrino, & Glaser, 1982; Kotovsky & Simon, 1973). Practice problems and exercises were developed, based on these pattern-description rules. Practice problems often involved content other than letters, so that the applicability of these rules to other content areas could be explored. For example, patterns of musical notes and travel schedules were devised based on these rules, and subjects were to identify the next note or destination in the series. No training problems were identical in content to test items. Subjects were taught through modeling, feedback, and practice procedures to identify these pattern description rules. Three strategies for identifying the patterns were emphasized in training: visual scanning of the series, saying the series aloud in order to hear the letter pattern, and underlining repeated letters occuring throughout the series. Once a hypothesis regarding the pattern type was generated, subjects were then taught to mark repetitions of the pattern within the series, and thus to determine the next letter required to fit the pattern rule.

Spatial orientation. A content task analysis of the PMA Space test was conducted to identify the angle of rotation for each answer choice. Practice problems were developed to represent the angle rotations identified in the task analysis (45°, 90°, 135°, and 180°). Cognitive strategies to facilitate mental rotation, which were focused on in training, included (a) development of concrete terms for various angles, (b) practice with manual rotation of figures prior to mental rotation, (c) practice with rotation of drawings of concrete, familiar objects prior to introduction of abstract figures, (d) subject-generated names for abstract figures, and (e) having the subject focus on two or more features of the figure during rotation. These cognitive strategies had been identified in prior descriptive research on mental rotation ability (Cooper & Shepard, 1973; Egan, 1981; Kail, Pellegrino, & Carter, 1980).

Results

Results of the study are reported in two parts. First, structural analyses of the measurement battery at pre- and posttest are described. Second, analyses of training effects at the level of ability factor scores are reported.

Structural Analyses of Measurement Battery

The structure of the latent ability constructs represented in the measurement battery was determined at pretest, prior to onset of training, on a total sample of 401 elderly subjects. Table 2 provides the intercorrelations among the observed measures; pretest correlations are below and posttest correlations are above the diagonal. Table 3 gives the raw score means for the Induction and Spatial Orientation tests at pre- and posttest, for stable and decline subjects within each of the training groups.

Table 2
Intercorrelations of Observed Variables at Pre- and Posttest

Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. PMA Reasoning	—	.84	.84	.68	.54	.48	.54	.43	.50	.64	.64	.59	.58	.61	.76	.51	.54
2. Letter Series	.80	—	.82	.75	.52	.46	.52	.45	.50	.60	.57	.62	.58	.63	.69	.49	.52
3. Word Series	.83	.76	—	.69	.51	.49	.55	.43	.49	.63	.62	.63	.59	.61	.76	.53	.52
4. Number Series	.70	.71	.65	—	.50	.43	.49	.41	.45	.47	.44	.56	.53	.56	.57	.41	.44
5. PMA Space	.53	.53	.53	.50	—	.76	.70	.52	.39	.36	.57	.39	.39	.41	.48	.27	.25
6. Object Rotation	.49	.48	.53	.42	.74	—	.78	.47	.35	.41	.56	.39	.40	.42	.50	.20	.19
7. Alphanumeric	.51	.52	.55	.42	.67	.76	—	.50	.40	.42	.57	.38	.38	.44	.56	.25	.25
8. Cube Comparison	.40	.36	.40	.36	.45	.37	.36	—	.34	.36	.48	.32	.29	.34	.37	.09	.14
9. Finding A's	.48	.45	.48	.36	.30	.30	.38	.20	—	.49	.50	.48	.48	.52	.50	.30	.30
10. Number Comparison	.60	.53	.63	.46	.43	.42	.46	.31	.49	—	.65	.63	.64	.66	.69	.39	.39
11. Identical Pictures	.60	.51	.63	.38	.50	.55	.57	.38	.44	.66	—	.43	.47	.51	.68	.37	.37
12. PMA Number	.58	.54	.64	.55	.43	.42	.42	.27	.39	.61	.44	—	.86	.79	.62	.40	.40
13. Addition	.55	.50	.60	.49	.39	.38	.39	.26	.41	.64	.47	.86	—	.87	.64	.40	.41
14. Subtraction and Multiplication	.57	.57	.61	.52	.41	.39	.44	.29	.47	.64	.50	.79	.83	—	.66	.41	.41
15. PMA Verbal	.72	.64	.73	.57	.51	.54	.54	.35	.42	.65	.67	.62	.59	.63	—	.63	.62
16. Vocabulary II	.46	.47	.46	.40	.25	.18	.27	.05	.32	.30	.28	.38	.35	.39	.52	—	.84
17. Vocabulary IV	.49	.50	.48	.44	.25	.23	.26	.13	.33	.30	.28	.38	.37	.41	.55	.81	—

Note. Values below the diagonal are for the pretest; values above the diagonal are for the posttest. PMA = Primary Mental Abilities.

An EFAP analysis was performed to determine the number of factors required for an optimal fit of the battery. Examination of the eigenvalues, chi squares, and Tucker-Lewis criteria suggested that a minimum of five factors was required. This finding fit well with our conceptual model. We consequently examined the factor structure of the pretest ability battery via confirmatory factor analyses, using LISREL V (Joreskog & Sorbom, 1981). As part of this analysis, we tested the equivalence of factor structure for stable and unstable, and male and female, subgroups. An acceptable five-factor model, $\chi^2(243, N = 401) = 463.17$, representing the hypothesized PMA factors (spatial orientation, inductive reasoning, perceptual speed, numeric, verbal) was obtained (Table 4). The accepted model holds factor loadings and factor intercorrelations invariant across groups. Relaxing these constraints did not yield any significant improvement in fit.

Factor regression weights for tests loading on the spatial orientation factor were PMA Space = .260, Object Rotation = .393, Alphanumeric = .287, and Cube Comparison = .060. Factor regression weights for inductive reasoning were PMA Reasoning = .378, ADEPT Letter Series = .213, Word Series = .298, and Number Series = .111. Factor regression weights for perceptual speed were Finding A's = .099, Number Comparison = .219, Identical Pictures = .317, and PMA Verbal = .356. Factor weights for numeric were PMA Number = .286, Addition = .447, Subtraction and Multiplication = .220, and Number Comparison = .047. Factor weights for verbal were PMA Verbal = .086, Vocabulary II = .317; and Vocabulary IV = .597.

To address the issue of pre–posttest structural stability in the measurement battery, an isolated stability model that constrained factor loadings and factor correlations across pre- and posttest occasions was tested for the spatial orientation and inductive reasoning training groups, separately. This model could be improved on slightly by relaxing the constraint on the factor loading for the Object Rotation test within the spatial orientation training group, and for the Word Series test within the inductive reasoning training group (reasoning: $\chi^2[440, N = 111] = 621.09$; space: $\chi^2[440, N = 118] = 747.25$). Further relaxations of constraints across test occasions did not yield any significant improvement in fit. Factor regression weights computed on the pretest and on the relaxed factor loadings at posttest did not differ significantly. Consequently, we elected to employ the pretest regression weights for computing factor scores because these weights are likely to be more stable, having been derived from a larger data set (see also Schaie, Willis, Hertzog, & Schulenberg, 1985). Factor scores were computed for each of the five abilities by standardizing the raw scores ($M = 50$; $SD = 10$) to the pretest base and then multiplying the standardized scores by their respective pretest regression weights.

Training Analyses of Factor Scores

To examine training effects at the factor level, a 2 (training: inductive reasoning, spatial orientation) × 2 (status: stable, decline) × 2 (gender) × 2 (occasion: pre, post) analysis of variance (ANOVA) with repeated measures was performed separately for each of the five ability factor scores (inductive reasoning, spatial orientation, perceptual speed, numeric, verbal). Table 5 shows the mean squares and F ratios for the main effects and interac-

Table 3
Raw Score Means for Inductive Reasoning and Spatial Orientation Measures for Stable and Decline Subjects at Pre- and Posttest

	Training group							
	Inductive reasoning				Spatial orientation			
	Stable (n = 56)		Decline (n = 54)		Stable (n = 51)		Decline (n = 67)	
Measure	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Inductive reasoning								
PMA reasoning	13.68	17.29	9.51	14.46	14.24	15.53	10.73	12.16
Letter series	8.68	11.21	7.38	9.51	8.69	9.79	6.35	7.27
Word series	15.73	18.03	12.92	15.24	15.21	17.04	11.92	13.13
Number series	4.80	5.72	4.68	4.75	4.60	5.88	3.93	4.49
Spatial orientation								
PMA space	19.02	21.93	14.41	16.87	17.69	22.10	8.66	16.57
Object rotation	32.59	37.64	24.18	30.04	31.86	36.83	22.49	29.20
Alphanumeric	36.15	40.88	30.10	33.34	37.29	41.56	28.04	33.65
Cube comparison	16.38	16.82	14.10	14.09	14.27	15.26	13.24	14.04

Note. PMA = Primary Mental Abilities.

tions for each of the five ability factors. To evaluate training results, it is necessary to examine the interactions of training and occasion effects. The Training × Occasion interactions for induction ($p < .001$) and for spatial orientation ($p < .05$) were significant. Post hoc analyses indicated significantly greater gain ($p < .05$) for the training group than for the control group on both abilities. None of the three-way or four-way interactions involving training and occasion were significant, indicating that the magnitude of training effects did not differ significantly across pretraining status or gender. Note that the Training × Occasion interactions were significant only for those two abilities that were the targets of training. There was a significant occasion main effect for all measures, indicating significant retest effects across pre–posttest occasions for both groups. Table 6 shows the factor-score means for the five abilities at pre- and posttest by training group.

Table 4
Five-Factor Model, With Factor Loadings and Intercorrelations

Variable	Factor 1	2	3	4	5
Test	Loadings				
PMA Reasoning	.921				
ADEPT Letter Series	.864				
Word Series	.900				
Number Series	.757				
PMA Space		.829			
Object Rotation		.883			
Alphanumeric		.844			
Cube Comparison		.474			
Finding A's			.545		
Number Comparison			.592	.273	
Identical Pictures			.819		
PMA Number				.910	
Addition				.941	
Subtraction–Multiplication				.885	
PMA Verbal Meaning			.698		.320
Vocabulary II					.870
Vocabulary IV					.929
Factor	Intercorrelation				
1. Inductive reasoning	—				
2. Spatial orientation	.681	—			
3. Perceptual speed	.822	.735	—		
4. Numeric	.692	.512	.695	—	
5. Verbal	.593	.305	.401	.454	—

Note. All factor loadings are significant, $p < .05$. PMA = Primary Mental Abilities. ADEPT = Adult Development and Enrichment Project.

Figure 1 presents mean pre–posttest factor gain scores for the five ability factors for both inductive reasoning and spatial orientation training groups; as hypothesized, significant differences between the two training groups occur only for the specific abilities on which they were trained.

The decliners in each training group included both subjects who had declined only on the ability trained and subjects who had declined on both abilities. To examine whether there were differential training gains for these two groups of decliners, one-way ANOVAS on the spatial orientation and inductive reasoning factor gain scores were conducted. There were no significant differences in factor gain scores for the two groups of decliners for either spatial orientation ($p < .53$) or inductive reasoning ($p < .88$).

To determine the proportion of subjects exhibiting reliable pre- and posttest improvement, the same criterion as for defining decline (i.e., a change score ≥ 1 *SEM*) was used to define reliable training gain. The proportion of subjects in the inductive reasoning training group showing a pre–posttest gain score ≥ 1 *SEM* on the ability trained were stables, 66%, decliners, 74.5%, and total, 70.5%. For the spatial orientation training group the proportions were stables, 47.1%, decliners, 62.7%, and total, 55.9%.

Table 5
Mean Squares and F *Ratios for Analyses of Variance on Ability Factor Scores*

Term	Ability factor									
	Reasoning		Space		Perceptual speed		Numeric		Verbal	
	MS	*F*	*MS*	*F*	*MS*	*F*	*MS*	*F*	*MS*	*F*
Training	336.58	2.18	84.19	0.65	47.56	0.41	627.38	3.33	502.62	3.33
Status	3038.35	19.65***	3884.11	30.10***	2752.59	23.63***	1904.50	10.11**	168.48	1.12
Training × Status	25.71	0.17	26.33	0.20	2.31	0.02	19.88	0.11	1007.72	6.68**
Gender	733.10	4.74*	852.04	6.60**	1711.66	14.70***	432.51	2.30	530.56	3.52
Training × Gender	362.67	2.35	521.31	4.04*	1037.19	8.90**	2.48	0.11	204.08	1.35
Status × Gender	30.31	0.20	423.18	3.28	10.63	0.09	182.97	0.97	154.11	1.02
Training × Status × Gender	0.08	0.00	79.17	0.61	25.10	0.22	87.32	0.46	36.33	0.24
Error	154.59		129.06		116.51		188.47		150.93	
Occasion	1649.15	303.15***	1556.41	195.48***	729.93	143.58***	298.01	108.52***	71.77	17.14***
Training × Occasion	205.98	37.86***	41.82	5.25*	0.62	0.12	1.62	0.59	1.16	0.28
Status × Occasion	1.76	0.32	9.48	1.19	4.53	0.89	7.34	2.67	2.89	0.69
Training × Status × Occasion	7.76	1.43	18.14	2.28	2.54	0.50	4.17	1.52	0.01	0.00
Gender × Occasion	0.58	0.11	4.14	0.52	11.87	2.33	5.39	1.96	0.40	0.10
Training × Gender × Occasion	1.18	0.22	16.27	2.04	8.49	1.67	3.90	1.42	0.47	0.11
Gender × Status × Occasion	0.07	0.01	0.75	0.09	5.31	1.04	0.02	0.01	0.01	0.00
Training × Gender × Status × Occasion	1.08	0.20	4.83	0.61	0.72	0.14	0.82	0.30	2.13	0.51
Error	5.44		7.96		5.08		2.75		4.19	

Note. df = 1, 221.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 6
Mean Factor Scores at Pre- and Posttest

	Training group			
	Inductive reasoning		Spatial orientation	
Ability factor	Pretest	Posttest	Pretest	Posttest
Inductive reasoning	50.25	55.49[a]	49.87	52.37
Spatial orientation	51.23	54.38	49.23	53.71[a]
Perceptual speed	50.40	52.91	49.32	51.93
Numeric	51.22	52.75	48.42	50.12
Verbal	51.57	52.27	49.06	49.94

Note. Standardized to $M = 50$ and $SD = 10$ on a sample of 401 subjects.
[a] Pre–posttest gain significantly greater for training group, $p < .05$.

Significant main effects and interaction terms, which were not directly related to training effects, follow for each of the five ability factors. For inductive reasoning, there were significant main effects for status ($p < .001$), gender ($p < .03$), and occasion ($p < .001$). The status and gender main effects reflect the lower scores across occasions for decliners and men, respectively. The occasion main effect represents retest effects occuring for both groups. For spatial orientation, there were significant main effects for status ($p < .001$), gender ($p < .01$), and occasion ($p < .001$). The status and gender main effects reflect the lower scores of the decliners and women, respectively, across occasions. There was a significant Training × Gender interaction ($p < .04$), indicating that summed across pre–posttest occasions, the performance of women trained on spatial orientation was significantly above that for control women trained on inductive reasoning, but this did not occur for men trained on spatial orientation, when they were compared with control men trained on inductive reasoning. For perceptual speed, there were significant main effects for status ($p < .001$), gender ($p < .001$), and occasion ($p < .001$). The status and gender main effects reflect higher scores for stables and women, respectively. There was also a significant Training × Gender interaction ($p < .003$), indicating that summed across pre–posttest occasions the performance of women trained on spatial orientation was significantly above that for control women trained on inductive reasoning. For numeric, there were significant status ($p < .002$) and occasion ($p < .001$) main effects. The status main effect indicated superior performance by the stables. For verbal, there was a significant occasion main effect ($p < .001$), and a significant Training × Status interaction ($p < .01$), indicating that across occasions, the performance of reasoning decliners was superior to that of space decliners.

Discussion

In this study we examined cognitive intervention effects within the context of a longitudinal study. Longitudinal research has indicated that early ability decline for most older adults is selective, often ability specific, rather than global or catastrophic. Moreover, there are wide individual differences in the specific abilities showing decline (Schaie, 1984). The initial phase of this study, which involved the classification of individuals with regard to decline status on two primary abilities, provides further support for the variability in patterns of cognitive functioning in later adulthood. Almost one half (46%) of the subjects exhibited no statistically reliable decline on either space or reasoning ability, studied over the previous 14-year period. Because the age of most of our subjects in 1970 was no older than early 60s, it is unlikely that many of the stable subjects had experienced significant decline prior to the base point in our classification procedure. Almost one third of the subjects (31%) showed decline on one of the abilities, but not on the other. Less than one fourth (22%) of the subjects showed decline on both space and reasoning. The wide variability in patterns of change is noteworthy, given that both of the abilities studied involve abstract reasoning on speeded measures and would thus be expected to exhibit normative decline based on the widely accepted classical pattern of cognitive aging (Botwinick, 1977).

Although the pre–posttest training gain was equivalent for both stable and decline subjects, the groups obviously differed in baseline at pretest. Consequently, the effects of training resulted in moving the decliners closer to their previous level of performance, while raising the performance of the stables beyond previously exhibited levels. Thus, training effects have qualitatively different implications for the two groups. Differentiation of these two kinds of effects requires the availability of longitudinal data.

Note that for almost one half of the subjects, there was no significant decline on either of the abilities studied, suggesting that for many of the elderly subjects, cognitive intervention efforts should focus on improving stable levels of functioning, rather than on remediation of decline. Given current cohort differences in ability performance level, many older adults may be disadvantaged when compared with younger age/cohorts, even though they showed no significant ability decline. Thus, intervention efforts may be useful in improving the performance of stable subjects, as well as in remediation efforts for those who have declined (Willis, 1985).

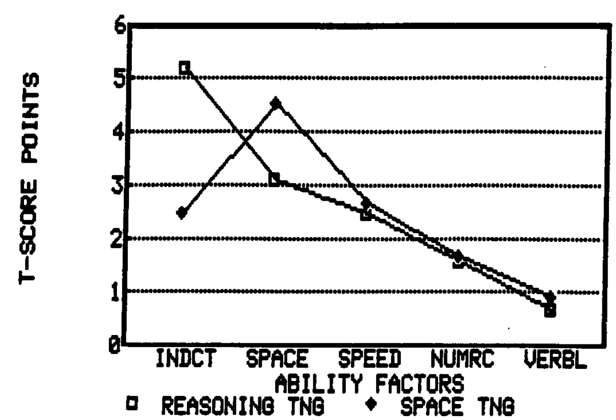

Figure 1. Pre- and posttest training gains in *T*-score points for the inductive reasoning and spatial orientation training groups on the five ability factors.

Significant training effects were demonstrated for both inductive reasoning and spatial orientation abilities. Three aspects of these findings merit further discussion: First, the finding of significant effects at the factorial level demonstrates that training is not limited to "teaching the test," but results in gain at the latent construct level. Training gains, as measured by specific observable tests, represent a confound of the variance common to the latent construct and the variance that is unique to that specific measurement instrument. However, it is change in the common variance, that is of primary interest. To assess such change, therefore, it is necessary to examine training gains at the factorial level, as was done in this study. For this purpose, it was essential to ascertain first that there is stability in the measurement framework from pretest to posttest, to assure that pre–posttest training gains are assessed within the same measurement structure. Stability of the measurement model across occasions was demonstrated.

A second major question focused on the differential effectiveness of training for remediating cognitive decline versus the attainment of enhanced performance levels in those elderly subjects showing no previous decline. Significant training effects were found for both decline and stable subjects. This finding is important because it suggests that cognitive training is effective not only in the remediation of decline, but also in improving the performance level of subjects showing no prior decline.

Third, training effects were found to be ability-specific. Note in Figure 1 that training effects were significant only for the ability factor targeted for training; significant training effects did not occur for the other abilities (perceptual speed, numeric, and verbal). Demonstration of ability-specific effects requires two conditions: first, that training effects be shown for the target abilities, and second, that no training effects be shown for other abilities not trained on. Both conditions were met. If training effects had occurred for abilities other than those trained, it could be argued that the effects occured as a result of increased test sophistication or increased response speed that could affect multiple abilities, rather than just the abilities trained.

Results of this study show that training efforts were effective in significantly improving the performance of a substantial number of older adults who had declined on the ability trained. For 40% of the decliners, training actually resulted in remediation to their 1970 performance level, 14 years previously (Schaie & Willis, 1986). Such reversal effects were demonstrated for both primary abilities, spatial orientation and inductive reasoning. Training procedures were also effective in enhancing the performance of those older persons who had remained stable on the target abilities; 66% of the stable inductive reasoning and 47% of the stable spatial orientation trainees showed significant pre–posttest improvement. Thus, for elderly subjects with known intellectual histories, it appears feasible to develop individual profiles of ability change and to target cognitive intervention efforts specifically to the needs of the individual, whether there is remediation of loss or increasing performance to a level not previously demonstrated.

Note that subjects in this study were community-dwelling elderly who had been screened by their physician for serious physical or mental impairment. We do not wish to suggest, therefore, that the methods used in this study would be equally effective with subjects suffering severe neurophysiological cognitive impairment. The decline observed in our community dwelling subjects, however, may have been associated with disuse or experiential changes in the environment that often occur in old age, rather than because of adverse physiological changes. The educational training procedures used in this study, therefore, may be particularly appropriate for the broad segment of the elderly population who are without significant neurological impairment.

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