Cognitive Training Effects on Primary Mental Abilities

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Cognitive decline is one of the most feared consequences of old age. The inability to care for oneself and, eventually, the loss of independence are among the outcomes of cognitive decline of concern to the elderly. While cognitive decline does appear currently to be largely irreversible with pathology, behavioral interventions are examining the extent to which cognitive functioning can be maintained and enhanced for normal, non-demented elderly.

Spatial orientation and inductive reasoning are two primary mental abilities which are often the focus of cognitive training efforts because they have been identified, through previous research, to exhibit early patterns of normative, age related decline (Schaie, 1983). These abilities have also been found to be associated with performance of tasks of daily living. Because of the wide span of individual differences in the decline of these two mental abilities, training effects may reflect remediation of decline, or improvement of cognitive ability beyond that experienced in the past.

Research Questions

Three major research questions will be addressed with this study. First, the effects of spatial orientation and inductive reasoning cognitive training interventions in 1984 and 1991 will be examined. Second, differences in training gains between 1984 and 1991 subjects will beexamined. In addition, training differences between decline and stable subjects, within training year, will also be explored. Finally, the effect of education and gender will be considered.

This study presents findings from the Seattle Longitudinal Study. Findings using longitudinal data, as applied to cognitive training, are unique in that individual differences in training effects can be examined. The classification of the subjects by decline status enabled us to compare across and within training year for individual differences in cognitive decline and training gains. Because there are such wide individual differences in the timing and rate of cognitive decline, understanding how these groups of older adults differently experience, and benefit from, cognitive training will enable us to better assist them in prolonged independent living and improved cognitive functioning.

Method

Subjects

Subjects were 407 older adults (male=183; female=224) from the Seattle metropolitan area, who had been participants in the Seattle Longitudinal Study (SLS) since 1970 or earlier (Schaie, 1983). All subjects are, or had been, members of the Group Health Cooperative of Puget Sound, a health maintenance organization. Mean age of the total sample was 73.1 years (range = 64-95; SD = 6.49). Mean educational level was 14.2 years (range = 7-20; SD = 2.96). Mean income level $21,079 (range = $1,000-$50,000; SD = $8,676).

The 1984 sample consisted of 228 older adults (male=97; female=131) with a mean age of 72.8 years (range = 64-95; SD = 6.43). The mean educational level of the 1984 sample was 13.9 years (range = 7-20; SD = 2.9). The 1991 sample consisted of 179 older adults (male=86; female=93) with a mean age of 73.4 years (range = 64-95; SD = 6.6). The mean educational level of the 1991 sample was 14.5 years (range = 7-20; SD = 3.0).

All subjects were community dwelling. Most of the subjects were Caucasian. Prior to initiation of the study, each subject's physician was contacted and asked 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 participants.

Subjects were classified as having declined or having remained stable over a 14 year period prior to training (1970-1984); (1977-1991) on the Thurstone (1948) Primary Mental Ability (PMA) Inductive Reasoning and Spatial Orientation measures.

The statistical criterion for decline was one standard error of measurement (SEM) or greater from the subject's baseline score (Reasoning = 4 raw score points; Space = 6 raw score points). A 1 SEM confidence interval was placed about each subject's baseline score (Dudek, 1979); if the subject's scores fell below this interval they were classified as having declines. Subjects whose scores remained within or above this interval were classified as having remained stable.

In the 1984 sample there were 107 subjects (46.7% of the sample) classified as having remained stable on both ability measures and 122 subjects (53.3%) who were classified as having declined on one or both of the ability measures. In the 1991 sample there were 86 subjects (48.3 %) who were classified as having remained stable on both ability measures and 92 subjects (51.7%) who were classified as having declined on one or both of the ability measures.

Assignment of subjects

Subjects were assigned to Spatial Orientation or Inductive Reasoning training based on their decline status. Subjects classified as having declined on one ability were placed in the training group on the ability exhibiting decline. Subjects who were classified as having declined on both abilities or as having remained stable on both abilities were randomly assigned to one of the training. group. This design employs subjects trained on one ability as controls for those trained on the other ability.

Procedure

The study involved a pretest-treatment-post-test control group design. All subjects had previously participated in the SLS and were informed via a series of letters that a new phase of the study was starting. Subjects indicating interest in the training study were visited in their homes by a staff member. These home visits were designed to assess if the subject's home was a suitable place for the training sessions to be conducted and to determine if the subjects had any sensory handicaps that might interfere with participation in the study. Any questions or concerns the subjects had were addressed during the home visit.

Measures

The pretest-post-test battery contained psychometric measures representing five primary mental abilities, including the PMA measures (Thurstone, 1948) administered at previous SLS assessments. Each ability was represented by three or four marker measures. The marker measures for Spatial orientation and Inductive reasoning are discussed in greater detail as these abilities are the target of the training sessions.

Spatial Orientation

Spatial orientation was assessed by four marker measures. Three of the measures (PMA Space, Object Rotation, and Alphanumeric Rotation) are multiple response measures of two-dimensional mental rotation ability. Subjects are shown target drawings and asked to identify which out of six of other drawings is the target drawing in different spatial orientations. There are two or three possible correct answers for each test item.

The Object Rotation test (Schaie, 1985) and the Alphanumeric test (Willis & Schaie, 1983) were designed so that the angle of rotation in each answer is identical to that of the angle used on the PMA Space test (Thurstone, 1948). However, the three test vary in item content. Abstract figures are used in the PMA test, drawings of familiar objects are used in the Object Rotation test, and the Alphanumeric test contains letters and numbers. The fourth test, Cube Comparison (Ekstrom, French, Harman, &Derman, 1976) assesses mental rotation in three dimensional space.

Inductive Reasoning

Inductive reasoning ability was assessed by four measures, PMA reasoning measure, ADEPT Letter Series test, Number Series test, and Word Series test.. The PMA reasoning measure (Thurstone, 1948) assesses inductive reasoning ability via letter series problems. A series of letters are presented and the subject must identify the next letter in the series from five letter choices. The Adult Development and Enrichment Project (ADEPT) Letter Series test (Blieszner, Willis, & Baltes, 1981) is similar to the PMA reasoning, but employs a number of different pattern-description rules. The Word Series test (Schaie, 1985) uses the same pattern-description rules for each item as the PMA reasoning test, but uses days of the week or months of the year instead of letters. The Number Series test (Ekstrom et al., 1976) uses different types of pattern-description rules involving mathematical computations and involves a series of numbers instead of letters. The PMA Spatial Orientation and Inductive Reasoning tests have been administered at pervious Seattle Longitudinal Study measurement points and are therefore the most direct assessment of training improvement and remediation of cognitive decline.

Training Programs

Subjects were administered a broad psychometric ability battery during two pretests sessions lasting approximately 2 and 1/2 hours each. The ability training consisted of five one hour individually conducted training sessions. Most subjects were trained in their homes. Two middle-aged trainers, with prior educational experience in working with older adults, served as trainers. Subjects were randomly assigned to the trainers, each trainer training approximately an equal number of stable and decline subjects in each ability. Following training, subjects were assessed on a post-test battery consisting of the same measures administered at pretest. Subjects were paid $100 for participation in the study.

Inductive Reasoning

Subjects were taught to identify four major pattern description rules (identity, next, skips and backward next). The subjects learned through modeling, feedback and practice procedures to learn to identify and solve problems. Practice patterns and problems were administered, completed and discussed. The practice items employed similar rules, but had different content than the items on the test measure, such as musical notes and travel schedules. No practice items were identical to the problems on the test measure.

Subjects were encouraged to say, read aloud, make tick marks or slashes to identify skips and to underline repeats int he sets to aide in identification of the pattern. Once the subject had a hypothesis as to what the pattern was, the trainer taught him or her how to identify a pattern within the series and name the next letter by following the rule.

Spatial Orientation

Spatial orientation involves speed and accuracy in mentally rotating abstract objects in two dimensional space. These cognitive skills are used in daily life when performing such tasks as reading a road map or interpreting floor plans. The subject must identify which of six drawings can be rotated to look like the target drawing. The six drawings are at 45, 90, 135, 180, 225, 270 and 315 degree angles. Some drawing presented to the subjects are mirror images of the target drawing.

Subjects are taught cognitive strategies before attempting to solve practice problems. These strategies include developing concrete terms, such as times on a clock, for each angle rotation, physically rotating objects before mentally attempting rotation, naming the abstract objects which need to be mentally rotated so they are more familiar tot he subject and focusing on two or more features of the object while rotating it.

Results

For each research question a repeated measures analysis of variance (ANOVA) was performed to examine the effects of gender, training program, decline status and year of training. After the fully crossed models were examined, non-significant interactions were removed from the model and the results of the reduced models were examined and interpreted. To determine the additional effect of education on cognitive training gains above and beyond the other variables in the model, an analysis of covariance (ANCOVA) was performed adding education as a covariate to the reduced models. All analyses were run separately for the inductive reasoning training group and for the spatial orientation training group.

Training effects in 1984 and 1991

Figures 1 and 2 show significant training effects as indicated by the training x occasion interaction were found for both the spatial orientation and inductive reasoning training groups in both 1984 and 1991 (Tables 1 & 2). Significant training effects were found at both the PMA test level and the ability factor level for spatial orientation ($p = <.001$, raw PMA space; $p = <.05$, space factor score) and inductive reasoning ($p = <.001$, raw PMA reasoning; $p = <.001$, reasoning factor score).

Differences in 1984 and 1991 replicates

Figures 3 and 4 show that non-significant occasion x training x replicate interactions were found for both reasoning and space training groups, indicating that averaged across stable and decline subjects, training gains did not differ significantly by replicate (1984 and 1991). In addition, non-significant occasion x training x status interactions for both training groups indicate that averaged across years, the stable and decline subjects did not differ in magnitude of training effects (Tables 1 & 2).

Higher order interactions of training effects by year and decline status

Table 5 shows that for the inductive reasoning training group, a non-significant higher order four way interaction among occasion, training, status (stable or decline) and year indicated that training effects were not specific to subjects' decline status. Nor did the training effects vary by year of training.

In contrast, for the spatial orientation training group, a significant occasion x training x status x year interaction ($p = <.05$, raw PMA reasoning) indicated that training effects differed by decline status across replicates (Table 1). Comparisons of means indicated that although the space training group had significantly higher scores at post-test than the comparison group, the magnitude of improvement was dependent on subjects' decline status and training year. More specifically, for subjects trained in 1984 greater training gains were observed for subjects classified as having declined on spatial orientation than those who were classified as having remained stable. However, for subjects trained in 1991, similar training gains were observed for decline and stable subjects (Figure 5). This four-way, higher-order interaction was not found to be significant at the spatial orientation factor level, only a trend was observed.

Effects of education and gender

To consider the relationship between subjects' education level and their training gains, an analysis of covariance with repeated measures was performed entering education as a covariate. The same pattern of findings occurred at both the PMA test level and the latent construct level when education was controlled (Tables 3 & 4). Non-significant occasion x training x gender interactions at both the PMA ability and factor levels for both reasoning and spatial abilities indicate that training effects do not differ significantly by subjects' gender .

Discussion

In this paper we examined the effects of spatial orientation and inductive reasoning cognitive training interventions in older adults. In addition, training differences between subjects who had not shown prior decline on either ability versus subjects who had declined over the prior 14-year period were also examined. Finally, the effect of education and gender on training improvement was considered.

Although cognitive decline appears to be largely irreversible with pathology, our findings indicate that cognitive functioning can be maintained and even enhanced in normal, non-demented elderly. Significant training effects were found for both inductive reasoning and spatial orientation in 1984 and 1991. Although some normative age-related decline in cognitive functioning is expected, subjects classified as having declined on one or both of the target abilities exhibited similar training gains to subjects classified as having remained stable over the prior 14-year interval. Averaged across replicates (1984 and 1991) the stable and decline subjects did not differ in magnitude of training effects indicating that both decline and stable subjects benefitted from the training intervention.

Although overall training effects did not differ by decline status, training effects specific to spatial orientation differed by decline status and year of training. Specifically, for subjects trained in 1984, those identified as having declined showed greater training gains than subjects classified as having remained stable. However, for subjects trained in 1991, the magnitude of training gains was similar for decline and stable subjects. These results suggest that, for certain abilities, subjects who have exhibited decline on the ability may benefit more from training interventions than subjects who have remained stable on the ability.

Findings for both spatial orientation and inductive reasoning were unaffected by education level and did not differ significantly by subjects' gender. These findings indicate that cognitive training interventions are successful in maintaining and enhancing cognitive functioning in normal, non-demented older adults. Cognitive functioning has been related to performance on tasks of everyday living and competence (Willis, 1987), suggesting that maintaining and improving cognitive functioning in older adults may prolong independent living and successful aging.

Table 1. Analysis of variance with repeated measures results for PMA Spatial Orientation (N=407)

SOURCE	DF	MS	F-VALUE
Occasion	1	2844.63	175.77***
Occasion x Sex	1	44.92	2.78
Occasion x Train	1	426.63	26.36***
Occasion x Stable	1	331.54	20.49***
Occasion x Year	1	0.058	0.00
Occasion x Train x Stable	1	23.69	1.46
Occasion x Train x Year	1	2.64	0.16
Occasion x Stable x Year	1	61.22	3.78
Occasion x Train x Stable x Year	1	72.93	4.51*
Error	398	16.18	

Note: * $p < .05$
** $p < .01$
*** $p < .001$

Table 2. Analysis of variance with repeated measures results for PMA Inductive Reasoning (N=407)

SOURCE	DF	MS	F-VALUE
Occasion	1	3071.70	292.06***
Occasion x Sex	1	17.22	1.64
Occasion x Train	1	1264.51	120.23***
Occasion x Stable	1	71.81	6.83**
Occasion x Year	1	2.42	0.23
Error	402	10.51	

Note: * $p < .05$
** $p < .01$
*** $p < .001$

Table 3. Analysis of covariance with repeated measures results for PMA Spatial Orientation, education entered as covariate (N=407)

SOURCE	DF	MS	F-VALUE
Occasion	1	293.72	18.22***
Occasion x Education	1	41.50	2.57
Occasion x Sex	1	39.67	2.46
Occasion x Train	1	428.83	26.60***
Occasion x Stable	1	332.55	20.63***
Occasion x Year	1	0.62	0.04
Occasion x Train x Stable	1	14.95	0.93
Occasion x Train x Year	1	2.43	0.15
Occasion x Stable x Year	1	59.15	3.67
Occasion x Train x Stable x Year	1	64.15	3.98*
Error	397	16.18	

Note: * $p < .05$
** $p < .01$
*** $p < .001$

Table 4. Analysis of covariance with repeated measures results for PMA Inductive Reasoning, education entered as a covariate (N=407)

SOURCE	DF	MS	F-VALUE
Occasion	1	103.57	9.83**
Occasion x Education	1	1.52	0.14
Occasion x Sex	1	17.68	1.68
Occasion x Train	1	1264.29	119.96***
Occasion x Stable	1	71.73	6.81**
Occasion x Year	1	2.09	0.20
Error	401	10.54	

Note: * $p < .05$
** $p < .01$
*** $p < .001$

Figure 1. Training Effects for Spatial Orientation

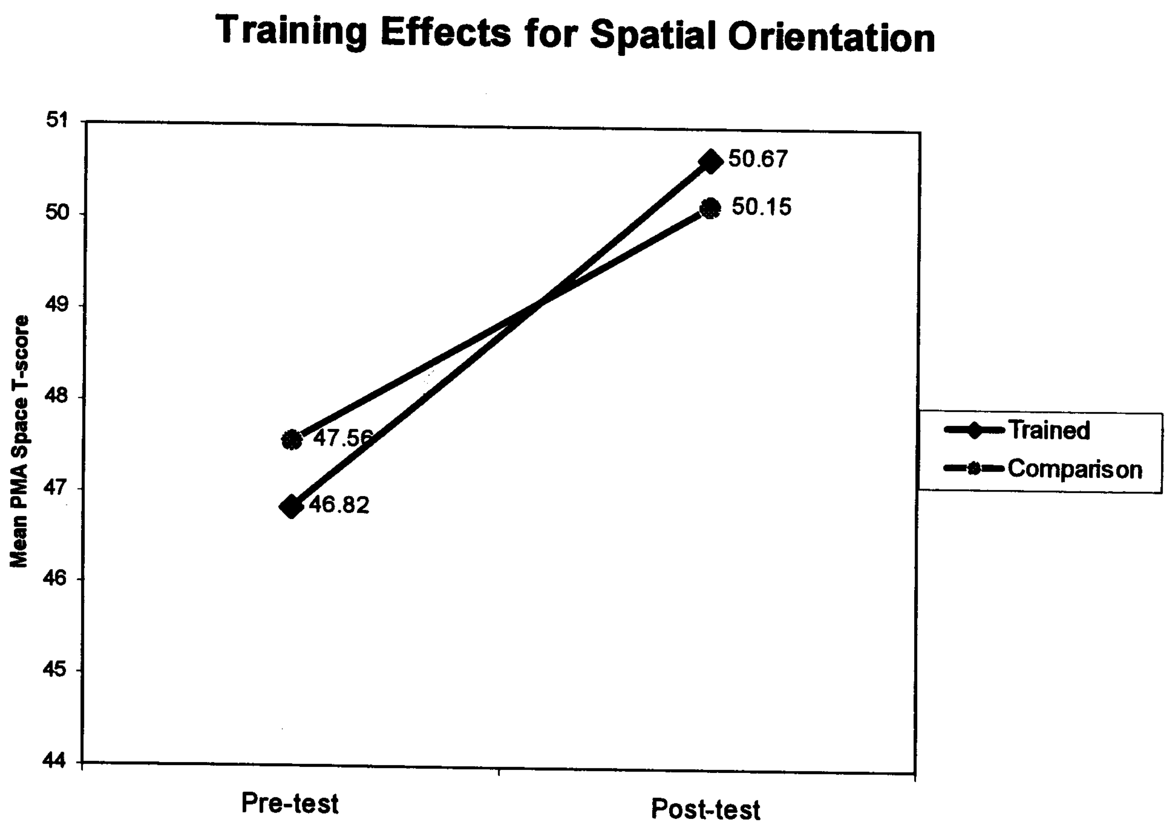


Figure 2. Training Effects for Inductive Reasoning

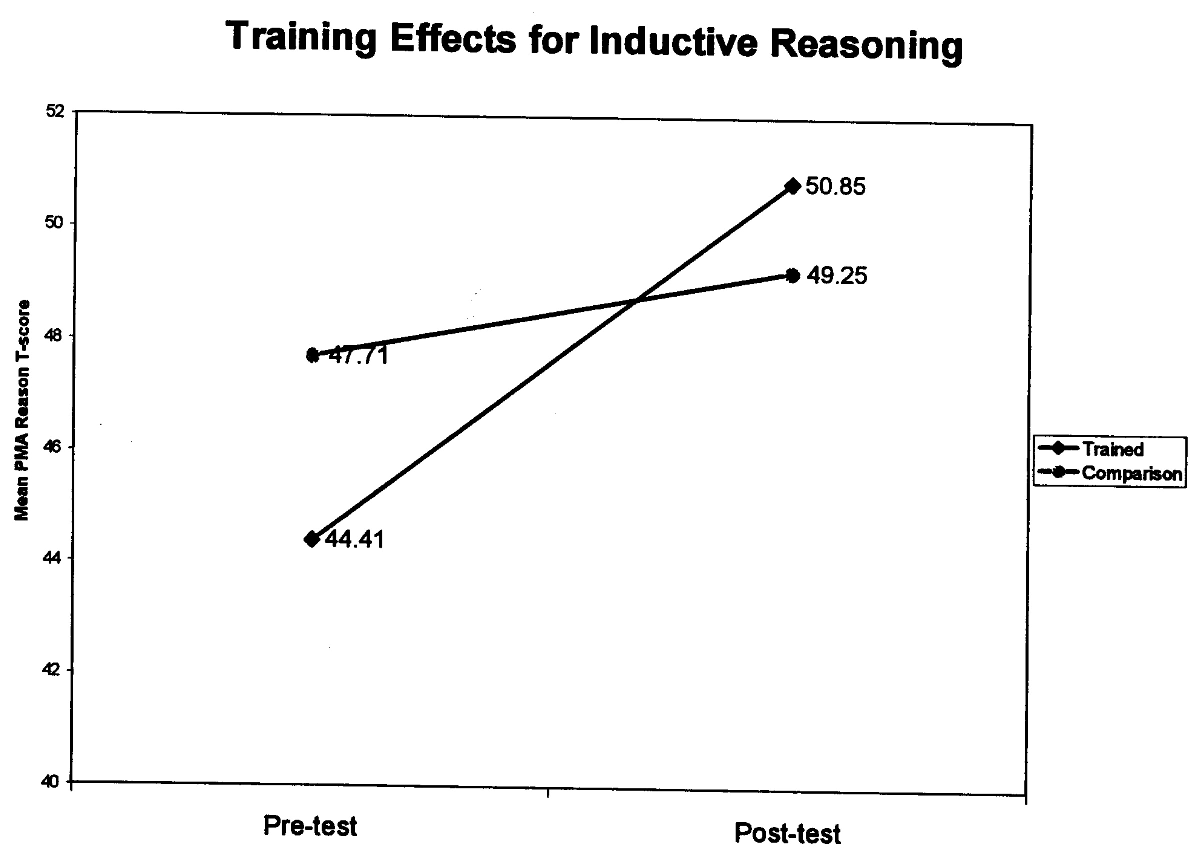


Figure 3. Training Effects for Spatial Orientation by Replicate

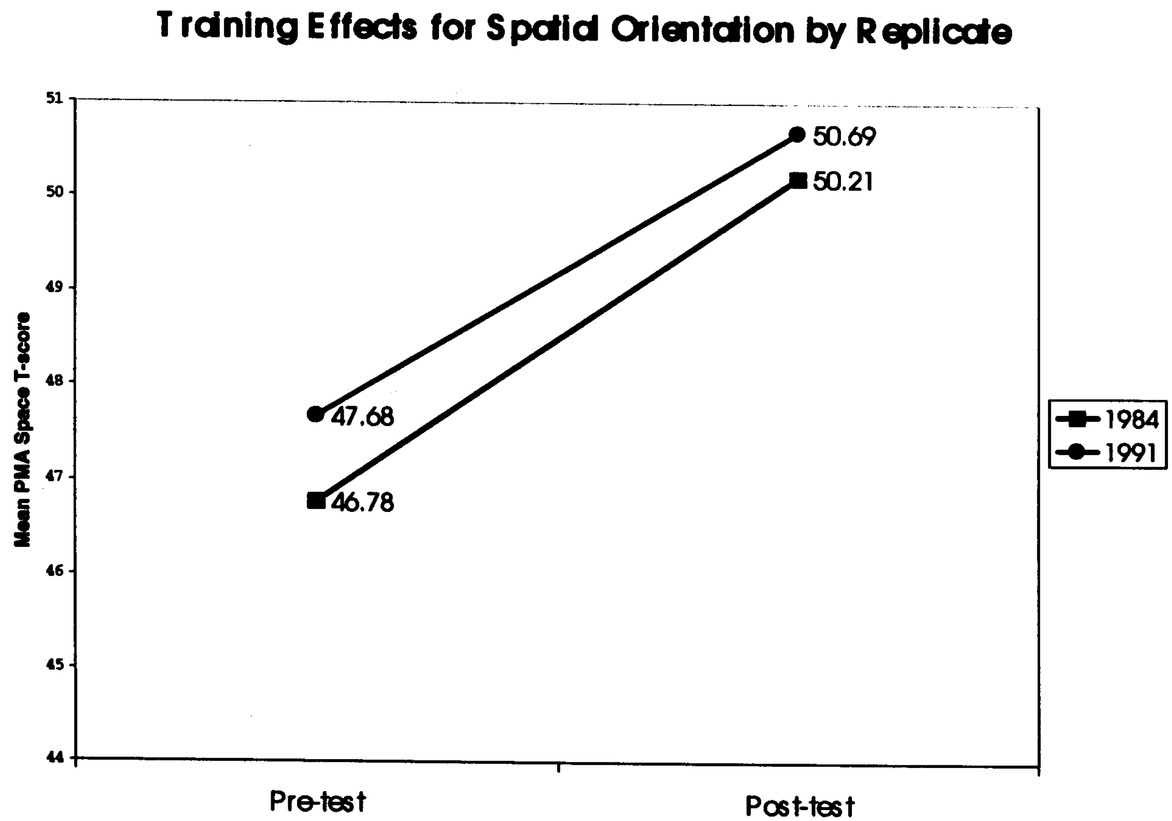


Figure 4. Training Effects for Inductive Reasoning by Replicate

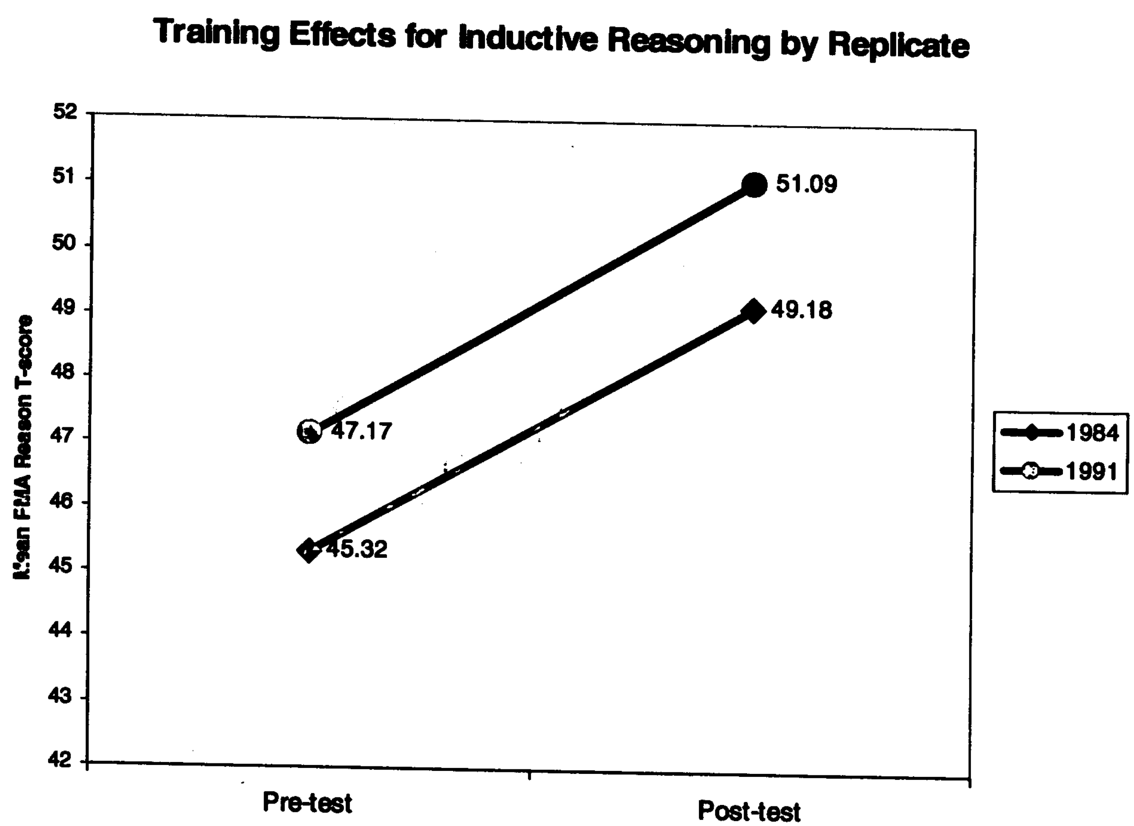
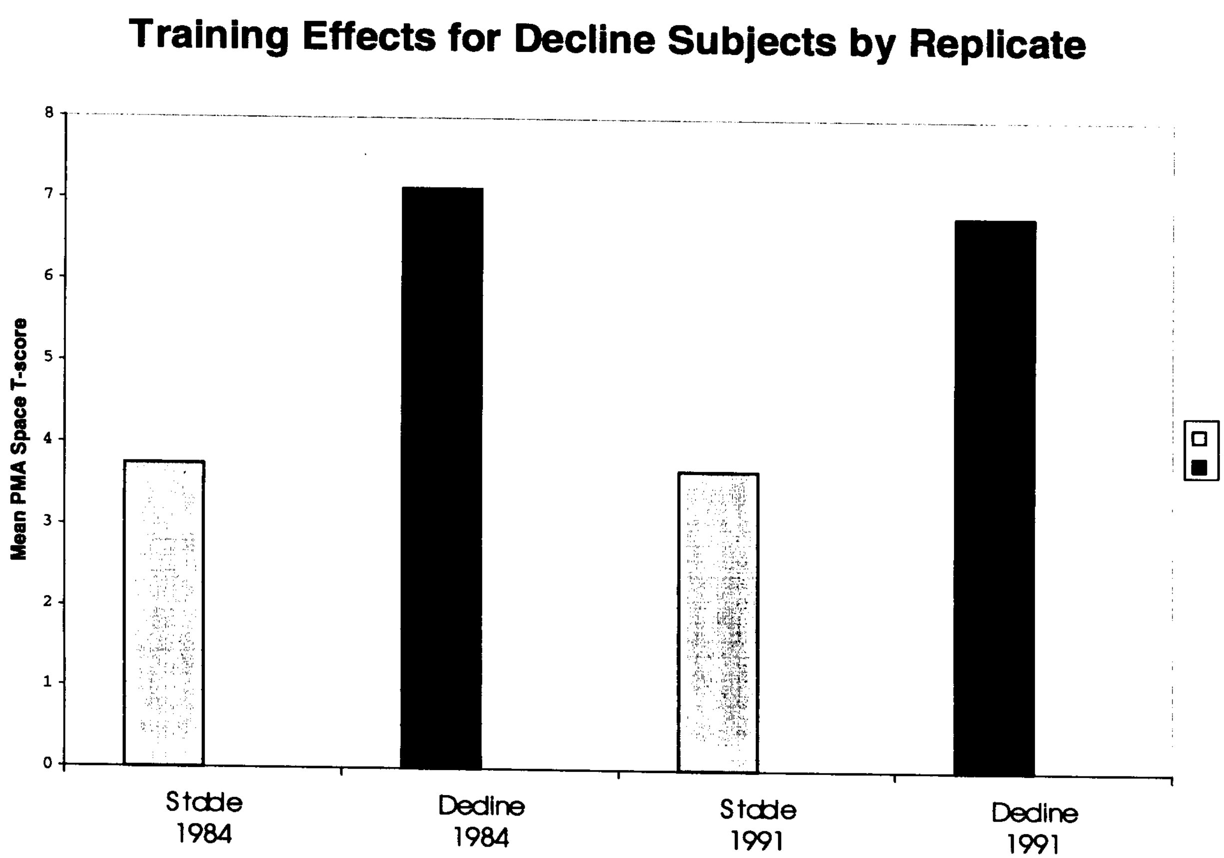


Figure 5. Training Effects for Decline Subjects by Replicate



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