Maintaining and Sustaining Cognitive Training Effects in Old Age

Sherry L. Willis and K. Warner Schaie
The Pennsylvania State University
University Park, Pennsylvania

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Introduction

Within the context of the Seattle Longitudinal Study (SLS) we have conducted cognitive training interventions with older adults for the primary abilities of Inductive Reasoning and Spatial Orientation in individuals who were followed for at least 14 years prior to the intervention and who could ®be classified as having remained stable or having reliably declined across this time interval (Schaie & Willis, 1986; Willis & Schaie, 1986, 1988). We were able to demonstrate that approximately two thirds of our study participants benefited significantly from training and that of those with reliably established decline, approximately 40% could be returned to the level they had held fourteen years earlier.

Question remains whether the effects of cognitive intervention such as ours do provide benefits that last over extended periods of time and whether it is possible to remediate further losses that occur as study participants move into advanced old age. To address these questions, we have just completed a seven-year follow-up of the original training study In this paper we will report data from the SLS that bear directly upon the question of maintaining and sustaining cognitive training effects. Specifically, we investigate the question whether or not persons receiving brief cognitive training remain at an advantage compared to those not so trained. And, second, we consider the effects of booster training to determine the benefits of further reactivation of the abilities trained earlier.

Method

Subjects.

The 1983/84 training phase of the SLS included 229 participants (113 women, 97 men) who were born in 1920 or earlier and who had been SLS participants for at least fourteen years. At that time their mean age was 72.8 years (*SD* =6.41, range 64 to 95 years). Mean educational level was 13.9 years (*SD*=2.98, range=6-20). There were no sex differences in age or educational Ievel. Mean income level was $19,879 (SD = $8,520; range = $1,000-$33,000). All ot the subjects were community dwelling, and most were Caucasian. All subjects who participated in the 1983/84 training and who were known to be alive in 1990 were contacted. 148 trained subjects agreed to participate in the follow-up study. The present preliminary report includes data for 123 of these subjects. Their age in 1990/91 averaged 78.14 years (*SD* =4.87; range 71 to 95 years).

Design and Procedure.

Classification Procedure. Subjects' test performances on the Thurstone (1948) Primary Mental Abilities (PMA) Reasoning and Space measures were classied as havig remained stable, or as having declined over tbe previous 14-year interval from1970 to 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 tclassified by defining a 1 standard error of measurement (SEM) confidence interval about their observed 1970 score (cf. Dudek, 1979). Subjects who in 1984 were within the confidence interval about their 1970 score were classified as stables. Those who fell below the inteval were classified as decliners. There were 107 subjects (46.7% of the sample) classified as havig remained stable on both ability measues; 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 dechned on both measures.

Subject assignment. In the original training, subjects were assigned to either inductive reasoning or spatial orientation training programs, based on their performance status (1970-1983/84). Subects 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 oneof the training programs. Spatial Orientation training subjects included 51 stables (28 women, 23 men) and 67 decliners (38 women, 29 men). Inductive Reasoning training subjects included 56 stables (31 women, 25 men) and 55 decliners (35 wome, 20 men). The present analysis deals with 57 Spatial Orientation training subjects including 27 stables (11 men, 16 women), and 36 decliners (10 men, 20 women), as well as 66 Inductive Reasoning training subjects including 27 stables (14 men, 23 women) and 29 decliners (10 men, 19 women).

Study design. The study involved a pretest-treatment-posttest control group design. The inductive reasoning training group served as a treatment controi for the spatial orientation training group, and vice versa. Subjects were administered a broad psychometric ability battery in two pretest sessions (21/2 hr per session). Training began within 1 week of pretest and involved five 1-hour individually conducted training sessions. The training sessions wcrc conducted within a two-week period. The majority of subjects were trained in their homes. Middle-aged persons with prior educational expcrience involving adults served as trainers. Subjects were randomly as-signed to the trainers within pragmatic constraints, such that each trainer trained approximately equal numbers of stable and decline subjects in each training program. Booster training was given on the same ability (inductive reasoning or spatial ability) that subjects had originally been trained on. Subjects were assessed wlthin 1 week of training on the same measures that were administered at pretest. They wcre paid $150 for participating in the study.

Measures

Thc pre-posttest battery involvcd psychometric mcasures represent-ing fivc primary mcnral abilitics, including the PMA measurcs (Thurstone, 1948), administered at previous SLS assessments. Each abiiity was represented by three to four marker measures.

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 subjcct is shown a model line drawing and asked to identify which of six choices shows thc model drawn in dfferent 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 idenilcal with the anglein 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 ability was assssed by four measures. The PMA Reasoning test (Thurstone & Thurstone, 1949) assesses inductive r:asoning ability via Ietter serics problems. Thc subject is shown a series of Ietters and must select tbe next Ietter in the series fromf ive Ietter choices. The Adult Development and Enrichent Project (ADEPT) Letter Serics test (Blieszner, Willis, & Baltes, 1981) also contains letter series problems; however. some of the problems involve patttern-description rules other than those found on the PMA measure. The Word Series test (Schaie, 1985) parallels thc PMA measure in that the same pattern-description rule is used for each item; however, the test stimuli are days of the wek} or months of the year rather than letters. The Number Series test (Thurstone, 1962) involves series of numbers rather than letters, and involves diferent types of pattern-dcxription 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 o ftraining improvement and remediation

Training Programs

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

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-desription 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-descripticn rules. Practice problems often involved contnt other than letters, so that the applicability of these rules to other content areas could be explorcd. For example. patterns of musical notes and travel schedules were devised based on these rules, and subjects were to asked 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 pattems 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. Oncc 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 lettcr required to fit thc patecrn rule.

Spatial Orientation. A contcnt task analysis of the PMA space tes twas conductcd to identify the angle of rotation for cach answer choicce. Practice problcms 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. in-cludcd (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 the introduction of abstract figures, (d) subject-generated names for abstract figures and (d) having the subject focus on two or more features of the figure during rotation. These cognitivc strategies had alsop ben identifid in prior descriptiec research on mental rotation ability (Cooper & Shepard, 1973; Egan,1981; Kail, Pellegrino, & Carter. 1980).

Results

Results of this study are reported in three parts: First, we describe the magnitude of the initial training for the surviving sample and the nature of attrition effects. Second, we consider the maintenance of training over seven years; that is, the question whether or not persons receiving brief cognitive training remain at a long-term advantage compared to those not so trained. And third, we report the effects of sustaining training effects by means of booster training in order to determine the benefits of further reactivation of the abilities trained earlier. For simplicity in presentation we emphasize the longitudinal markers that were applied throughout the SLS. But if time allows we will also show data at the latent construct level (i. e., factor scores summed across the markers for each of the two abilities on which we have trained subjects.

Magnitude of Initial Training. During the 1983/84 training study significant training effects were obtained for both abilities trained. Because of the approximately 40% attrition in the follow-up studies, we recomputed training effects for the surviving sample. Overall, there was appoximately 1/2 *SD* gain in each training program. These effects continue to be significantly greater than those for the comparison control group. However, contrary to findings in the unattrited sample, there was significantly greater effect for those subjects who had been identified as decliners (see Figure 1). These results reflect greater retention of those of the decline subjects who showed significant training gain in the initial training. There was an interaction effect in retention for the stable subjects. Those with greater training gain on Space also showed higher retention, but those with greater training gain on Reasoning showed lower retention.

Insert Figure 1 about here

Maintenance of training effects. We next consider the extent to which training gains are retained after seven years. In 1990/91 subjects trained in 1983/84 were functioning, on average, at their 1983/84 pretest level on the trained ability. In contrast, the comparison group (those trained on the other ability) were functioning significantly below their 1983/84 pretest level. As shown in Figure 2, there was a significant maintenance of function on the trained ability even after a seven-year interval. For the total group, this was a modest effects, amounting to approximately .3 *SD* . Once again, however, this effect was most pronounced for those subjects who had been classified as decliners for purposes of the initial training. For both abilities these individuals, on average, still performed above their 1983/84 pretest level, while their comparisons had declined further. The trained groupsof decliners, in 1990/91, had an advantage of approximately .4 *SD* over their comparison groups. By contrast, those who had been stable in 1983/84 were at approximately .15 *SD* advantage over their comparisons on Reasoning, while the difference between the stable experimental and control groups on Space was not statistically significant.

Insert Figure 2 about here

Sustaining training effects through booster training. When the previously trained subjects were put once again through the same training regimen that they had experienced earlier, significant ability-specific training effects were obtained for both training condiitons as well as the subsets of subjects who had been classified as having declined or remained stable at initial training. That is, in all instances gains from pretest to tposttest were significantly larger than for the untrained comparison groups. However, the effects of the 1990/91 booster training were of somewhat lower magnitude in these subjects who are now seven year older.

Of particular interest is the question of cumulative magnitude of initial and booster training when compared with control groups who had the same amount of attention (by being trained on another ability). As shown in Figure 3, there is a clear advantage for those subjects who were originally identified as experiencing decline. After booster training, they are at a better than 1/2 *SD* advantage over their comparison groups. The training advantage for those subjects described as stable at initial training is more equivocal. It is still highly significant for Reasoning, although their advanctage is more modest, but there is no significant cumulative advanage for stable subjects who were trained on Space. In order to show the generality of these findings beyond the prime longitudinal marker, we also computed factor scores across each set of four markers of the abilities on which we trained. Figure 4 shows the cumulative training effects at the latent construct level, which ware quite similar to those shown on the previous figure.

Insert Figures 3 and 4 about here

Replication of training effects. In order to assess the replicability of our training effects with another sample, we also trained an additional 145 subjects who met the original selection criteria in 1990/91 but who had not been trained previously. Preliminary anlyses of the replication (first time training) suggest that signficant training effects and near transfer to alternate operational forms of the target tests can again be demonstrated, and that significant effects of training in excess of pretest-posttest practice can be demonstrated as well at the latent variable level. We also replicate stronger training effects for the Inductive Reasoning than the Spatial Orientation ability. Figure 5 compares training gains at the factor level for initial training in 1983/84 and 1990/91 and effects of booster training (1990/91) for Induction and Space training. The lower average level of gain in the booster training could be due to the fact that subjects on average are now in the old-old range, or that the residual of the earlier training brought them closer to their personal asymptote. Further analyses and additional data collections will be needed to answer this question.

Insert Figure 5 about here

Summary

Follow-up of cognitive training over a seven-year period has demonstrated that trained subjects who at initial training had shown significant decline remain at substantial advantage over untrained comparison groups. Booster training increases the advantage of these groups further. Long-term effects for those who had reamined stable at in itial training differed by ability. More modest, but significant effects, were shown to prevail on Reasoning but not on Space training. In addition, replication of initial training with a new sample, demonstrated similar magnitudes of training effects, with greater training success for the Reasoning training program.

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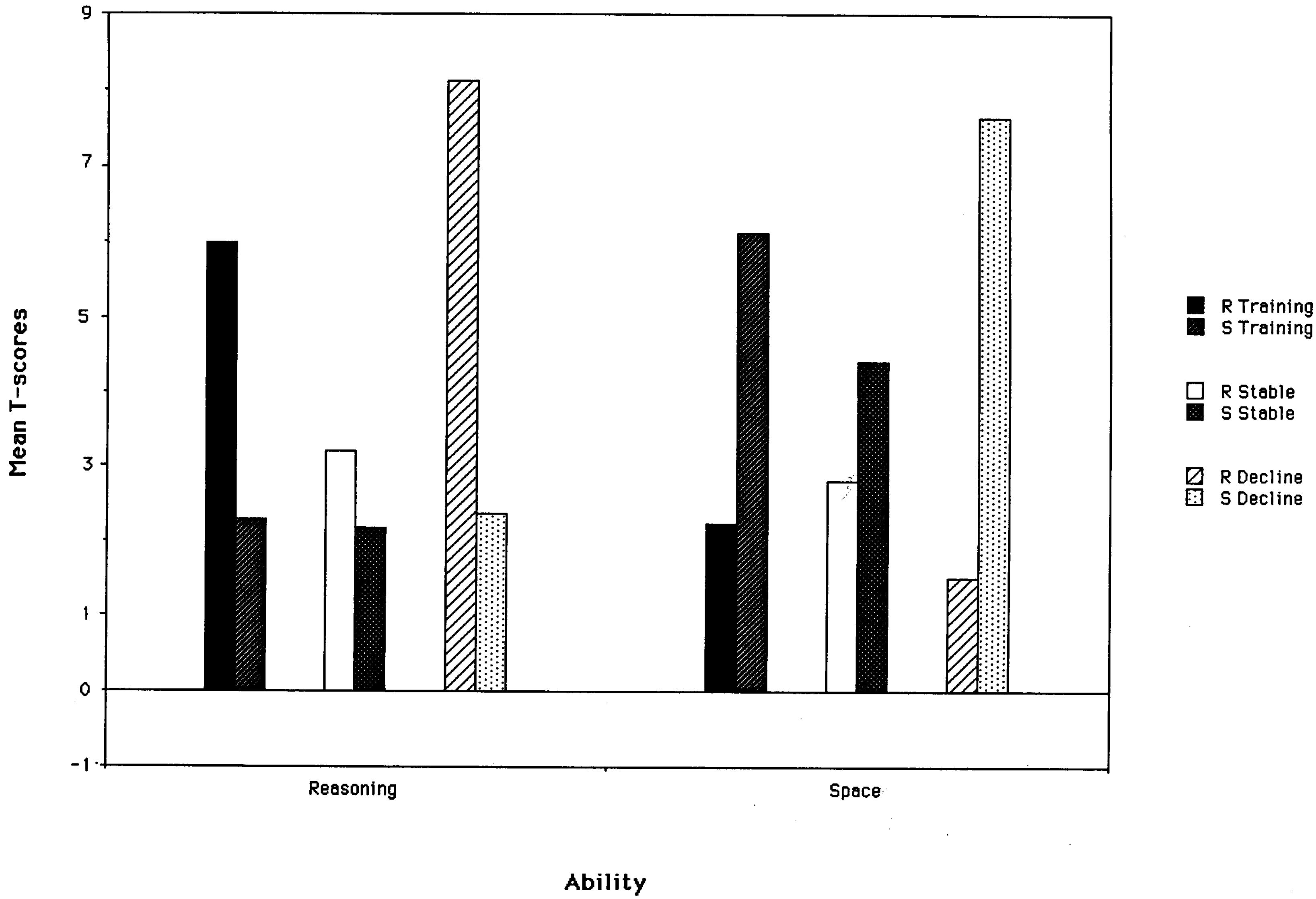
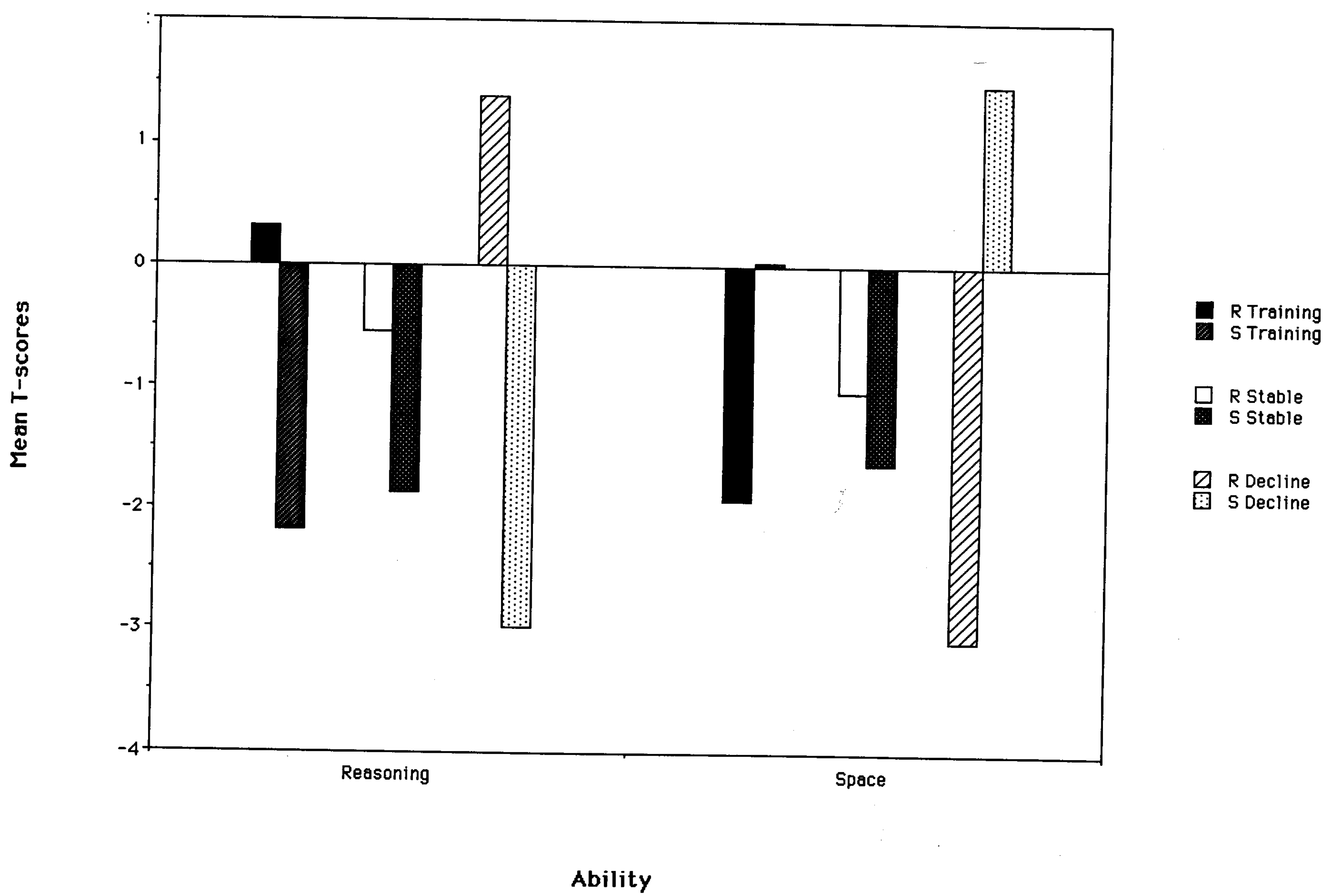
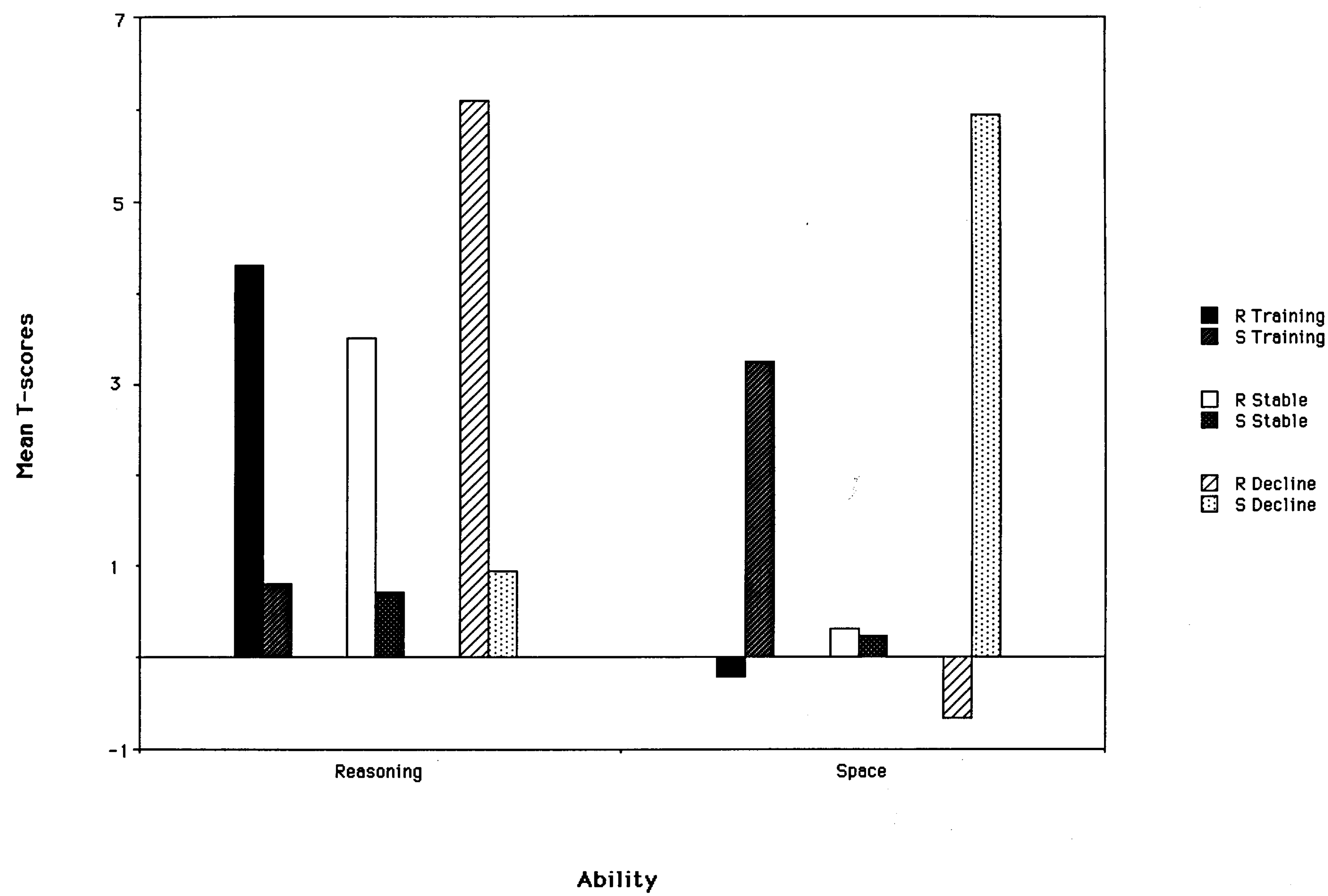
1983 Training Gain from Pretest to Posttest



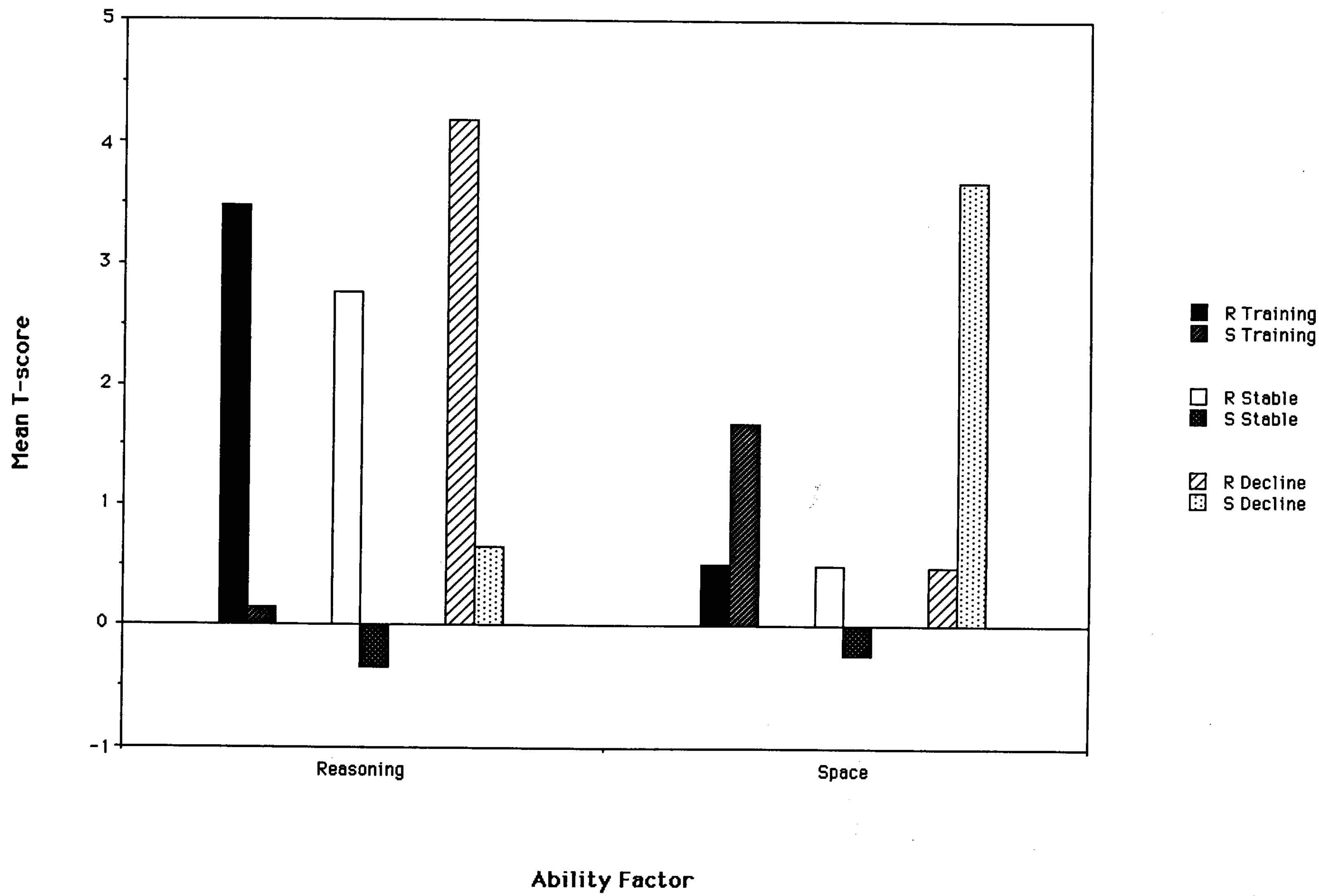
7-Year Maintenance of Training Effects: Change from 1983 Pretest to 1990 Pretest



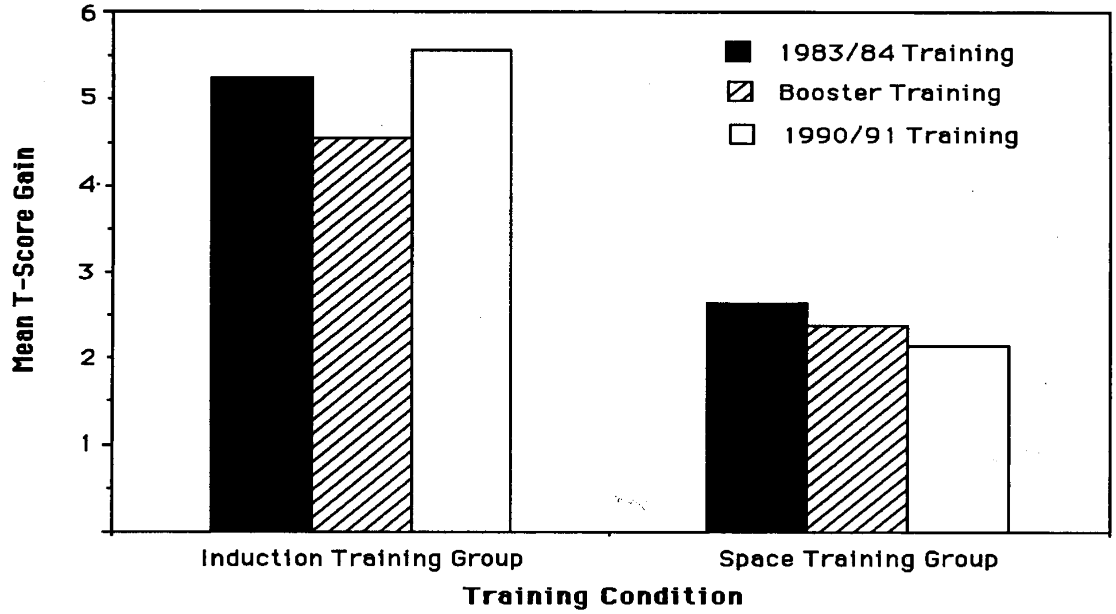
Cumulative Effects from 1983 Pretest to 1990 Posttest



Cumulative Effects at Factor Level 1983 Pretest to 1990 Posttest



Pretest-Posttest Training Gain on Induction



Pretest-Posttest Training Gain on Space