AGE/COHORT DIFFERENCES IN COGNITIVE TRAINING

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AGE-COHORT DIFFERENCES IN COGNITIVE TRAINING EFFECTS

Recent research in cognitive training has gone beyond simply examining whether training procedures are effective in modifying performance to asking what are the *individual differences* and treatment conditions associated with training gain. In this paper we will report on training research conducted within the Seattle Longitudinal Study. Our focus will be on age/cohort differences in training effects. The three age/cohorts were mean age 65.5, 72.5, and 80 years at the time of training.

The training research conducted within the Seattle Longitudinal Study is unique in that training effects can be examined within the context of the individual's pattern of long-term age-related change. In early training research there was often the implicit assumption that training improvement represented remediation of prior age-related decline. However, longitudinal findings indicate that there are wide individual differences in the pattern and rate of age-related change. There are individuals in old-old age who have exhibited not reliable decline on certain abilities. The question arises of the relative effectiveness of training for older adults who have *not declined* versus those who *have declined.*

Moreover, prior descriptive research indicates that there are *qualitative* changes in cognitive behavior with age. With regard to age-related decline, there is continuing debate regarding the extent to which decline is attributable to *slowing* in response speed or rate of processing, or whether decline is characterized by inefficient use of *cognitive strategies* and loss in *accuracy*. Studies of expertise also indicate that older adults can utilize compensatory mechanisms to make-up for age-related loss in speed of responding. For example, older typists compensated by processing larger chunks of information; other studies report older adults becoming more accurate or cautious in order to maintain high levels of performance in the face of declines in speed.

In our training research, we then examine whether the qualitative changes in cognitive performance associated with decline and with training improvement *differ* or are *mirror images* of each other. Moreover, does the utilization of compensatory mechanisms within the context of a training study vary by *age/cohort*, or by whether subjects have shown prior decline on the ability. That is, does the nature of decline and of training gain vary for individuals in their 80's, 70's and 60's? We hypothesize that even in advanced age, adults can improve their cognitive performance through training procedures that emphasize relevant cognitive strategies. Further, we hypothesize that for the oldest cohorts the accuracy acquired through enhanced use of cognitive strategies may become increasingly salient in compensating for behavioral slowing.

In this study we will address 3 questions: 1) Are there age/cohort differences in the magnitude of training gain, and in the remediation of age-related decline. 2) Are the qualitative changes associated with age-related decline and with training improvement mirror images of each other? 3) Does the nature of qualitative change differ by age/cohort or by stable versus decline status?

Methods

Subjects

Subjects were 229 older adults (M = 97; F = 132) 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. This health organization includes members from a wide range of occupational categories, representing the upper 75% of the socio-economic status range. Mean age of the total sample in 1984 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 gender differences in age or educational level. Mean income level was $19,879 (Range = $1,000-$33,000); SD = $8,520). All subjects were community-dwelling. Most of the subjects were Caucasian. Prior to the 1984 phase of the study, each subject's physician was contacted and asked to indicate whether the subject suffered any known physical or mental disabilities (e.g., sensory, motor, memory deficits), that would interfere with participation in the study; subjects identified as incompetent to take part in test-taking or training activities were not included in the study.

For the purpose of this study, subjects were divided into three age/cohorts. Subject characteristics by age/cohort are shown in Table 1. The oldest cohorts represented the birth cohorts 1889-1907, with a mean age of 80 years in 1984. The middle cohort represented the birth cohorts 1908-1914, with a mean age of 72.5, and the youngest cohort represented the birth cohorts 1915-1920, with a mean age of 65.5.

Design and procedure

The design of the study, involving two phases, is presented in Figure 1. In phase one, individual subjects' scores were examined over the fourteen-year interval (1970-1984) to categorize subjects as having remained stable or having decline on two Thurstone primary abilities (Thurstone & Thurstone, 1949); specifically, subjects' scores on the Reasoning and on the Spatial Orientation tests were examined in 1970, 1977, and 1984. Subjects were categorized as having remained stable on both Space and Reasoning, having decline on both, or having decline on one ability only. In phase two, subjects were assigned to treatment conditions, based on their change status. Subjects who had declined on only one ability were assigned to the ability on which they had declined; subjects who had remained stable on both abilities or who had declined on both abilities were randomly assigned to treatment condition.

Phase 1. The statistical criterion for the definition of decline was one standard error of measurement or greater (space = 6 raw score points; reasoning = 4 raw score points). Subjects were first classified by defining a 1 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 they were considered to be stable. Next their 1984 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 score dropped to 1 SEM below their 1977 score were reclassified as decliners.

Classification of subjects was: Stable on both abilities 47%; decline on both abilities 22%; decline on reasoning only 15%; decline on space only 16%. As would be expected from prior descriptive research on age-related cognitive decline, decliners were significantly older than stables.

Given the classification procedure described above, there was the possibility of statistical regression effects occurring, such that 1970 high scorers could have been erroneously classified in the decline group and the low scorers in the stable group. To examine the 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).

Phase 2. The second phase of the study, conducted in 1984, involved a pretest-treatment-posttest control group design. Subjects were pre- and posttested on a five-hour psychometric ability battery, including the

Thurstone primary abilities. The 1984 longitudinal data point served as the pretest. Subjects were assigned to space or reasoning training according to the procedure described above. Space training subjects (N = 118) included: 32 Oldest Cohort (Stable = 10; Decline = 22), 44 Middle Cohort (Stable = 19; Decline = 25), and 42 Youngest Cohort (Stable = 22, Decline = 20). Reasoning training subjects (N = 111) included: 30 Oldest Cohort (Stable = 8; Decline = 22), 39 Middle Cohort (Stable = 19; Decline = 20), and 42 Youngest Cohort (Stable = 29; Decline = 13).

All subjects had previously participated in the SLS and were informed via a series of letters that a new phase of the study was beginning. Subjects indicating an interest in participation in the training phase 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 which might interfere with participation, and to determine whether the home was a suitable place for conducting the training sessions.

Following the pretest, subjects assigned to Space training participated in 5 one-hour individually conducted training sessions. 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. Subjects were paid $100 for participation in the study.

Training Programs

Space training program. The focus of the Space training program was on facilitating the subject's use of effective cognitive strategies identified in previous descriptive research on mental rotation ability (Cooper & Shepard, 1973; Egan, 1981; Kail, Pellegrino, & Carter, 1980). Cognitive strategies that were focused upon in training included: 1) Development of concrete terms for various angles; 2) Practice with manual rotation of figures prior to mental rotation; 3) Practice with rotation of drawings of concrete, familiar objects prior to rotation of abstract figures; 4) Subject-generated names for abstract figures; and 5) Attention to two or more features of the figure during rotation. Prior research had shown that these strategies were useful in facilitating speed and accuracy of mental rotation. Strategies, such as use of concrete terms for angles, and encouraging subjects to generate familiar names for abstract figures were designed to reduce memory load, and thus facilitate speed of mental rotation.

Reasoning training program. For each item of the 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, 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. These multiple procedures were employed in order to optimize training effects, rather than to assess their differential effectiveness. Three strategies for identifying the patterns were emphasized: visual scanning of the series, saying the series aloud in order to hear the letter pattern, and underlining repeated letters occurring 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.

Measures and scoring procedures

The findings to be reported are based on data for the PMA Spatial Orientation and Reasoning tests (Thurstone & Thurstone, 1949), since these are the ability measures for which both longitudinal and training data are available.

Measures. The PMA Spatial Orientation test (Thurstone, 1948) is a multiple response measure of two-dimensional mental rotation ability. In each of the 20 test items, the subject is shown a model line drawing and is asked to identify in which of the 6 answer choices the model is shown in a different spatial orientation (45,90,135,180 degree rotation). Two or three

answer choices in each test item are rotated drawings of the model (same image); the remaining three or four choices are mirror images of the model. Traditionally, the test score has been the number of rights minus the number of wrongs.

The PMA Reasoning test (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. Traditionally, the test score has been the number of rights.

Accuracy and speed change scores. The traditional scoring procedures for the space and reasoning tests provide little information on the nature of behavioral differences or change, given that the score is based on the raw number of items attempted and does not reflect relative changes in accuracy as the number of items attempted varies across occasions. For example, as the number of items attempted decreases as a function of age-related decline, accuracy (i.e., proportion of attempted items answered correctly) may or may not decline. Space and reasoning item responses were componentialized in order to permit computation of accuracy and speed change scores for 1970-84 and for pre-posttest intervals.

1. *Space accuracy and speed change scores.* On the space test, a subject's responses (Maximum = 120) were componentialized into four subscores (Rights, Wrongs, Omits, Mirror). The rights subscore is the sum of the correctly marked same image figures; maximum score = 54. The mirror subscore was the sum of the mirror-image figures that were not

marked, within the total number of items attempted. The wrongs subscore was the sum of the mirror images that were incorrectly marked as being the same image as the model. The omits subscore was the sum of the same image figures that were not marked (omitted) within the total number of items attempted. The total number of correct responses equals the sum of the rights and mirror subscores. The total number of incorrect responses equals the sum of the wrongs and omits subscores. The attempts scores is the sum of the right, wrong, omit, and mirror subscores.

To assess change in accuracy across occasions, an accuracy score was computed as the proportion of the attempted answer choices that were marked correctly (e.g., 1970 rights subscore + 1970 mirror subscore/1970 attempts score). An expected score for the second occasion (1983 pre or 1984 post) was computed, assuming that level of accuracy remained constant across the two occasions. For example, the 1984 expected score was computed as the proportion of 1970 correct responses (1970 rights + 1970 mirrors) multiplied by the 1984 attempts score. The change in accuracy between 1970 and 1984 was computed as the observed 1984 correct responses (e.g., 1984 rights + 1984 mirrors) minus the 1984 expected score). A speed of problem solving change score was then obtained by subtracting the 1984 accuracy change score from the observed change score. The observed change score was computed as the change in the total number of correct responses (e.g., the sum of the 1970 rights + mirror subscores minus the sum of the 1984 right + mirror subscores).

Accuracy and speed change scores were computed for the 1970-84 interval and for the pretest-posttest interval.

2. *Reasoning accuracy and speed change scores*. A subject's responses (Maximum = 20) can be componentialized into three subscores (Rights, Wrongs, Omits). The rights subscore is the number of items answered correctly. The wrongs subscore is the number of items answered incorrectly. The omits are the number of items not answered, but followed by at least one correctly or incorrectly answered item. The attempts score is the sum of the rights, wrongs, omits subscores.

To assess change in accuracy across occasions, an accuracy score was computed as the proportion of the attempted answer choices that were marked correctly (e.g., 1970 rights subscore/1970 attempts score). An expected score for the second occasion was computed, assuming that level of accuracy remained constant across the two occasions. For example, the 1984 expected score was computed as the proportion of 1970 correct responses (1970 rights) multiplied by the 1984 attempts score. The change in accuracy between 1970 and 1984 was computed as the observed 1984 correct responses (e.g., 1984 rights) minus the 1984 expected score). A speed of problem solving change score was then obtained by subtracting the 1984 accuracy change score from the observed change score. The observed change score was computed as the change in the total number of correct responses (e.g., the 1970 right minus the 1984 right subscores). Accuracy and speed change scores were computed for the 1970-84 interval and for the pretest-posttest interval.

Results

Age/cohort differences in level of performance across occasions

Figure 2 presents the mean PMA Reasoning scores at three occasions (1970, 1984 pretest, 1984 posttest) for subjects in the three age/cohorts trained on reasoning ability. Mean age of each age cohort in 1984 was 80, 72.5 and 65.5 years, respectively. Mean performance of stable subjects appears in the top part of the figure; mean performance of decline subjects in the lower part of the figure. Similarly, Figure 3 presents the mean PMA Space scores for subjects in the three age/cohorts trained on spatial ability.

Significant training effects were found for both space and reasoning training groups and for stable and decline subjects within each training program. Note that following training, stable subjects within each age/cohort were performing at a level above their 1970 level. In contrast, for decline subjects, training resulted in a partial or complete remediation of performance back to the 1970 mean level. Remediation of decline was not complete for the oldest cohort, in that the mean posttest score was below the mean 1970 score. In contrast for the middle and youngest age/cohorts, there was no significant difference between 1970 and 1984 posttest mean scores.

Age/cohort differences in accuracy and speed change scores across occasions

Reasoning training. Figure 4 shows accuracy and speed change scores for stable and decline subjects for the three age/cohorts (Figure 4a - Oldest, Figure 4b - Middle, Figure 4c - Youngest). The left-hand side of each figure presents change for the 1970-1984 interval, and the right-hand of each figure presents change for the pretest-posttest interval.

Several findings are of interest: 1) For each of the three age/cohorts, age-related decline (1970-84) involves declines in both speed and accuracy of performance; 2) While magnitude of training gain is greater for decline subjects in the Middle and Youngest cohorts, there is no significant difference in training gains for stable and decline subjects in the Oldest cohort; 3) Training gain for the Oldest cohort is almost totally due to an increase in accuracy, while training gain for the Middle and Youngest cohorts reflects increase in both accuracy and speed. The proportion of total gain attributed to accuracy is somewhat greater for stable subjects.

Space training. Figure 5 shows accuracy and speed change scores for stable and decline subjects for the three age/cohorts (Figure 5a - Oldest, Figure 5b - Middle, Figure 5c - Youngest). The left-hand side of each figure presents change for the 1970-1984 interval, and the right-hand of each figure presents change for the pretest-posttest interval.

Several findings are of interest: 1) For each of the three age/cohorts, age-related decline (1970-84) involves declines in both speed and accuracy of performance; 2) Training gain for stable subjects is largely due to an increase in speed of problem solving; this is true for all three age/cohorts; 3) While training improvement for decliners in the Middle and Youngest cohorts is due to increase in both accuracy and speed of responding, training gain for the Oldest cohort is totally attributed to increase in accuracy.

Discussion

In this paper we examined the nature of behavioral change associated with age-related decline and training improvement for older adults from three age/cohorts. In addition, the nature of behavioral change was examined for individuals within each age/cohort who had exhibited two different longitudinal trajectories with regard to the ability on which they were trained - subjects who had not shown prior decline on the ability versus subjects who had declined over the prior 14-year interval.

In an attempt to consider age-related decline and training data within the context of two somewhat competing approaches to the explanation of age deficits, changes in accuracy versus speed of problem solving were examined. One approach argues that slowing is one, if not the most important change occurring with age (Salthouse, 1985). Some researchers focus on a general slowing mechanisms in the central nervous system, while others are exploring a multidimensional approach to behavioral slowing. In contrast, other researchers have focused on utilization of cognitive strategies as a central issue in cognitive aging (Craik & Trehub, 1982; Denney, 1980). A number of studies have shown older adults to be less likely to utilize spontaneously strategies shown to facilitate cognitive problem solving. As a result of limited strategy utilization, the cognitive performance of older people is often less accurate and less efficient. However, training research, including this study, indicates that older adults can be induced to use these strategies.

Of particular interest in this symposium are the findings with regard to the Oldest cohort, subjects who were mean age 80 years at the time of training (Figures 4a and 5a). First, note that the magnitude of training gain for Oldest cohort stable subjects in both reasoning and space training was roughly equal to the magnitude of training gain for stable subjects in the Middle and Youngest cohorts. However, decliners in the Oldest cohort exhibited less training gain than decliners in the other cohorts. Second, training gain for decliners in both space and reasoning was due almost totally to an increase in accuracy. In advanced old age, irreversible behavioral slowing may be increasingly associated with chronic disease, related drug treatments, and neurological impairment. Cognitive strategies that maintain or enhance accuracy of performance may then become increasingly salient in intellectual functioning of the very old. At the same time it should be noted that training gain is largely due to an increase in speed of problem solving for the oldest stable subjects trained on space. These subjects were functioning prior to training at a high level of accuracy and thus the only way to improve performance under timed conditions was to increase one's rate of responding. This finding suggests that behavioral slowing is not universal or irreversible for all subjects in very old age. Finally, it should be noted that the nature of behavioral change varies across abilities, even in advanced old age. For inductive reasoning, change in accuracy appears more salient, while speed of problem solving appears more salient in mental rotation.

Table 1

Subject Characteristics by Age/Cohort

	Oldest Cohort				Middle Cohort				Youngest Cohort			
	Stable		Decline		Stable		Decline		Stable		Decline	
	R	S	R	S	R	S	R	S	R	S	R	S
Age	80.8	80.7	81.6	81.9	72.4	72.4	73.0	73.0	66.5	66.4	66.6	66.9
	(4.1)	(3.5)	(4.3)	(4.8)	(1.9)	(1.8)	(1.9)	(1.9)	(1.7)	(1.7)	(1.7)	(1.8)
Education	13.2	13.8	14.7	14.3	13.5	14.4	13.9	13.0	13.7	14.1	14.3	13.6
	(3.7)	(3.6)	(3.2)	(3.4)	(3.0)	(2.9)	(2.9)	(2.9)	(2.4)	(2.3)	(2.8)	(2.9)
Income	9.0	9.3	8.3	7.9	9.2	11.4	12.1	9.6	11.8	11.7	11.1	11.5
	(3.5)	(4.2)	(4.7)	(4.2)	(3.9)	(4.0)	(3.8)	(4.1)	(3.9)	(4.2)	(4.3)	(3.7)
Gender												
Male %	37	42	23	50	47	32	45	36	45	45	46	45
Female %	63	58	77	50	53	68	55	64	55	55	54	55

Figure 1

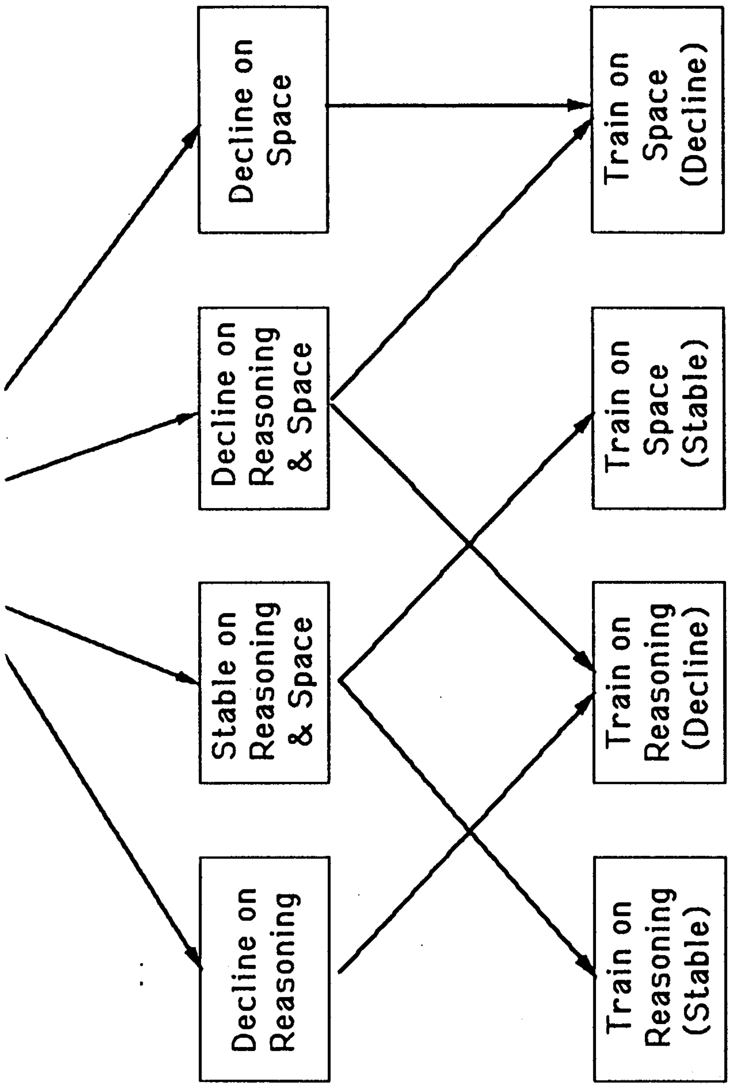
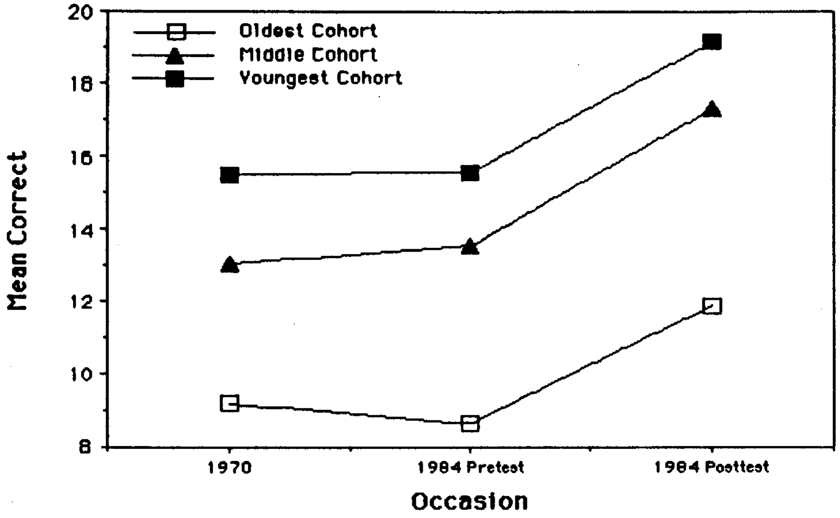
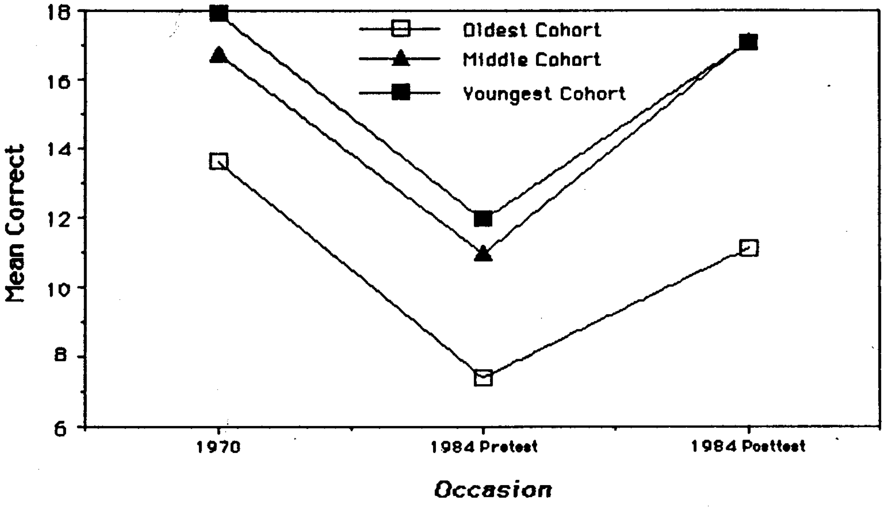


Figure 2



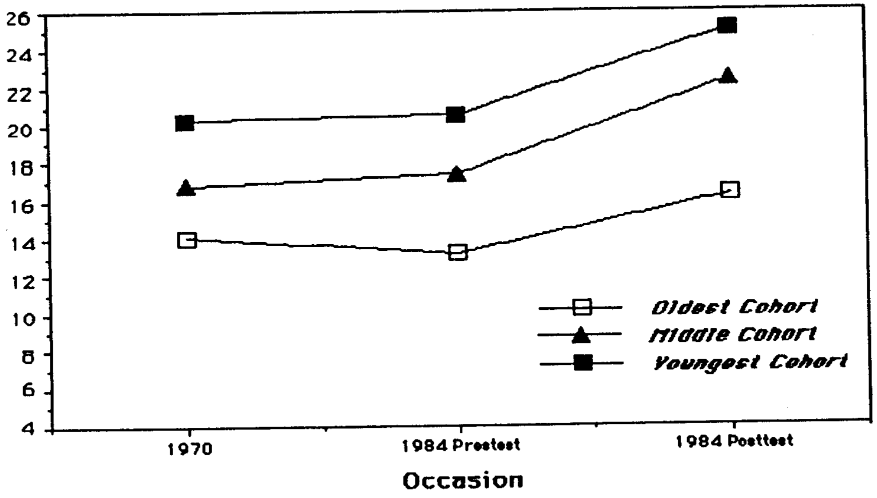
Reasoning Performance for Stable Subjects



Reasoning Performance for Decline Subjects

Figure 3

Space Performance for Stable Subjects



Space Performance for Decline Subjects

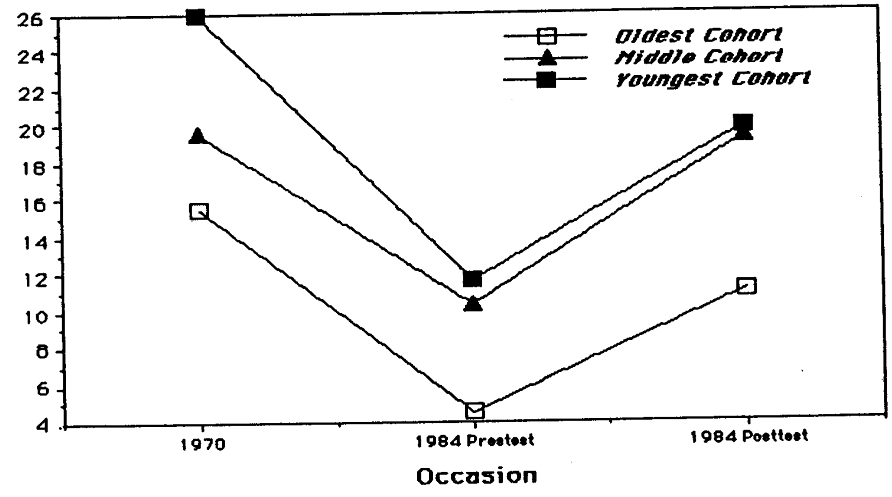
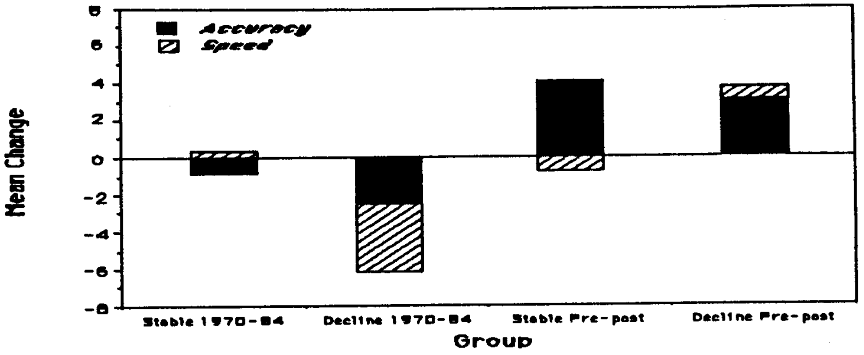
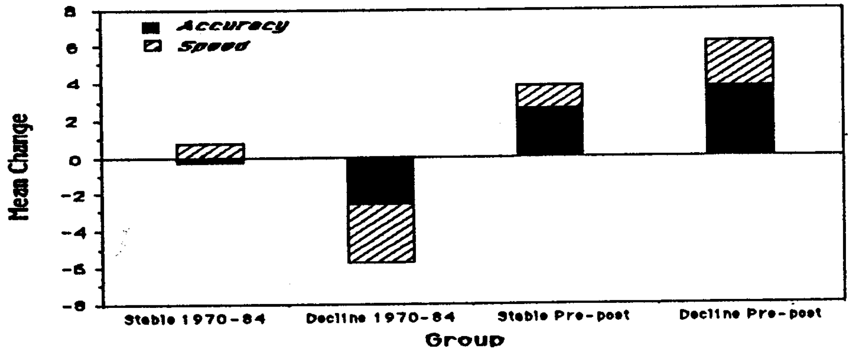


Figure 4

Cohort 1: Change in Reasoning Performance



Cohort 2: Change in Reasoning Performance



Cohort 3: Change in Reasoning Performance

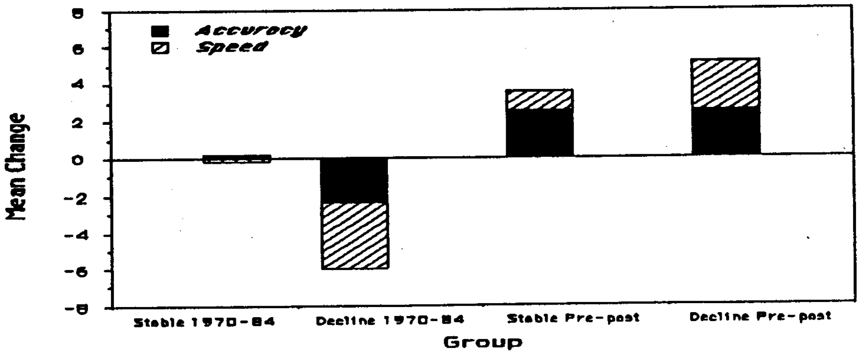
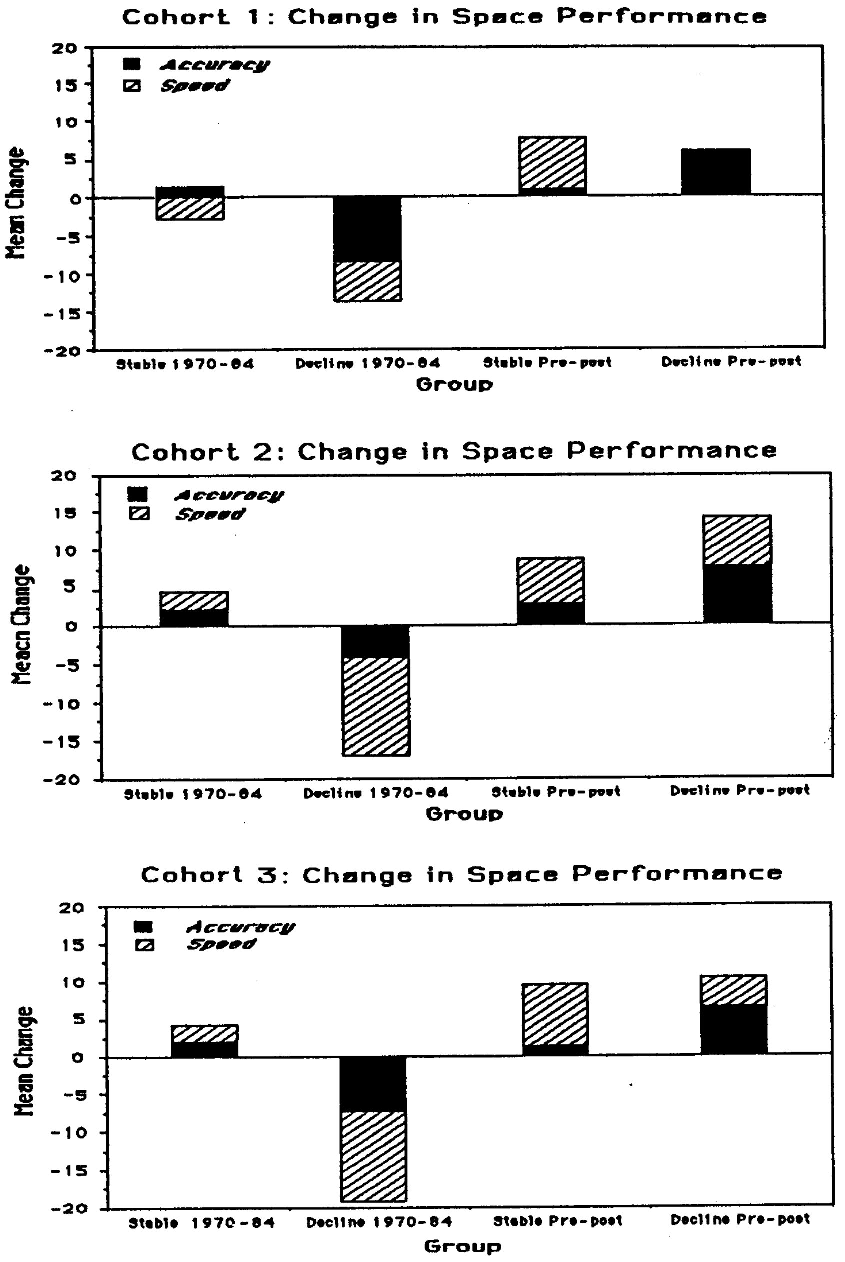


Figure 5


Cohort 1: Change in Space Performance
Accuracy
Speed
Mean Change
20
15
10
5
0
-5
-10
-15
-20
Stable 1970-84
Decline 1970-84
Stable Pre-post
Decline Pre-post
Group
Cohort 2: Change in Space Performance
Accuracy
Speed
Meacn Change
20
15
10
5
0
-5
-10
-15
-20
Stable 1970-84
Decline 1970-84
Stable Pre-post
Decline Pre-post
Group
Cohort 3: Change in Space Performance
Accuracy
Speed
Mean Change
20
15
10
5
0
-5
-10
-15
-20
Stable 1970-84
Decline 1970-84
Stable Pre-post
Decline Pre-post
Group