Maintenance of Cognitive Training Effects in the Seattle Longitudinal Study

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Cognitive training effects through behavioral intervention have been well-demonstrated in a number of mental abilities including inductive reasoning (Blieszner, Willis, & Baltes, 1981) Hayslip, Maloy, & Kohl, 1995; Schaie & Willis, 1986; Willis & Schaie, 1986) spatial orientation (Willis & Schaie,1986; Schaie & Willis, 1986), and memory (Kliegl, Smith, & Baltes, 1989; Rebok,, Rasmussen, & Brandt, 1997). Although immediate training effects have received much attention, little work has been done to determine the long-term effects of behavioral intervention on cognitive performance. The present study examines seven-year maintenance of Inductive Reasoning and Spatial Orientation training gains in the Seattle Longitudinal Study.

Maintenance of training effects

The few studies examining maintenance of training effects employ shorter time lapses between post-testing and follow-up testing than the present study. Blieszner, Willis, and Baltes (1981) assessed the maintenance of inductive reasoning training one week, one month, and three months following training. Results showed that training participants performed significantly better than control subjects at one week and one month follow-ups but that training and control participants were not performing at significantly different levels at the three month follow-up. In contrast, Willis and Nesselroade (1990) found that reasoning training participants performed at a significantly higher level on reasoning measures than control subjects five years after the second phase (booster) of training. Because of contrasting results and the scarcity of maintenance studies it is clear more work is necessary in this area.

Cognitive strategy use and training gains

A popular interpretation of the poor performance of older adults on complex cognitive tasks has been that many elderly are ineffective in the use of relevant strategies. A strategy has been defined as one of several alternative methods for performing a particular cognitive task. Salthouse (1991) has identified several assumptions regarding strategies as they are studied in cognitive aging: 1) Strategies are specific to particular tasks. 2) Variations in use of strategies have consequences for level of performance on a specific cognitive task. 3) Evidence used to infer the use of strategy must be distinct from that used to indicate the level of performance on the cognitive task.

Research within the Seattle Longitudinal Training Study has identified cognitive strategy use, resulting from Inductive Reasoning behavioral intervention, as a mechanism of training gain (Saczynski, Willis, & Schaie, in press). Participants trained on reasoning showed significantly more strategy use gain from pre to post-test than did the control participants who were trained on spatial orientation. Additionally, higher strategy use by inductive reasoning trainees was also associated with greater training gain on reasoning outcomes. Although cognitive strategy use has been investigated for it's association with initial training gains, there is little work on it's relation to the maintenance of training gains.

Activity level and training gains

It has long been debated whether the intellectual stimulation experienced in regular everyday activities is adequate to maintain cognitive functioning or to increase cognitive performance (Arbuckle, Gold, Andres, Schwartzman, & Chaikelson, 1992; Hultsch, Hertzog, Dixon, & Small, 1999). Findings on the role of context on cognitive ability are mixed. Hultsch and colleagues (1999) found that although the relationship between activity and cognition increased with age cross-sectionally, longitudinally there was not a strong relationship between change in activity levels and change in cognitive functioning. In contrast, Arbuckle et al. (1992) found that health, intellectual, and educational activities were positively related to maintenance of intellectual performance.

Saczynski, Willis, and Schaie (2000) examined change in activity levels and the maintenance of cognitive training gains within a subset of the Seattle Longitudinal Training Study participants. Results showed that increases in solitary activity following training were associated with the maintenance of Spatial Orientation training gains. Because previous results did not yield predictive power of specific activity factors, the present study aims to predict maintenance of training gains with sum hors of activity as reported by participants.

Long-term goals of most training efforts often include maintained, or improved, ability performance and prolonged independent living through maintained independence in activities of daily living. With these goals in mind it is clear that the long-term effects of training must be examined years after initial training rather than simply months.

The present study examines long-term maintenance of Inductive Reasoning and Spatial Orientation training gains in the Seattle Longitudinal Study (SLS). Two main research questions will be addressed: 1.) What individual demographic and lifestyle variables at initial training predict seven-year maintenance of training gains? And 2.) Is cognitive strategy use on reasoning measures immediately after training associated with the seven year maintenance of reasoning training gains?

Method

Participants

Participants who were initially trained in 1984 and 1991 and who were available for follow-up 7-years later (1991 or 1998) consisted of 210 older adults with a mean age of 70.2 years at time of training (range = 64-85; SD = 4.79). Mean education level of the maintenance sample was 14.3 (range = 7-20; SD = 2.76) and mean income level was $21,218 (range = $1,000 - $$50,000; SD = $8,587)

Attrition Analysis

An attrition analysis was performed to determine if the maintenance sample ($\underline{N}$ = 210) differed significantly from the original sample of training participants ($\underline{N}$ = 408) on a number of demographic variables including age, education, and income. Results showed that the maintenance sample differed significantly from the original sample on age at initial training. Participants who were available for follow-up testing 7-years later were significantly younger at

the time of initial training than the original sample. There were no significant education or income differences between the original and maintenance samples.

Replicate differences: Maintenance subjects first trained in 1984 were compared to those first trained in 1991 on age, education, and income to determine if there were significant differences between the replicates. Results showed that there were significant education differences with the 1991 participants reporting significantly higher levels of education than the 1984 participants. There were no age or income differences between the two replicates.

Design and Procedure

Classification of participants: Participants were classified into those who had declined and those who had remained stable on the Thurstone (1948) Primary mental Ability (PMA) Inductive Reasoning and Spatial orientation measures over the 14-year period prior to training (1970-1984 for the 1984 sample; 1977-1991 for the 1991 sample; and 1984-1998 for the 1998 sample). The statistical criterion for "decline" was one standard error of measurement (SEM) or below their 1970 or 1977 score.

Assignment of participants: Participants were assigned to training on either Inductive Reasoning or Spatial Orientation. Participants who were identified as having declined on a single target ability were assigned to a training program in that ability while those who were identified as having remained stable or declining on both abilities were randomly assigned to one of the training programs.

Procedure: A pretest-posttest control group design will be used with participants trained on one ability serving as control for those trained on the other ability. The training involved five one-hour training sessions usually conducted in the participant's home. Immediately following training participants were administered a post-test battery of measurements involving the same measures as at pre-test.

Training Programs

Inductive Reasoning: Participants were taught to identify four major pattern description rules (repeats of a letter pattern (aabccdeef...); skips in a letter/number pattern (acegi...); the next number/letter in order in the pattern (abcde...); and backwards letter/number sequences (zyxwv...); see Schaie and Willis (1986) and Willis (1990) for further description of training procedures. These pattern descriptions have been studied extensively in prior research on inductive reasoning (Kotovsky & Simon, 1975; Holzman, Pelligrino, & Glaser, 1982). The participants learned through modeling, feedback and practice procedures to identify the pattern and solve letter series problems involving the pattern. In addition, practice problems were employed involving similar rules, but with different content, such as musical notes and travel schedules. No practice items were identical to the problems on the criterion measures.

Participants were taught and encouraged to use strategies for identifying the pattern; these strategies were shown in previous research to be useful (Pelligrino et al., 1972). Four primary strategies were taught 1) Saying aloud the series, 2) Underlining repetitions in the pattern (aabccdeef...), 3) Making slash marks to separate repetitions in the pattern (aab/ccd/eef/...), and 4) Making tick marks to indicate skips in a pattern (a'c'e'g...). The use of these strategies (underlining, slashes, and tick marks) required participants marking on training or test materials and was used in assessing strategy usage.

Spatial Orientation: Spatial orientation involves speed and accuracy in mentally rotating abstract objects in two dimensional space. The participant's task was to identify which

of six drawings could be rotated to look like the target drawing. The six drawings are at 45, 90, 135, 180, 225, 270 and 315 degree angles. Some drawings were mirror images of the target drawing.

Participants were taught strategies for solving spatial problems, that had been identified in prior research (Cooper & Shepard, 1973). These strategies included developing concrete terms for abstract figures, physically rotating objects before mentally attempting rotation, mentally naming the abstract objects which need to be rotated so they were more familiar to the participant and focusing on two or more features of the object while rotating it. None of these strategies involved marking on training or test materials.

The strategies taught in induction and spatial training were specific to the ability being trained; and were very different for each training group. Following training, participants were administered a post-test with the same measures as the pretest.

Strategy Usage Coding Procedure

Participants' pre and posttest materials for the ADEPT Letter Series and Word Series tests were coded for strategy use. Only markings associated with the strategies taught during the inductive reasoning training were scored for strategy use. Three strategies were coded: 1) slashes between repeats in patterns; 2) tick marks between skipped letters or words; and 3) underlining of repeated letters/words in a series. A minimum of two "strategy marks" was required in order for an item to be scored as exhibiting strategy use. In order to identify strategy use on the measures of inductive reasoning, trained coders followed strict guidelines for the coding procedure. Coders were blinded as to the training group of the participant. Inter-rater reliability was assessed among the two coders and was found to be .87.

Each item was coded "0" or "1" for whether or not strategy use was indicated. Total strategy use scores were calculated separately for the ADEPT Letter Series and Word Series measures by summing the number of individual items on which strategy use was indicated. Change scores representing post-test minus pre-test changes in strategy use were computed for each participant on both the ADEPT Letter Series and Word Series measures and used in regression analyses. Confirmatory factor analyses were conducted on pre and posttest cognitive batteries to determine stability of the factor pattern across occasions (Schaie & Willis, 1986; Willis & Schaie, 1986; Schaie, Willis, Hertzog, & Schulenberg, 1987). Factor scores were computed.

Measures

Inductive Reasoning: Reasoning ability involves identifying a pattern or rule required to solve a serial problem and using that pattern to solve subsequent incidents of the problem. Four measures assessed the effectiveness of the training on inductive reasoning: The ADEPT Letter Series test, the Word Series test, Primary Mental Abilities (PMA) Reasoning, and the Number Series test. The ADEPT Letter Series and the Word Series measures were used in coding of strategy use at pre- and posttest.

ADEPT Letter Series (Blieszner, Willis, & Baltes, 1981). The Adult Development and Enrichment Project (ADEPT) Letter Series test assesses inductive reasoning ability via letter series problems. The participant is shown a series of letters and must select the next letter in the pattern from five answer choices. The score range is 0-20 with each item scored correct (1) or incorrect (0). This test is similar to the Primary Mental Abilities (PMA) Reasoning measure (Thurstone, 1948) but uses additional pattern-description rules.

Word Series (Schaie, 1985). The Word series measure parallels the PMA Reasoning measure (Thurstone, 1948), as it used the same pattern-description rules, but uses words such as days of the week or months of the year as stimuli rather than letters. In addition, test stimuli are presented as a column, whereas PMA Reasoning stimuli are presented in a row. The score range is 0-30 with one point for each item answered correctly.

Primary Mental Abilities (PMA): Inductive Reasoning (Thurstone, 1948). Reasoning ability is measured by presenting the participant with a series of letters in a pattern. The participant must detect the pattern and identify the next letter in the series according to the pattern. Although this measure would be the most direct measure of training gain, it could not be coded for strategy use because participants' answers were recorded on an answer sheet which was separate from the test stimuli and strategy use could not be coded based on the answer sheet; this test format has been used since the inception of the SLS in 1956. In contrast the ADEPT Letter Series and Word Series tests involved participants circling the correct answer choice directly on the test form and strategy use could be assessed. The test contains 30 items and the participant is given six minutes of time to work.

Number Series (Ekstrom, French, Harman, & Derman, 1976). The Number Series test involves series of numbers rather than letters or words. The pattern description rules used on the Number Series test are different from those in the other reasoning measures and involve mathematical computations. Number Series problems were not included in the training. Since the type of strategy markings were different, strategy use was not coded for Number Series. This test contains 15 items and has a 4.5 minute time limit.

Spatial Orientation: Spatial Orientation ability involves mentally rotating objects and was assessed by four measures: PMA Space, Object Rotation, Alphanumeric Rotation, and Cube Comparisons.

Primary Mental Abilities: Spatial Orientation (Thurstone, 1948). The PMA Space measure involves both speed and accuracy in choosing which of six answer choices can be rotated to match a target object. The test contains 20 items and had a five-minute time limit.

Object Rotation (Schaie, 1985). The Object Rotation test consists of angles of rotation which are identical to those used in the PMA Space test. The participant is shown a model object and is asked to identify which of six answer choices shows the model object drawn in different spatial orientations. There are two or three correct responses for each item. This test contains 20 problems and has a five minute time limit.

Alphanumeric Rotation (Schaie, 1985). The Alphanumeric Rotation test contains numbers and letters and identical angles of rotation to those used on the PMA Space test. The participant is shown a model stimuli and is asked to choose which of six answer choices can be rotated to look like the target letter or number. This test contains 20 items and has a five minute time limit.

Cube Comparisons (Elkstrom et al., 1976). The Cube Comparisons test requires participants to mentally rotate objects in three-dimensional space. The participant is presented looks at two cubes and has to identify if they are the same or different by mentally rotating the blocks. This test contains 21 items and has a three minute time limit.

Demographic and Activity Variables: The Life Complexity Inventory (LCI) (Gribben, Schaie, & Parham, 1980) was used to collect demographic information including age, education, income, and gender. This measure also examines a broad range of adult activities and interests. Participants report hours per week spent engaging in each of 34 leisure activities. Activities such as exercise, cultural activities, social activities, religion, educational activities, and household chores are represented. Total hours of activity, summed across all activities, was used in the present study.

Results

The results address two main questions: 1. What individual demographic and lifestyle variables at initial training predict seven-year maintenance of Inductive Reasoning and Spatial Orientation training gains? 2) Is cognitive strategy use on reasoning measures immediately after training associated with the seven-year maintenance of Inductive Reasoning training gains? Maintenance of training gains were examined stringently from Post-test 1 (immediately following training) – Pre-test 2 (seven-years later). Hierarchical regression was used to examine the relationship between a number of individual characteristics and the 7-year maintenance of Spatial Orientation and Inductive Reasoning training gains.

Seven-year maintenance of level of performance

Inductive Reasoning: Hierarchical regression analyses were used to investigate the relationship between a number of independent variables, including training group, strategy use, hours of leisure activity, age, education, and gender, and the seven year maintenance in level of performance on Inductive Reasoning at the latent factor level. For inductive reasoning, performance at post-test 1 was entered into the first step of the model to control for previous level of performance. Training group and pre to post-test increase (following initial training) in strategy use following on the Letter Series and Word Series reasoning measures at initial training were entered into the model in the second step. In the third step of the model, participants' stability status in the 14-years prior to training and total hours of activity per week spent engaging in leisure activities were entered followed by demographic variables including age, education and gender in the fourth and final step of the reasoning model.

Table 1 shows hierarchical regression results for the maintenance of reasoning performance. Results showed that performance on reasoning at the factor level seven years earlier was a significant predictor of maintenance of performance, resulting in an R^2 of .793. Expectedly, higher reasoning performance at Post-test 1 was associated with greater maintenance of level of performance over the 7-year period.

Training group and strategy use on the Letter Series and Word Series measures were entered into the model in the second step resulting in a significant change in the R^2 of the model (F (4,199) = 3.50, p<.01). Training group was found to be a significant predictor of maintenance of level of reasoning performance over the seven-year maintenance period. Although the rate of decline (Pt1-Pre2) was steeper for the training group, their scores did not differ significantly from their pre-test scores seven-years (Pre1) earlier. In contrast, control participants (trained on space) fell significantly below their pre-test scores seven years earlier (See Figure 1). Strategy use on reasoning measures was not found to be a significant predictor of maintenance of performance.

Participants' stability status in the 14-years prior to training and total hours per week spend engaging in leisure activities were entered in the third step of the model, resulting in a non-significant change in the R^2 of the model (F (6, 197) = .002). In the fourth and final step of the model demographic variables including age, education, and gender were entered resulting in a significant change in the R^2 of the model (F (6, 191) = .015, p< .001). Age and education were both significant predictors of maintenance of performance in the 7-year period following training. Examination of the parameter estimates associated with the age and education variables suggests that younger participants and participants reporting higher education showed greater maintenance of reasoning performance (Table 1). Results did not differ by gender.

Spatial Orientation: Table 2 shows hierarchical regression results for maintenance of spatial orientation performance in the seven years following training. Space performance at post-test 1 was entered into the first step of the model and resulted in an R^2 of .744. Training group, stability status in the 14-year period prior to training, and total hours of leisure activity per week were entered in the second step of the model resulting in a non-significant change in the R^2 of the model (F (4, 199) = 1.56). Training group, stability status and hours of activity were not found to be significant predictors of maintenance of spatial orientation performance. In the third and final step of the model demographic variables including age, education and gender were entered resulting in a significant change in the R^2 of the model (F (7, 193) = 3.61, p < .001). Age was significantly related to maintenance of space performance. Examination of the parameter estimate associated with age indicates that younger participants show greater maintenance in level of spatial ability in the seven years following training. Results did not differ by education status or gender.

Discussion

The present study examined the association between individual demographic and lifestyle variables and the time of initial training and seven-year maintenance of cognitive Inductive Reasoning and Spatial Orientation training gains within the Seattle Longitudinal Training Study. Results showed that for both Inductive Reasoning and Spatial Orientation, higher scores at Post-test 1 (seven-years earlier) and younger age at time of initial training were significantly related to maintenance of training gains. For reasoning, higher education and training group membership were also associated with maintenance of training gains.

Although training on the target ability was not significantly related to maintenance of Inductive Reasoning or Spatial Orientation training gains, reasoning trained participants were still functioning at their Pre-test levels seven years earlier while control participants had fallen below their Pre1 scores. Results for non-significant maintenance by training group are in contrast to findings by Willis and Nesselroade (1990) who found trained participants to perform at significantly higher levels than control participants five years after the second phase of training. However, the present study investigates maintenance of only initial training gains in contrast to Willis and Nesselrodae who report maintenance of combined initial and booster training gains. The present results in combination with the results by Willis and Nesselroade suggest that booster training may be an important component in the maintenance of training

gains. In addition, the investigation of variables moderating the relationship between training and long-term maintenance of performance may reveal that long-term maintenance of training gains is highly related to variables such as overall health or incidence of specific chronic conditions.

Surprisingly, cognitive strategy use gain from Pre1 to Post-test1 (following initial training) was not significantly related to maintenance of reasoning training gains. Although strategy use has been found to be associated with initial training gains (Saczynski, Willis, & Schaie, 2000a) strategy use seven-years earlier did not predict maintenance of training gains. It is possible that the maintenance of strategy use (Pt1-Pre2) may show more association with maintenance of reasoning training gains. Because strategy use has been identified as a mechanism of training gain, it is likely that participants who maintain strategy use will also maintain training gains to a greater degree than those who do not show maintenance of strategy use.

There also may be variables mediating the relationship between strategy use and maintenance of training gain, such as health and personality. Future investigations will focus on examination of such relationships. Additionally, further investigation of strategies at the item level may help to identify individual strategies which are efficacious for maintenance of training effects.

Sum of hours of activity at time of training was also not identified as a significant predictor of maintenance of training in the present study. Because activity level in the present study was examined at the time of training it represents the participant's level of activity seven-years prior to the time of testing under investigation. Although this study aims to identify variables at the time of training associated with long-term maintenance of training effects, for activity level it may be more useful to look at change in sum of hours of activity, or maintenance of overall activity levels, in the seven-years following training to predict maintenance of training gains. Because activity level is the one variable under investigation in the present study which participants could change in the interval between Post-test 1 and Pre-test 2, changes in activity levels in the seven-year period between training and follow-up testing may be more useful in predicting maintenance of training gains. Examination of individual activities, rather than sum of hours of activities or activity factors, may also yield more predictive power over the maintenance of training gains in addition to identifying specific activities highly associated with maintenance of cognitive functioning.

Limitations

There are a number of limitations to the present study. Although education was not found to be related to maintenance of spatial orientation training gains, the sample was highly educated therefore not generalizable to all older adults. In addition, all of the subjects were in good health at the time of initial training and the sample had a high income level. Although this sample may not be representative of all older adults, it is comparable to that of most cognitive training efforts.

Figure 1.

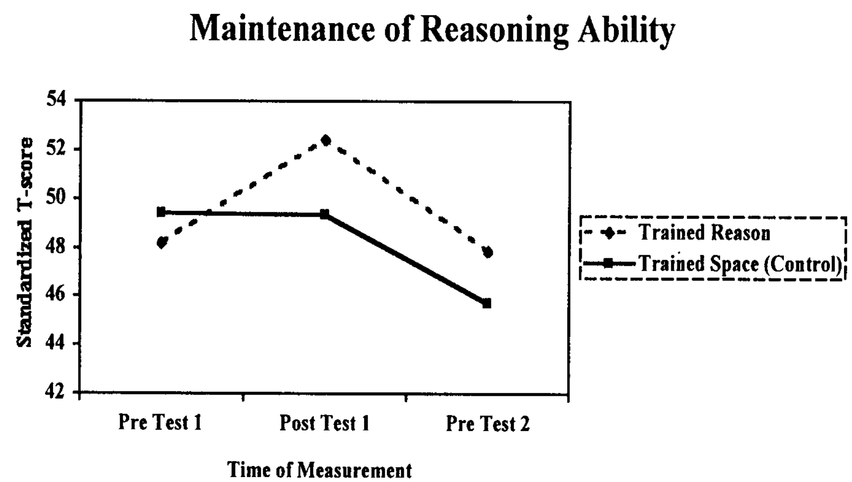

Table 1. Hierarchical regression results for variables predicting 7-year maintenance of reasoning performance at the latent factor level (N = 206)

Predictor	Step 1			Step 2			Step 3			Step 4		
	B	SE B	β	B	SE B	β	B	SE B	β	B	SE B	β
Reasoning Performance												
Pt1	11.01	0.04	0.89***	1.02	0.04	0.90***	1.01	0.04	0.89***	0.95	0.0	40.83***
Training Group				1.92	0.65	0.11**	2.01	0.65	0.12**	1.51	0.66	0.09*
Strategy Use –Letter Series (Pt1)				0.02	0.10	0.01	0.03	0.10	0.01	-0.02	0.10	-0.01
Strategy Use – Word Series (Pt1)				0.04	0.08	0.02	0.04	0.08	0.02	0.03	0.08	0.02
Stability Status (Pr1 – Pt1)							-0.47	0.55	-0.03	-0.28	0.54	-0.02
Sum Hours of Activity (Pt1)							0.02	0.01	0.04	0.12	0.13	0.04
Age										-0.22	0.06-	
0.12**												
Education										0.26	0.11	0.08*
Gender										0.01	0.60	0.01
R^2		0.793			0.803			0.805			0.820	
ΔR^2					0.010**			0.002			0.015***	
(df)		(1, 205)			(4, 199)			(6, 197)			(6,191)	

Note. Coding for Training Group variable: 1=Trained Space, 2=Trained Reason; Coding for Stability Status variable: 1=Stable; 2=Decline; Coding for Gender variable: 1=male; 2=Female; * $p < .05$; ** $p < .01$; *** $p < .001$

Table 2. Hierarchical regression results for variables predicting 7-year maintenance of spatial orientation performance at the latent factor level (N = 203)

Predictor	Step 1			Step 2			Step 3		
	B	SE B	β	B	SE B	β	B	SE B	β
Space Performance Pt1	1.00	0.04	0.86***	0.99	0.04	0.86***	0.95	0.05	0.82***
Training Group				-0.68	0.58	-0.04	-0.78	0.57	-0.05
Stability Status (Pr1)				-0.44	0.58	-0.03	-0.19	0.58	-0.01
Sum Hours of Activity (Pt1)				0.02	0.13	0.05	0.02	0.01	0.06
Age							-0.17	0.07	-0.10*
Education							0.08	0.11	0.03
Gender							-0.07	0.66	-0.01
R^2	0.744			0.750			0.762		
ΔR^2				0.006			0.013***		
(df)	(1,202)			(4,199)			(7,193)		

Note. Coding for Training Group variable: 1=Trained Space, 2=Trained Reason; Coding for Stability Status variable: 1=Stable; 2=Decline; Coding for Gender variable: 1=male; 2=Female; * $p < .05$. ** $p < .01$. *** $p < .001$.

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