Aging Neuropsychology and Cognition
2002, Vol. 9, No. 1, pp. 48–60

1382-5585/02/0901-048$16.00

Strategy Use in Reasoning Training With Older Adults

Jane S. Saczynski, Sherry L. Willis, and K. Warner Schaie
Department of Mental Hygiene, John Hopkins University, Baltimore, MD, USA

ABSTRACT

The relationship between strategy use and cognitive training gains on reasoning ability is examined in a sample of 393 older participants in the Seattle Longitudinal Training Study. Pre- and posttest gains on the use of strategies specific to reasoning ability were compared for the elderly trained on reasoning versus spatial orientation ability. The present study involves an objective behavioral method of measuring strategy use on tests of inductive reasoning. Results showed that participants trained on reasoning significantly increased strategy use from pre- to posttest on two reasoning outcome measures compared to participants trained on spatial orientation. Higher strategy use by inductive reasoning trainees was also associated with greater training gain on reasoning outcome measures, suggesting strategy use as a possible mechanism of training gain. In addition, young–old participants and those with higher education, irrespective of training condition, exhibited greater pre- to posttest gain in strategy use.

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. Previous research on expertise (Charness, 1981) and studies with younger age groups (Craik, 1977; Kausler, 1994) have identified a number of strategies that were related to higher performance on target cognitive tasks.

A strategy has been defined as one of the 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 the 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.

There has been considerable debate whether the poor cognitive performance of the elderly is due to a production deficit or processing deficit with regard to strategies. The production deficiency position holds that older adults are capable of using strategies, but frequently or spontaneously do not use effective strategies (Kausler, 1994). The processing deficiency position holds that some optimal strategies may be very demanding for older adults and hence older adults may be ineffective in using such strategies (Charness, 1985; Guttentag, 1985).

Debate and research on strategy use has focused primarily on memory processes. Studies have shown older adults, given simple instructions to use a specific strategy, improved their subsequent performance on a memory task compared to other older adult groups not informed on the use of a particular strategy (Hertzog, McGuire, & Lineweaver, 1998; Mason & Smith, 1977; Treat & Reese, 1976).

A major problem in the study of strategy use has been the type of evidence used to infer that older adults have indeed been using a particular strategy. Researchers have had difficulty

Address correspondence to: Jane S. Saczynski, Department of Mental Hygiene, Johns Hopkins University, 624 North Broadway, Baltimore, MD 21205, USA. E-mail: jsaczyns@jhsph.edu
Accepted for publication: May 02, 2001.

identifying a measure of strategy use that was truly objective and valid and that was distinct from that used to indicate level of performance on the cognitive task. Three types of procedures have frequently been used to assess strategy use, each having limitations in its validity as evidence of strategy use. First, retrospective self reports conducted after performance of the memory task have been cited as evidence of strategy use (Camp, Markley, & Kramer, 1983; Hertzog et al., 1998; Verhaeghen & Marcoen, 1994). Second, versions of the think aloud technique have been used during the memory task. In a recent study by Dunlosky and Hertzog (1998), older adults were asked to describe the strategy used, item by item, while performing the memory task. Third, measures of time allocated to different components of the cognitive task have been used as indicators of facility of strategy use (Salthouse, Legg, Palmon, & Mitchell, 1990; Salthouse & Prill, 1987; Stine, 1990).

Retrospective self-reports have been the most frequent procedure. Hertzog et al. (1998) measured strategy use by assessing the nature of causal attributions for performance reported by participants after testing. Participants were not directly asked about strategies and, therefore, only reported strategy use if they felt it had influenced their performance on the memory test. Camp and coworkers (1983) examined spontaneous memory strategies by asking participants to describe what they had done to help them remember the words in a list recall exercise. Although no intervention was attempted, strategies reported by the participants were categorized according to levels of processing (Craik, 1977; Craik & Lockhart, 1972). Results showed that although a diverse set of strategies were reported, procedures categorized as using deeper levels of processing were associated with better performance on the recall task (Camp et al., 1983).

Verhaeghen and Marcoen (1994) assessed strategy use in young and older adults using a 16-item questionnaire. On a 5-point Likert scale, participants reported the extent to which each of the 16 strategies were used on tests of ordered list recall. Age differences were found for several factors of strategy use. Associating items in a list and rehearsal were negatively related to age while concentrating was found to be age-independent. Verhaeghen and Marcoen (1994) also found that self-reported strategy use was explained by age differences in cognitive abilities, providing support for the production deficiency hypothesis. Murphy, Schmitt, Caruso, and Sanders (1988) examined the role of monitoring on serial recall. Although participants received no formal training, older adults, who were instructed to use a self-testing strategy, showed significantly more strategy use as well as improved memory performance.

Given the prominence of strategy use interpretations of deficits in cognitive performance, many cognitive intervention studies have focused on training strategies shown in prior research to be effective in performance on the target cognitive task. Strategies trained have included imagery and the method of loci (Baltes & Kliegl, 1992; Kliegl, Smith, & Baltes, 1989; Verhaeghen & Marcoen, 1996; Yesavage, Rose, & Bower, 1983), categorization (Rebok, Rasmusson, & Brandt, 1997), marking of patterns in serial problems (Schaie & Willis, 1986; Willis & Schaie, 1994), and video-administered combined training (West & Crook, 1992). Again, most of the cognitive training research with an emphasis on strategies has focused on various aspects of memory performance.

A critical assumption in many of these cognitive intervention studies is that the training of specific strategies was associated with improved performance on the key ability. Just as in the previous experimental studies on the link between strategies and memory performance, the intervention studies have typically provided little direct evidence of enhanced strategy usage and its relation to training improvement. Although Hertzog et al. (1998) found use of optimal strategies to be positively related to recall performance, their results were based on retrospective self-reported strategy use. Similarly, Verhaeghen and Marcoen (1996) examined the relationship between self-reported correct strategy use following method of loci memory training. Although they found a trend for increasing training benefit for correct strategy use in older adults, results may have been biased by participants' self-report.

The purpose of the present study is to examine strategy use in relation to training studies conducted within the Seattle Longitudinal Study (SLS). Cognitive training research within the SLS has focused on two abilities, inductive reasoning and spatial orientation, shown in prior longitudinal research to exhibit relatively early age-related decline beginning in the mid 1960s (Schaie, 1996). Training on both inductive reasoning and spatial orientation focuses on strategies that are unique to the ability trained (Cooper & Shepard, 1973; Kotovsky & Simon, 1973; Schaie & Willis, 1986). The strategies trained for inductive reasoning involve having the participant make specific marks on training items to identify the patterns in a series. Successful training of these strategies should result in participants trained on inductive reasoning making such marks on inductive reasoning test items at posttest. Since participants trained on spatial orientation received training on strategies unique to spatial tasks, they should not show training effects on strategies specific to inductive reasoning.

The following questions related to strategy use in inductive reasoning training are addressed by the study: (1) Does the increase in strategy use, as indicated by pattern marking on test problems, differ by training group from pre- to posttest? (2) What participant characteristics are associated with strategy use? (3) Is a pre- to posttest increase in strategy use associated with training gain on inductive reasoning outcome measures?

METHOD

Participants

Participants were 393 older adults (male = 177; female = 216) from the Seattle metropolitan area, who had participated in the SLS since 1970 or earlier (Schaie, 1983). All participants were, or had been, members of the Group Health Cooperative of Puget Sound, a health maintenance organization. Mean age of the total sample was 72.9 years (range = 64–95; *SD* = 6.41) at the time of initial training (1984 or 1991). Mean educational level was 14.1 years (range = 7–20; *SD* = 3.05). Mean income level was $21,079 (range = $1,000 – $50,000; *SD* = $8,676).

The sample includes participants who were trained for the first time in 1984 or 1991 on either inductive reasoning or spatial orientation. The 1984 sample consisted of 215 older adults (male = 96; female = 119) with a mean age of 72.7 years (range = 64–95; *SD* = 6.35). The mean educational level of the 1984 sample was 13.90 years (range = 7–20; *SD* = 3.11). The 1991 sample consisted of 178 older adults (male = 83; female = 95) with a mean age of 73.3 years (range = 64–93; *SD* = 6.5). The mean educational level of the 1991 sample was 14.4 years (range = 7–20; *SD* = 3.0). There were no age or educational differences between the 1984 and 1991 samples.

The Inductive Reasoning training group (combined across the 1984 and 1991 samples) consisted of 188 participants with a mean age of 73.0 years (range = 64–93; *SD* = 6.7). The mean education level of the inductive reasoning training group was 14.1 years (range = 7–20; *SD* = 2.9); and the group had a mean income of $20,137. The Spatial Orientation training group consisted of 205 participants with a mean age of 72.9 years (range = 64–95; *SD* = 6.2). The mean education level of the group was 14.1 years (range = 7–20; *SD* = 3.0) and they had a mean income of $21,057. There were no age or educational differences between the reasoning and space training participants. All participants were community dwelling and most were Caucasian. Prior to the entry into the study, each participant's physician was contacted and asked whether the participant suffered any known physical or mental disability that would interfere with participation in the study; participants, thus identified, were not included in the study.

Design and Procedure

Classification of Participants

Participants in both 1984 (*N* = 215, aged 64–95) and 1991 (*N* = 178, aged 64–93) 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-years prior to training. The statistical criterion for 'decline' was one standard error of measurement (SEM) or greater (Reasoning = 4 raw score points; Space = 6 raw score points) below their 1970 score or 1977 score, respectively (Schaie & Willis, 1986).

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. Participants who were identified as stable or decliners on both target abilities were randomly assigned to one of the training programs.

Procedure
A pretest–posttest control group design was used. Participants trained on spatial orientation were employed as controls for participants trained on the inductive reasoning. The training involved five 1-hr training sessions usually conducted in the participant's home by 1 of 3 middle-aged trainers with prior experience of working with older adults. Following training, participants were administered a posttest battery involving the same measures as the pretest.

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 (Holzman, Pelligrino, & Glaser, 1982; Kotovsky & Simon, 1973). 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. Four primary strategies were taught: (1) Saying aloud the series; (2) Underlining repetitions in the pattern (*aa*bc*cd*e*e*f. . .); (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, which 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 were at 45°, 90°, 135°, 180°, 225°, 270° and 315° 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 consisted of developing concrete terms for abstract figures, physically rotating objects before mentally attempting rotation, mentally naming the abstract objects which needed to be rotated so that 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 of being trained and were very different for each training group. Following training, participants were administered a posttest with the same measures as the pretest.

Measures
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 Adult Development and Enrichment Project (ADEPT) Letter Series test, the Word Series test, PMA Reasoning test, and the Number Series test. The ADEPT Letter Series and the Word Series measures were used in the coding of strategy use at pre- and posttest.

ADEPT Letter Series
The ADEPT Letter Series test assesses inductive reasoning ability via letter series problems (Blieszner, Willis, & Baltes, 1981). The participant is shown a series of letters and must select the next letter in the pattern from 5 answer choices. The score range is 0–20 with each item scored correct (1) or incorrect (0); the test time limit is 4.5 min. This test is similar to the PMA Reasoning measure (Thurstone, 1948), but uses additional pattern-description rules.

Word Series
The Word Series test is defined as a near transfer measure of reasoning training (Schaie, 1985). The Word Series measure parallels the PMA Reasoning measure (Thurstone, 1948), as it uses 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; the test time limit is 6 min.

PMA Inductive Reasoning
Reasoning ability is measured by presenting the participant with a series of letters in a pattern (Thurstone, 1948). 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 the participants' answers were recorded on an answer sheet that was separate from the test stimuli. Although some participants did mark on test stimuli, these test booklets containing all 5 PMA tests were reused and markings were erased immediately after testing sessions by testers. Strategy use could not be coded based on the answer sheet. This test format, using PMA test booklets and separate answer sheets, 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 range is 0–30; the test time limit is 6 min.

Number Series

The Number Series test involves series of numbers rather than letters or words (Ekstrom, French, Harman, & Derman, 1976). 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. The test range is 0–15; the test time limit is 4.5 min.

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. To ensure reliability, a minimum of two 'strategy marks' was required in order for an item to be scored as exhibiting strategy use. The two required markings could represent two different strategies (slash, tick) or two markings representing two instances of the same strategy (two ticks representing two omitted letters). In order to identify strategy use on the measures of inductive reasoning, trained coders followed strict guidelines for the coding procedure. Coders were blinded to the training group of the participant. Inter-rater reliability among the two coders was .87.

Each item was coded '0' or '1' for whether or not strategy use was indicated. The total strategy use scores were calculated separately for the ADEPT Letter Series and Word Series measures by summing up the number of individual items on which strategy use was indicated. Change scores representing posttest minus pretest 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 have been conducted on the pre- and posttest cognitive batteries to determine stability of the ability factor pattern across occasions (Schaie & Willis, 1986; Schaie, Willis, Hertzog, & Schulenberg, 1987; Willis & Schaie, 1986). Factor scores were computed for inductive reasoning and mental rotation abilities.

RESULTS

The results address 3 questions: (1) Does the increase in strategy use indicated by pattern marking on reasoning test problems differ by training group from pre- to posttest? (2) What participant characteristics are associated with strategy use? (3) Is a pre- to posttest increase in strategy use associated with training gain on inductive reasoning at the factor level? Repeated measures analysis of covariance was performed to examine the effects of training group, gender, decline status, replicate, and age on strategy use. Hierarchical regression was used to investigate the association between increases in strategy use, a number of demographic variables, and reasoning training gains at the level of factor scores.

Pre- to Posttest Increase in Strategy Use

Table 1 shows pre- and posttest means and standard deviations for strategy use on the ADEPT Letter Series and Word Series inductive reasoning measures for reasoning and space training groups, by decline status, gender, age/cohort, and training replicate.

Letter Series

For the ADEPT Letter Series measure, a repeated measures Analysis of Covariance (ANCOVA) was performed to investigate the association between a number of variables including age/cohort, training group, gender, inductive reasoning decline status, and change in strategy use. Specifically, a 2 occasion (pretest, posttest) $\times$ 2 training group $\times$ 2 reasoning status (stable, decline) $\times$ 2 replicate (1984, 1991) $\times$ 3 age/

Table 1. Pretest and Posttest Means and Standard Deviations for Number of Items Reflecting Strategy Use for ADEPT Letter Series and Word Series Measures by Training Group ($N = 393$).

	Letter Series		Word Series	
	Pretest	Posttest	Pretest	Posttest
Trained on reasoning				
Total	.25 (0.93)	4.64 (4.07)	.22 (1.30)	3.33 (5.30)
Decline status				
Stable on reasoning	.43 (1.25)	5.13 (4.49)	.37 (1.76)	3.59 (5.84)
Decline on reasoning	.05 (0.27)	4.11 (3.51)	.06 (0.39)	3.05 (4.67)
Sex				
Male	.24 (1.02)	4.93 (4.60)	.22 (1.55)	0.57 (2.16)
Female	.26 (0.86)	4.39 (3.58)	.22 (1.05)	2.80 (4.59)
Age / Cohort				
64–70	.37 (1.17)	5.36 (4.56)	.33 (1.66)	4.12 (6.07)
71–77	.10 (0.41)	3.96 (3.17)	.12 (0.52)	2.67 (4.23)
78–95	.07 (0.38)	3.07 (2.75)	.00 (0.00)	1.46 (2.62)
Replicate				
1984	.20 (0.73)	4.66 (4.19)	.13 (0.68)	3.17 (5.17)
1991	.32 (1.16)	4.61 (3.93)	.35 (1.83)	3.54 (5.50)
Trained on space				
Total	.33 (1.33)	0.62 (1.90)	.45 (1.99)	0.73 (2.51)
Decline status				
Stable on reasoning	.42 (1.55)	0.73 (2.17)	.57 (2.32)	0.87 (2.83)
Decline on reasoning	.10 (0.40)	0.34 (0.86)	.14 (0.51)	0.37 (1.39)
Sex				
Male	.40 (1.56)	0.76 (2.26)	.65 (2.42)	0.92 (2.88)
Female	.27 (1.12)	0.50 (1.55)	.28 (1.54)	0.57 (2.16)
Age / Cohort				
64–70	.48 (1.65)	0.97 (2.48)	.58 (2.48)	1.04 (3.16)
71–77	.09 (0.38)	0.24 (0.61)	.24 (0.94)	0.28 (1.13)
78–95	.30 (1.35)	0.07 (0.27)	.44 (1.63)	0.56 (1.76)
Replicate				
1984	.21 (1.20)	0.54 (1.78)	.37 (1.98)	0.65 (2.26)
1991	.47 (1.47)	0.70 (2.04)	.55 (2.00)	0.82 (2.80)

cohort (64–70 years, 71–77 years, and 78–85 years) × 2 sex ANCOVA was conducted (Table 2). Education was entered into the analysis as a covariate. The dependent variable was pre- and posttest strategy use scores. Inductive reasoning status was defined as ‘decline’ if the participant’s score at pretest was one SEM below their PMA reasoning measure 14 years prior to training. Full models were run and results examined, all nonsignificant higher order interactions were excluded from the final, reduced models reported here.

A significant occasion × training group interaction ($p < .001$) indicated that participants trained on inductive reasoning showed significantly greater increase in strategy use from pre- to posttest than did participants trained on spatial orientation (Fig. 1). A significant occasion × education interaction ($p < .05$) suggested that irrespective of training group, participants with higher education showed significant pre- to post-test strategy use gain. A significant occasion × age / cohort interaction indicated that pre- to posttest strategy use gain differed by the participants’ age. Examination of the means revealed that younger participants (age 64–70) showed significantly greater gain in strategy use from pre- to post-test than did older participants (ages 71–77 and 78–85, Table 1). Skewness and kurtosis for the distribution of change in strategy use in the reasoning trained group on both the Letter Series and Word Series tests were both within

Table 2. Repeated Measures ANCOVA Results (Final Models) for Items Exhibiting Strategy Use on ADEPT Letter Series and Word Series Measures, Education Entered as Covariate ($N = 393$).

	Letter Series			Word Series		
Source	DF	MS	*F*-Value	DF	MS	*F*-Value
Occasion	1	7.18	1.07	1	0.15	0.04
Training group	1	125.87	10.19**	1	403.22	64.58***
Sex	1	23.59	1.91	1	3.43	0.55
Age / Cohort	2	36.68	2.97	2	41.34	6.62**
Replicate	1	1.44	0.12	1	6.96	1.12
Reasoning decline status	1	17.74	1.44	1	28.16	4.51*
Occasion × Education	1	47.86	7.17**	1	39.96	9.41**
Occasion × Training group	1	179.07	26.82***	1	442.92	104.31***
Occasion × Sex	1	8.83	1.32	1	2.83	0.67
Occasion × Age / Cohort	2	20.59	3.08*	2	22.47	5.29**
Occasion × Reasoning status	1	0.01	0.00	1	2.31	0.54
Occasion × Replicate	1	6.05	0.91	1	13.94	3.28
Occasion × Sex × Train	1	14.30	2.14	1	1.07	0.25
Occasion × Age / Cohort × Train	2	10.50	1.57	2	5.04	1.19
Occasion × Reasoning decline status × Training group	1	0.09	0.01	1	3.36	0.79
Occasion × Train × Replicate	1	0.92	0.14	1	1.36	0.32

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

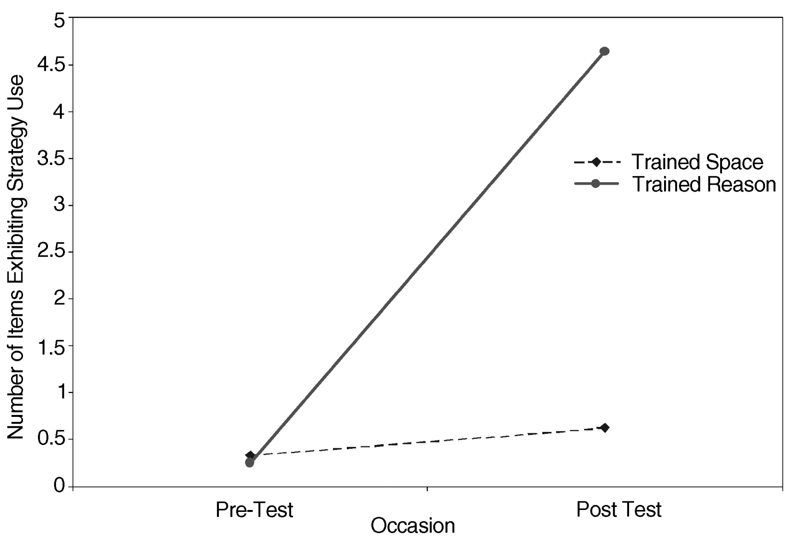

Fig. 1. Mean pre- to posttest number of items showing strategy use: ADEPT Letter Series ($N = 393$).

normal ranges (Letter Series: skewness = 0.97; kurtosis = 1.15; Word Series: skewness = 2.01; kurtosis = 2.68). The implications of the normal range of the skewness and kurtosis are that although the instances of strategy use varied across the participants, strategies were used by a large number of participants.

Nonsignificant occasion × sex and occasion × reasoning status interactions indicated that pre- to posttest strategy use gain did not differ between males and females or by participants' reasoning decline status. The occasion × replicate interaction was also nonsignificant suggesting that increases in strategy use from pre- to posttest did not differ across the 1984 and 1991 replicates. All higher order interactions were nonsignificant (Table 2).

Both the Letter and Word Series measures are timed tests and the majority of subjects attempt far fewer than the maximum number of items (Letter Series = 20 items; Word Series = 30 items). Thus, to examine the proportion of items involving strategy use, the sum score for strategy use was divided by the number of items attempted, separately by occasion and training group. The proportion of attempted items involving strategy use was: Letter Series: Pretest: Reasoning 8%, Space 9%; Posttest: Reasoning 37%, Space 4%; Word Series: Pretest: Reasoning 2%, Space 2%; Posttest: Reasoning 19%, Space 4%.

Word Series

A repeated measures ANCOVA was performed to investigate the association between age/cohort, gender, training group, replicate, and inductive reasoning status, and change in strategy use from pre- to posttest on the Word Series measure. Specifically, a 2 occasion (pretest, posttest) × 2 sex × 2 training group (reasoning, space) × 3 age/cohort (64–70, 71–77, and 78–85) × 2 replicate (1984, 1991) × 2 inductive reasoning status (stable, decline) ANCOVA was conducted (Table 2). Education was entered as a covariate. The dependent variable was pre- and posttest strategy use scores on the Word Series measure. A fully crossed model was run and results were examined. Nonsignificant higher order interactions were excluded from the final, reduced model reported here.

Figure 2 illustrates a significant occasion × training group interaction ($p < .001$) indicating that participants trained on inductive reasoning showed significantly greater pre- to posttest strategy use gain on Word Series than control participants trained on spatial orientation. A significant occasion × education interaction ($p < .01$) suggests that irrespective of training group, participants with higher education were more likely to show pre- to posttest strategy use gain (Table 2). A significant occasion × age/cohort interaction ($p < .05$) indicates that pre- to posttest gain on strategy use differed according to the participants' age. Examination of the means revealed that the youngest group (age 64–70) had significantly greater pre- to posttest strategy use gain than both the middle and older groups (ages 71–77 and 78–85, respectively) (Table 1). Nonsignificant occasion × sex or occasion × reasoning decline status interactions suggested that pre- to posttest strategy use gain did not differ by the participants' sex or reasoning status. A nonsignificant occasion × replicate interaction indicated that pre- to posttest strategy use change did not differ between 1984 and 1991 replicates. Table 2 shows that all higher order interactions were nonsignificant.

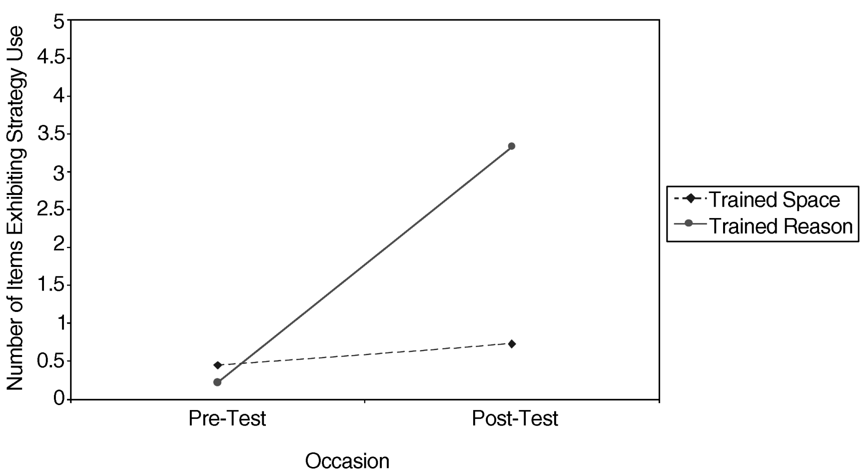

Fig. 2. Mean pre- to posttest number of items showing strategy use: Word Series measure ($N = 393$).

Strategy Use and Training Gains

Hierarchical regression was used to investigate the relationship between strategy use and pre- to posttest training gains on the Reasoning factor score. Factor weights reported by Schaie and Willis (1986) were used for computing the Reasoning factor scores. Factor regression weights for tests loading on the Reasoning factor were: PMA Reasoning = .378; ADEPT Letter Series = .213; Word Series = .298; Number Series = .111. Strategy use was averaged across the Letter Series and Word Series tests at each occasion. The interaction term of training group by pre- to posttest change in strategy use was entered into the models in the first step since it was the variable of interest. In addition, change in strategy use, decline status on inductive reasoning and training group were entered in to the first step of the model. In the second step, demographic variables including age, gender, and education were added. The interaction term of change in strategy use by age, gender, and education, and by reasoning decline status were added in the third and final step of the model.

Table 3 shows hierarchical regression results for pre- to posttest gains on the Reasoning factor. Training group, pre- to posttest change in strategy use, reasoning decline status, and the interaction between training group and change in strategy use were entered in the first step of the model resulting in an R^2 of .204. The training group by pre- to posttest change in strategy use interaction was found to be a significant ($p < .01$) predictor of pre- to posttest gain on the Reasoning factor. Examination of the parameter estimate associated with this interaction revealed that participants, who were trained on reasoning and who showed greater pre- to posttest strategy use gain, also showed greater pre- to posttest gain on Reasoning ability. Training group ($p < .001$) and change in strategy use ($p < .001$) were also significant predictors of pre- to posttest ability gain. Parameter estimates associated with these variables suggest that participants who were trained on inductive reasoning showed significantly greater pre- to posttest gain than participants who were trained on spatial orientation, and participants who showed increased strategy use also showed significant gain on Reasoning ability. Reasoning stability was also a significant predictor of pre- to posttest Reasoning gain ($p < .01$) with subjects who were classified as having declined on inductive reasoning ability showing greater gains (Table 3).

Table 3. Hierarchical Regression Results for Variables Predicting Pre- to Posttest Change in Reasoning Ability Factor ($N = 381$).

Predictor	Step 1		Step 2		Step 3	
	B	MS	B	MS	B	MS
Training group × Strategy gain	−0.13**	87.30	−0.08**	87.30	−0.11**	72.03
Strategy gain	0.22***	273.23	0.11***	273.23	−0.03	10.36
Training group	2.62***	384.79	2.71***	348.79	1.05**	45.73
Reasoning status	−0.62**	81.87	−0.76**	81.87	0.25	2.25
Age			−0.06*	48.07	−0.03	9.61
Gender			0.02	0.15	−0.14	2.69
Education			−0.03	4.31	−0.01	0.84
Strategy gain × Reasoning status					−0.05	5.97
Strategy gain × Age					−0.01	0.13
Strategy gain × Gender					−0.05	4.77
Strategy gain × Education					0.02	8.52
R^2			0.204		0.217	0.223
ΔR^2					0.013**	0.006
(*df*)			(4, 376)		(7, 373)	(11, 369)

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

In the second step of the model demographic variables (age, education, and gender) were added resulting in a significant change in the R^2 of the model (F (7, 373) = 2.15, $p < .01$). Table 3 shows that age was significantly related to ability gain ($p < .05$) with younger subjects showing greater pre- to posttest gain. Education and gender were nonsignificant predictors of ability gain (Table 3). In the third and final step of the model, the interactions terms of change in strategy use by demographic and reasoning stability variables were entered, resulting in a nonsignificant change in the R^2 of the model (F (11, 369) = 0.66). None of the interaction terms were significant predictors of training gains (Table 3). In the final model only the training group × strategy use interaction and training group were significant predictors of reasoning ability gain.

DISCUSSION

The present study examined pre- and posttest increases in strategy use and the relation of strategy use gain to cognitive training gains on reasoning ability.

Results showed that inductive reasoning training resulted in a significantly greater pre- to posttest increase in strategy use on inductive reasoning measures than spatial orientation training. Increased strategy use at posttest was shown on both Letter Series and Word Series. The significant increase of strategy use on Word Series problems is notable. The reasoning training focused on the use of markings with stimuli involving letter series presented horizontally in a line. The Word Series problems involved different stimuli (words), and problems were presented vertically in a column. Thus participants had to transfer strategy markings to different stimuli and to problems presented in a different spatial format.

Increased strategy use as a result of reasoning training was associated with greater gains on the Reasoning ability factor. These results are similar to those of Verhaeghen and Marcoen (1996) who found a trend for correct strategy use to be related to increased memory training grains. Our findings suggest strategy use as a mechanism of training gain in the present study. Because there has been considerable debate whether ability training results are due to the acquisition of skills (i.e., strategies trained during the intervention), these results are especially informative. The identification and quantification of strategy use as the possible mechanism of training gain suggests that the acquisition of skills is a significant factor in producing training gains.

Prior research examining strategy use in experimental aging research as well as training studies has focused on strategies associated with memory ability. This study extends research on strategy use to inductive reasoning ability. Reasoning ability has been found to be strongly related to working memory, executive functioning, and cognitive everyday problem solving (Lezak, 1995; Salthouse, 1991; Willis, Jay, Diehl, & Marsiske, 1992). The present study contributes to the understanding of strategy use in relation to this important higher order cognitive skill.

Change scores were used in the present study to examine pre- to posttest gain in strategy use and also pre- to posttest Reasoning ability gain. The reliability of change scores with regard to mental abilities has been well established (Baltes, Dittmann-Kohli, & Kliegl, 1986; Nesselroade, Stiger, & Baltes, 1980). Because magnitude of training gain, rather than posttest level of performance, was of interest, change scores were used rather than predicting posttest scores using pretest scores as a covariate. Of particular interest was the amount of variance in Reasoning gain that was associated with the interaction of training group and strategy use gain.

Findings support and extend the production deficiency hypothesis (Kausler, 1994) which states that older adults do not spontaneously produce or use strategies as effectively as well as the findings of age differences in strategy acquisition (Verhaeghen & Marcoen, 1996; Verhaegen, Marcoen, & Goossens, 1992). In addition, better educated participants, irrespective of training group, showed greater gain in strategy use. Thus, the focus on age in the production deficiency hypothesis may reflect, in part, the higher educational level of younger age / cohorts. In this study young–old participants (age 64–70) were more likely to show significant pre- to posttest strategy use gain than old–old participants (age 71–85) irrespective of training group. However, results also showed that most participants trained on reasoning showed increased strategy use, for both Word Series and Letter Series measure irrespective of age. Our study does not clarify whether limited use of strategies at pretest is due to inability to use strategies or reluctance to use strategies. However, with regard to the processing position, the data show older adults can be trained to use strategies to identify a pattern in complex reasoning tasks.

Most prior research on the production and processing deficiency positions has been cross-sectional in design. Further examination of these positions using longitudinal and pre- and posttest designs are needed to study the development and plasticity of strategic behavior across the adult lifespan. Study of the individual difference characteristics (e.g., age) and experimental conditions facilitating or limiting strategy production has received relatively little attention and merits further investigation in future research. The finding in this study that higher education was associated with strategy use gain irrespective of training group suggests the need to examine other ability and cognitive variables that may be associated with spontaneous strategy use skill with relatively little practice.

This study presents an objective, item by item, behavioral measure of strategy use on reasoning tests. Although deficits in strategy use have been hypothesized to be related to poor performance by older adults on tests of cognition (Charness, 1985; Guttentag, 1985; Kausler, 1994; Salthouse, 1981), many prior studies have been unable to employ an objective behavioral measure of strategy use, often relying on self-report. Many strategies used in memory training (e.g., visualization) or computation exercises are not easily measured in an objective manner. The study findings lend further support to strategy usage as a mechanism of training gain.

It is important to consider the difference between self-report versus objective measures of cognitive strategy use. Because little work has been done to compare the differential efficacy of these two methods of strategy use measurement, it is difficult to compare self-reports results to those found through objective measurement. Objective measurement of strategy use is an important first step in the effort to compare these two methods. Future studies should attempt to assess the efficacy of self-reported strategy use in comparison to objective measurement.

The generalizability of the study findings are somewhat limited by characteristics of the sample. Elderly participants were well educated, with above average socioeconomic status as a whole. Further investigation at the item level may also help to identify which particular strategies (i.e., underlining, tick marks) are most efficacious for older adults, aiding in the creation of training programs which will yield maximum results. Lemaire and Reder (1999) have stressed the importance of multiple strategy use for the successful accomplishment of cognitive tasks; thus, the specific combination of strategies used would be of interest. Additionally, the possible identification of common errors and strategy misuse at the item level would result in further insight into age differences in strategy production and use.

In summary, the study describes a procedure for an objective behavioral measurement of usage of strategies taught during training on outcome measures. Study findings indicate a significant increase in strategy usage on two outcome measures. Increase strategy usage was shown to be related to training gain on Reasoning factor scores.

ACKNOWLEDGEMENTS

The research reported in this article was supported by Grant AG08055 from the National Institute on Aging. The first author was supported by a Predoctoral Fellowship (M18904) from the National Institute on Mental Health awarded to the Pennsylvania State University. We gratefully acknowledge the enthusiastic cooperation of members and staff of the Group Health Cooperative of Puget Sound.

REFERENCES

Baltes, P.B., Dittmann-Kohli, F., & Kliegl, R. (1986). Reserve cpacity of the elderly in aging sensitive tests of fluid intelligence: Replication and extension. *Psychology and Aging*, *1*, 172–177.

Baltes, P.B., & Kliegl, R. (1992). Further testing of limits of cognitive plasticity: Negative age differences in a mnemonic skill are robust. *Developmental Psychology*, *28*, 121–125.

Blieszner, R., Willis, S.L., & Baltes, P.B. (1981). Training research in aging on the fluid ability of inductive reasoning. *Journal of Applied Developmental Psychology*, *2*, 247–265.

Camp, C.J., Markley, R.P., & Kramer, J. (1983). Spontaneous use of mnemonics by elderly individuals. *Educational Gerontology*, *9*, 57–71.

Charness, N. (1981). Search in chess: Age and skill differences. *Journal of Experimental Psychology: Human Perception and Performance*, *7*, 467–476.

Charness, N. (1985). Aging and problem solving performance. In N. Charness (Ed.), *Aging and human performance* (pp. 225–259). Chichester: Wiley.

Cooper, L.A., & Shepard, R.N. (1973). The time required to prepare for a rotated stimulus. *Memory and Cognition*, *1*, 246–250.

Craik, F.I.M. (1976). Depth processing as a predictor of memory functioning. *Bulletin de Psychologie*, Special Annual, 133–142.

Craik, F.I.M. (1977). Age differences in human memory. In J.E. Birren & K.W. Schaie (Eds.). *Handbook of the Psychology of Aging* (1st ed., pp. 384–420). New York: Van Nostrand Reinhold.

Craik, F.I.M., & McDowd, J.M. (1987). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Behavior*, *11*, 671–684.

Craik, F.I.M., & Lockhart, R.S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, *11*, 671–684.

Dunlosky, J., & Hertzog, C. (1998). Aging and deficits in associative memory: What is the role of strategy production? *Psychology and Aging*, *13*, 597–607.

Ekstrom, R.B., French, J.W., Harman, H., & Derman, D. (1976). *Kit of factor-referenced cognitive tests* (Rev, ed.). Princeton, NJ: Educational Testing Service.

Guttentag, R.E. (1985). Memory and aging: Implications for theories of memory development during childhood. *Developmental Review*, *5*, 56–82.

Hertzog, C., McGuire, C.L., & Lineweaver, T.T. (1998). Aging, attributions, perceived control, and strategy use in a free recall task. *Aging, Neuropsychology, and Cognition*, *5*, 85–106.

Holzman, T.G., Pelligrino, J.W., & Glaser, R. (1982). Cognitive dimensions of numerical rule induction. *Journal of Educational Psychology*, *74*, 360–373.

Kausler, D.H. (1994). *Leaning and memory in normal aging*. New York: Academic Press.

Kliegl, R., Smith, J., & Baltes, P.B. (1989). Testing-the-limits and the study of adult age differences in cognitive plasticity of a mnemonic skill. *Developmental Psychology*, *25*, 247–256.

Kotovsky, K., & Simon, H.A. (1973). Empirical tests of a theory of human acquisition of concepts for sequential patterns. *Cognitive Psychology*, *4*, 399–424.

Lemaire, P., & Reder, L. (1999). What affects strategy selection in arithmetic? The example of parity and five effects on product verification. *Memory and Cognition*, *27*, 364–382.

Lezak, M.D. (1995). *Neuropsychological assessment* (*3rd ed*). Oxford, UK: Oxford University Press.

Mason, S.E., & Smith, A.D. (1977). Imagery in the aged. *Experimental Aging Research*, *3*, 17–32.

Murphy, M.D., Schmitt, F.A., Caruso, M.J., & Sanders, R.E. (1988). Metamemory in older adults: The role of monitoring in serial recall. *Psychology and Aging*, *2*, 331–339.

Nesselroade, J.R., Stigler, S.M., & Baltes, P.B. (1980). Regression toward the mean and the study of change. *Psychological Bulletin*, *88*, 622–637.

Rebok, G.W., Rasmusson, D.X., & Brandt, J. (1997). Improving memory in community elderly though group-based and individualized memory training. In D.G. Payne & F.G. Conrad (Eds.) *Intersections in basic and applied memory* (pp. 327–343). New Jersey: Lawrence Erlbaum.

Salthouse, T.A. (1991). *Theoretical perspective on cognitive aging*. Hinsdale, NJ: Erlbaum.

Salthouse, T.A., Legg, S., Palmon, R., & Mitchell, D.R. (1990). Memory factors in age-related differences in simple reasoning. *Psychology and Aging*, *5*, 9–15.

Salthouse, T.A., & Prill, K.A., (1987). Inferences about age impairments in inferential reasoning. *Psychology and Aging*, *2*, 43–51.

Schaie, K.W. (1983). The Seattle Longitudinal Study: A 21-year exploration of psychometric intelligence in adulthood. In K.W. Schaie (Ed.), *Longitudinal studies of adult psychological development* (pp. 64–135). New York: Guilford Press.

Schaie, K.W. (1985). *Manual for the Schaie-Thurstone adult mental abilities test* (*STAMAT*). Palo Alto, CA: Consulting Psychologists Press.

Schaie, K.W. (1996). *Intellectual development in adulthood*. New York: Cambridge University Press.

Schaie, K.W. & Willis, S.L. (1986). Can decline in adult intellectual functioning be reversed? *Developmental Psychology*, *22*, 223–232.

Schaie, K.W., Willis, S.L., Hertzog, C., & Schulenberg, J.E. (1987). Effects of cognitive training on primary mental abilities. *Psychology and Aging*, *2*, 233–242.

Stine, E.L. (1990). On-line processing of text written by younger and older adults. *Psychology and Aging*, *5*, 68–78.

Thurstone, L.L. (1948). *Primary mental abilities*. Chicago: University of Chicago Press.

Treat, N.J., & Reese, H.W. (1976). Age, imagery, and pacing in paired associate learning. *Developmental Psychology*, *12*, 119–124.

Verhaeghen, P., & Marcoen, A. (1994). The production deficiency hypothesis revisited: Adult age differences in strategy use as a function of processing resources. *Aging and Cognition*, *1*, 323–338.

Verhaeghen, P., & Marcoen, A. (1996). On the mechanisms of plasticity in young and older adults after instruction in the Method of Loci: Evidence for and amplification model. *Psychology and Aging*, *11*, 164–178.

Verhaeghen, P., Marcoen, A., & Goossens, L. (1992). Improving memory performance in the aged through mnemonic training: A meta-analytic study. *Psychology and Aging*, *7*, 242–251.

Willis, S.L. (1990). Current issues in cognitive training research. In E.A. Lovelace (Ed.), *Aging and cognition: Mental processes, self-awareness and interventions*. North-Holland: Elsevier Science Publishers B.V.

Willis, S.L., Jay, G.M., Diehl, M., & Marsiske, M. (1992). Longitudinal change and prediction of everyday task competence in the elderly. *Research on Aging*, *14*, 68–91.

Willis, S.L., & Schaie, K.W. (1986). Training the elderly on the ability factors of spatial orientation and inductive reasoning. *Psychology and Aging*, *1*, 239–247.

Willis, S.L., & Schaie, K.W. (1994). Cognitive training in the normal elderly. In F. Forette, Y. Christen, & F. Boller (Eds.), *Plasticite cerebrale et stimulation cognitive*. Paris: Fondation Nationale de Gerontologie.

West, R.L., & Crook, T.H. (1992). Video training of imagery for mature adults. *Applied Cognitive Psychology*, *6*, 307–320.

Yesavage, J.A., Rose, T.L., & Bower, G.H. (1983). Interactive imagery and affective judgements improve face-name learning in the elderly. *Journal of Gerontology*, *38*, 197–203.