Change in Activity Levels and Maintenance of Cognitive Training Effects

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One line of research on individual-difference variables as potential influences on cognitive ability focuses on contextual variables and the individual (Schaie, 1996; Schooler, 1990). Within this line of research the disuse theory (Salthouse, 1991) and the environmental complexity hypothesis (Schooler, 1987) have been proposed. The disuse theory attributes cognitive decline to decrease in intellectually engaging activities resulting in atrophy of cognitive ability while the environmental complexity hypothesis states that different patterns of engagement in everyday activities lead to different trajectories of cognitive development in later life.

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.

In addition to the above descriptive research on cognitive stimulation, intervention research has shown that older adults can improve their cognitive performance through training, sometimes to a level higher than that which they experienced before training (Kliegl, Smith,& Baltes, 1990; Willis & Schaie, 1986). The present study expands prior work which found that spending more hours per week engaging in household, educational, and leisure activities was positively associated with significantly greater immediate cognitive training gains as well as the seven-year maintenance of training effects (Saczynski, Willis, & Schaie, 1999). These findings suggest that there is a positive association between activity level and cognitive training gains but do not examine the seven-year change in activity following training and it's association with the maintenance of training gains.

The present study aims to identify the impact of changes in activity level on older adults' ability to maintain cognitive intervention effects over time. It will extend previous findings of a positive relationship between activity level and maintenance of training gains by examining the relationship between change in activity level and seven-year maintenance of cognitive training gains.

Two major research questions are addressed in the present study: What are the individual predictors of increases/decreases in activity levels f over a seven-year period following cognitive training? Is there an association between seven-year change in activity levels and maintenance of the effects of cognitive training?

Method

Participants

Participants were 138 older adults (male = 51; female = 87) from the Seattle metropolitan area, who had been participants in the Seattle Longitudinal Study (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 70.6 years (range = 64-85; SD = 4.95) at time of training (1984). Mean educational level was 14.2 years (range = 7-20; SD = 2.86). Mean income level was $21,560 (range = $1,000-$50,000; SD = $7,174).

Participants included those trained on Inductive Reasoning or Spatial Orientation in 1984 who were available for follow-up in 1991. The Inductive Reasoning training group consisted of 74 participants (male = 28; female = 46) with a mean age of 70.6 years at the time of training (1984) (range = 64-85; SD = 5.04). The mean education level of the inductive reasoning training group was 14.0 years (range = 7-20; SD = 2.73) and the group had a mean income of $23,880. The Spatial Orientation training group consisted of 64 participants (male = 23; female = 41) with a mean age of 70.9 years (range = 64-85; SD = 4.98). The mean education level of the group was 14.3 years (range = 8-20; SD = 2.98) and they had a mean income of $21,860.

There were no age or educational differences between the reasoning and space training participants. All participants were community dwelling. Most of the participants were Caucasian. Prior to entry into the study, each participant's physician was contacted and asked whether the participant suffered any known physical or mental disabilities that would interfere with participation in the study; participants so identified were not included in the study.

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-years (1970-1984) prior to training. The statistical criterion for "decline" was one standard error of measurement (SEM) or greater (Reasoning = 4 raw points; Space = 6 raw points) below their 1970 score (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 one-hour training sessions usually conducted in the participant's home by one of three middle-aged trainers with prior experience with working with older adults. Following training, participants were administered a post-test battery of measurements involving the same measures as the pretest.

Measures

Primary Mental Abilities (PMA): Inductive Reasoning (Thurstone, 1948). 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. The ability was 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. This test contains 30 items and has a time limit of six minutes.

Primary Mental Abilities (PMA): Spatial Orientation (Thurstone, 1948). Spatial ability involves both speed and accuracy in mentally rotating objects in two-dimensional space. The participant is presented with a target object and must choose which of six answer choices could be rotated to the target object, rather than mirror images. The six answer choices are at 45, 90, 135, 180, 225, 270, or 315 degree angles or were presented as mirror images of the target object. This test contains 20 items and has a five-minute time limit.

Life Complexity Inventory (LCI) (Gribben, Schaie, & Parham, 1980). This measure contains demographic information and data on a broad range of adult activities and interests.

Development of activity factors: The leisure activity measure derived from the LCI is a list of 34 leisure activities based on the work of Lowenthal and associates (Lowenthal, et al., 1975). Activities such as exercise, cultural activities, social activities, religion, educational activities, and household chores are represented. Development of the activity factors involved exploratory and confirmatory factor analyses performed on Seattle Longitudinal Study data in 1977 and 1984 to create six activity factors and associated factor weights (x^2 (100) = 155.56 ($p < .001$), GFI = .974 (AGFI = .965), RMSEA = .032; O'Hanlon, 1993). Given the considerable overlap 1977 and 1984 samples to the present sample (1984, 1991), the same six activity domains (household, social, educational/cultural, fitness, solitary, and communication) and factor weights developed by O'Hanlon were used (see Table 1).

The same procedures were followed in creation of the activity factors as in the O'Hanlon (1993) study. The data for each of the leisure activities was inspected and outlying cases were trimmed to be within three standard deviations of the mean for each variable. To achieve normality of the distribution of scores, the activity variables were

transformed using square root and logarithmic transformations. Transformed scores were used in all subsequent analyses. Factors were computed from the transformed scores.

The sum of hours variable represents a sum of hours spent per week engaging in the six activity factors, again transformed variables were used in the creation of this variable. Change score variables represent the change in each activity domain and change in sum hours of activity reported per week in the seven years following training (1984-1991). Transformed variables were used in the creation of all change scores. Change scores variables are not presented in Table 1 as they were not used by O'Hanlon (1991).

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...)). These pattern descriptions have been studied extensively in prior research on inductive reasoning (Kotovsky & Simon, 1975; Hotzman, Pelligrino, & Glaser, 1972). The participants learned through modeling, feedback and practice procedures to identify the pattern and solve letter and number 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 shown in previous research to be useful (Pelligrino et al., 1972; see also Saczynski, Willis, & Schaie, 2000). Four primary strategies were taught 1) Saying aloud the series, 2) Underlining number or letter 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…).

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.

Results

The results address two questions: 1) What are the individual predictors of increases/decreases in activity levels in the seven-years following cognitive training, and 2) Is there an association between seven-year change in activity levels and maintenance of the effects of cognitive training? Separate hierarchical regression analyses were performed for Inductive Reasoning and Spatial Orientation.

Predictors of Change in Global Activity Level Following Training

Hierarchical regression analyses were used to examine the relationship between a number of predictor variables including decline status, training group, gender, education, and age, and the dependent variable, seven-year change (1984-1991) in activity level. The dependent variable represented the change in the sum of hours of activity reported per week in the seven-year period from 1984 to 1991 following training. Decline status and training group were entered in the first step of the model followed by demographic variables in the second step of the model. Finally, the interactions between training group, gender, age, and education and decline status were entered in the third and final step of the model. All continuous variables (age and education) were centered in order to create interaction terms in the regression analysis (Aiken & West, 1991).

Table 2 shows hierarchical regression results for seven-year change in global activity level following cognitive training. Decline status and training group were entered in the first step of the model resulting in an R^2 of .107. Decline status was found to be a significant ($p < .05$) predictor of change in activity level. Examination of the parameter estimate associated with the decline status variable revealed that participants who had been classified as having declined in the 14-year period prior to training were more likely to show maintenance/increases in activity level in the 7 years following training. Training group was not predictive of change in activity level (Table 2).

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 ($F (5, 130) = 3.52$, $p < .01$; $R^2 \Delta = .07$). Gender was a significant ($p < .05$) predictor of change in activity level with men showing significantly more increase/maintenance of activity level following training than women. In the third and final step of the model interactions between decline status and demographic variables and training group were entered resulting in a non-significant change in the R^2 of the model ($F (9, 126) = 1.41$; $R^2 = .14$). None of the interaction terms were significant predictors of change in activity level.

Change in Activity and Maintenance of Training Effects

Hierarchical regression was used to investigate the relationship between seven-year changes in activity levels on the activity sum score and on each of the six activity factors (household, social, educational/cultural, fitness, solitary, and communication) and maintenance of Inductive Reasoning and Spatial Orientation training gains. In both models, the six activity factors and the sum of hours variable were centered. Analyses are presented separately for space and reasoning measures. Full models were run and non-significant variables removed in the final models, only final models are presented.

Inductive Reasoning: Table 3 shows hierarchical regression results for the seven-year maintenance of reasoning training gains. The dependent variable, maintenance of inductive reasoning training gain, represents decline, improvement, or stability from post-test 1984 (following training) to pre-test 1991. This stringent method of assessing maintenance assesses maintenance of training gains and not simply maintenance of ability performance as it takes into consideration initial training effects. Seven-year change in the six activity factors and the change in sum of hours of activity reported per week were entered in the first step of the model resulting in an R^2 of .058. None of the variables entered in the first step of the model were significant predictors of the maintenance of reasoning training gains. Decline status and training group were entered in the second step of the model resulting in a non-significant change in the R^2 of the model (F (9, 128) = 2.14). Neither training group nor decline status were significant predictors of the maintenance of reasoning training effects (Table 3).

In the third and final step of the model the interaction between decline status and change in solitary activity was entered into the model resulting in a significant change in the R^2 of the model (F (10, 127) = 5.52; $p < .001$). Table 3 shows that the interaction tem was a significant ($p < .05$) predictor of the seven-year maintenance of Inductive Reasoning training gains. Post-hoc analyses indicated that stable participants who reported a decrease in solitary activity in the seven years following training showed greater maintenance of reasoning training gains.

Spatial Orientation: Table 4 shows hierarchical regression results for the seven-year maintenance of space training gains. Seven-year change in the six activity factors and the change in sum of hours of activity reported per week were entered into the first step of the model resulting in an R^2 of .058. Change in solitary activity was found to be a significant ($p < .05$) predictor of maintenance of Spatial Orientation training gains. Examination of the parameter estimate associated with the solitary activity factor indicated that participants who reported an increase in solitary activity in the seven years following training showed maintenance of space training gains. All other variables were non-significant predictors of maintenance.

Training group, decline status and gender were entered in the second step of the model resulting in a non-significant increase in the R^2 of the model (F (10,127) = 0.97). Table 4 shows that maintenance of space training gains was not significantly predicted by training group, decline status or gender. In the third and final step of the model interaction between change in solitary activity and decline status and gender were entered into the model resulting in a non-significant change in the R^2 of the mode (F (12,125) = 0.51). Neither interaction term was a significant predictor of the maintenance of Spatial Orientation training gains.

Discussion

The present study examined the association between changes in activity level following training and the seven-year maintenance of Inductive Reasoning and Spatial Orientation cognitive training gains. In addition, individual predictors of change in activity level in the seven years following training were also examined.

Decline status and gender were found to be significant predictors of change in global activity level in the seven years following training. Participants classified as having declined in the 14-year period prior to training showed greater maintenance/increase in activity levels following training, irrespective of training group. Without a non-trained group with which to compare change in activity level in the seven-years following training we are unable to state that training resulted in decliners' increased activity level. However, because prior research has found that decliners show somewhat greater training gains on both Inductive Reasoning and Spatial Orientation (Saczynski, Willis, & Schaie, 1999; Schaie & Willis, 1986; Willis & Schaie, 1986) than do stable participants, it is possible that training is responsible for increases in global activity level, irrespective of training group. Results also indicated that men showed significantly more maintenance/increase of activity in the seven years following training than did women.

Findings on the association between seven-year change in activity level and maintenance of training gains revealed that enhancement and maintenance of training gains was associated with change in only specific activities. The concurrent relationship between activity and cognitive training gains appears to be related to overall activity level while the longitudinal relationship is influenced by only specific activities.

Longitudinally, changes in solitary activity were associated with maintenance of both reasoning and space training gains. For reasoning, participants who were classified as having declined in the 14-year period prior to training and who had reported a decrease in solitary activity following training showed more maintenance of reasoning training gains. In contrast, participants who reported an increase in solitary activity in the 7 years following training showed greater maintenance of Spatial Orientation training effects. These findings are similar to those of Arbuckle and his colleagues (1992) who found that health, educational, and intellectual activities were positively related to maintenance of intellectual performance. It is important to note that it is difficult to compare findings on activity levels as measurement varies greatly; therefore comparisons between studies should be interpreted with caution.

Change in sum of hours of leisure activity reported per week in the seven years following training was not significantly related to maintenance of spatial orientation or inductive reasoning training gains although sum of activity hours has been found, in prior work, to be positively related to immediate space and reasoning training gains (Saczynski, Willis, & Schaie, 1999). These results suggest that the concurrent relationship between activity level and cognitive training gains may be related to global activity level while the longitudinal relationship is associated with only specific activities.

Although the present study found a longitudinal relationship between activity level and cognition, results on the differences between concurrent and longitudinal relationships are similar to those of Hultsch and colleagues (1999) who found that while cross-sectionally the relationship between activity and cognition increased, longitudinally there was little association between the two.

Increases in the activities associated with the solitary activity factor, crafts, outdoor activity, and time spent alone (Table 1), may be associated with strategies taught in the space training program. Specifically, improved Spatial Orientation ability may lead to increased craft activity, the activity loading highest on the solitary factor, as this leisure activity could involve spatial tasks such as mental rotation and abstract figures.

Limitations

There are a number of limitations to the present study. Although the results were not affected by education, the sample was highly educated and therefore not generalizable to all older adults. In addition, all of the participants were in good health and the sample had a high mean income level. Although this sample may not be representative of all older adults, it is comparable to that of most cognitive training efforts.

As in most longitudinal research, selective attrition could be affecting the results of the present study. Participants who were in poor health or were having a problem with the training program would have been more likely to drop out before the second pre-test (1991), which could have resulted in a healthier and cognitively superior sample of participants on which maintenance of training effects were assessed, differences between the original and maintenance samples will be examined in attrition analyses.

It is also important to note that the change in activity level may reflect positive or negative change in health. Given that the present study did not include health measures we were unable to assess the influence of the seven-year change in health on activity levels.

Table 1. Lisrel maximum likelihood estimates for final activity model.

Variable	Household	Social	Educ/Cult.	Fitness	Solitary	Comm.	Unique Variance
Cooking	.807						.348
Chores	.733						.463
Shop	.427	.261					.654
Be Visited		.682					.535
Visit		.696					.516
Social		.363	.288				.701
Educ			.625				.609
Cult			.565				.681
Self			.504				.745
Sport				.386			.851
Fit				.618			.618
Outdoor				.301	.194		.848
Alone					.487		.763
Craft					.603		.637
Talk						.749	.440
Dream						.533	.715
Write	.296					.356	.710

Note: Table from O'Hanlon (1993).

Table 2. Hierarchical regression results for variables predicting 7-year maintenance of global activity level (N = 138)

Predictor	Step 1		Step 2		Step 3	
	B	MS	B	MS	B	MS
Decline Status	8.83*	2621.55	10.53*	2964.32	12.87*	2964.32
Training Group	0.43	6.30	1.27	57.02	1.82	57.02
Gender			-8.78*	2899.01	-5.77*	2899.01
Age			-0.51	733.13	-2.39	733.13
Education			0.97	984.77	4.60	984.77
Decline Status x Training Group					1.17	1.27
Decline Status x Gender					-2.51	0.14
Decline Status x Age					1.38	1170.42
Decline Status x Education					-2.49	1470.71
R^2	0.036		0.107		0.144	
ΔR^2			0.071**		0.037	
(df)	(2, 135)		(5, 130)		(9, 126)	

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

Table 3. Hierarchical regression results for variables predicting 7-year maintenance of inductive reasoning training gains. (N = 138)

Predictor	Step 1		Step 2		Step 3	
	B	MS	B	MS	B	MS
Sum of Hours	-0.04	33.61	-0.04	33.61	-0.05	33.61
Household Activity	1.48	35.57	1.65	35.57	1.82	35.57
Social Activity	0.16	0.02	0.16	0.02	0.14	0.02
Cultural Activity	0.88	21.18	1.07	21.18	1.25	21.18
Fitness Activity	0.61	4.10	0.33	4.10	0.65	4.10
Solitary Activity	1.54	92.06	1.59	92.06	-3.66	92.06
Communication Activity	-1.12	48.34	-1.03	48.34	-0.78	48.34
Decline Status			-1.60	65.57	-1.67	65.57
Training Group			-1.34	57.77	-1.19	57.77
Solitary Activity x Decline Status					3.92*	153.29
R^2	0.058		0.089		0.127	
ΔR^2			0.031		0.038***	
(df)	(7, 130)		(9, 128)		(10, 127)	

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

Table 4. Hierarchical regression results for variables predicting 7-year maintenance of spatial orientation training gains. (N = 138)

Predictor	Step 1		Step 2		Step 3	
	B	MS	B	MS	B	MS
Sum of Hours	-0.09	19.37	-0.08	19.38	-0.07	19.38
Household Activity	1.63	37.36	1.511	37.36	1.38	37.36
Social Activity	-0.50	18.89	-0.51	18.89	-0.55	18.89
Cultural Activity	1.49	36.00	1.64	36.00	1.51	36.00
Fitness Activity	0.55	1.41	0.82	1.41	0.98	1.41
Solitary Activity	2.18*	165.59	2.11*	165.59	2.13*	165.59
Communication Activity	-0.59	13.34	-0.58	13.34	-0.70	13.34
Decline Status			-0.16	3.07	-0.36	3.07
Gender			0.65	13.28	0.88	13.28
Training Group			1.67	89.56	1.43	89.56
Solitary Activity x Decline Status					-0.18	1.47
Solitary Activity x Gender					2.43	35.95
R^2	0.058		0.079		0.087	
ΔR^2			0.021		0.008	
(df)	(7, 130)		(10, 127)		(12, 125)	

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

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