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Cognitive Training Gain as a Predictor of Mental Status

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We examined the association of proximal and distal training gain to subsequent mental status ratings in 302 participants (*M* = 76.62 years) trained on inductive reasoning or spatial orientation in the Seattle Longitudinal Study. Only training effects on reasoning ability were predictive of mental status group membership. Participants subsequently rated as probably demented did not significantly differ from nondemented participants in magnitude of reasoning training gain 14 years prior to assessment, but they did 7 years prior to status ratings. Proximal training gain 1 year prior to assessment was 0.40 *SD* for nondemented participants, compared with 0.25 and 0.10 *SD* for at-risk and probably demented participants, respectively. The combination of reasoning ability training and increased proximal training gain on reasoning ability was associated with a decreased likelihood of being rated as probably demented.

On average, beginning in their mid-60s, adults experience a normative age-related decline in fluid-type abilities such as abstract reasoning, spatial orientation, and speed of processing. There are wide individual differences in the timing and rate of this decline (MacDonald, Hultsch, & Dixon, 2003; Schaie, 1996). Prior cognitive training research has focused on abilities exhibiting early normative decline; these interventions have demonstrated that age-related decline can, in some instances, be improved or remediated in normal nondemented older adults (Ball et al., 2002; P. B. Baltes, Kliegl, & Dittmann-Kohli, 1988; Schaie & Willis, 1986; Willis & Schaie, 1986). However, not all older adults benefit equally from cognitive training. It is possible that the limited training effects shown for some adults may be associated with a very early preclinical phase of cognitive impairment. Our purpose in the current study was to examine the relationship between training effects and subsequent mental status for participants involved in cognitive training within the Seattle Longitudinal Study. Specifically, we examined the predictive validity of cognitive training that occurred 14 years, 7 years, or approximately 1 year prior to the assessment of mental status for a community sample of elderly individuals.

Many of the same abilities and processes that longitudinal studies have shown to exhibit normative age-related decline have also been found to be important predictors for discriminating between normal aging and early neuropathology (Albert & Killiany, 2001; Albert & Moss, 2002). The dimensions showing early ability decline include memory (episodic, delayed recall), higher order cognition (e.g., abstract reasoning, working memory, executive functioning), and processing speed. Decline in memory has been among the most commonly reported predictors for discriminating normal and pathological aging (Almkvist & Winblad, 1999; Bäckman et al., 2004; Morris et al., 1989). Executive functions, including abstract reasoning, are often among the fluid abilities showing early decline in normal aging (Schaie, 2005); executive dysfunctions also occur earlier in the disease progression for frontal or frontal-subcortical dementia and may initially be more severe.

The specificity of preclinical cognitive deficits is unresolved (Bäckman, Jones, Berger, Laukka, & Small, 2005). Although memory performance is among the earliest and most salient abilities exhibiting preclinical deficits, the literature suggests a wide array of other cognitive domains implicated in the preclinical phase. Neuroimaging studies indicating atrophy in various brain regions also support the involvement of multiple abilities in the preclinical phase (Albert & Killiany, 2001).

Findings from a limited number of prospective studies indicate a lengthy preclinical phase of cognitive decline that can extend up to several decades preceding the onset of Alzheimer's disease. The abilities identified as the earliest predictors have varied from study to study. The Framingham Study, which covered a 22-year surveillance period, found that presence or absence of probable Alzheimer's disease was related to initial test performance on retention of information and abstract reasoning (Elias et al., 2000; Linn et al., 1995). In a prospective study encompassing 15 years, healthy adults who eventually developed dementia performed poorer than adults who did not develop dementia on psychometric testing at initial assessment (Rubin et al., 1998).

The role of cognitive reserve both in normative aging and as a predictor of cognitive impairment and dementia is of considerable current interest. Cognitive reserve capacity refers to the overall learning potential or plasticity of a person's cognitive system (P. B. Baltes, 1987; Katzman, 1993). There have been at least two lines of research on the impact of mentally stimulating activity: training studies and self-reported activity. Higher educational level and involvement in cognitively stimulating activities have been proposed to be associated with a reduced risk of cognitive impairment or dementia (Bäckman et al., 2004; Katzman, 2003; Scarmeas, Levy, Tang, Manly, & Stern, 2001; Verghese et al., 2003; Wilson et al., 2002). Most studies examining the association of cognitive stimulation and risk of cognitive impairment have been descriptive, linking self-reports of engagement in cognitive activities over many years to level of performance on neuropsychological measures and clinical assessment. Alternative interpretations of findings have been proposed. Cognitive engagement may be protective, or reduced cognitive stimulation may be associated with early preclinical cognitive decline.

Yesavage and colleagues have conducted memory training research on individuals with varying degrees of cognitive impairment (Hill, Evankovich, Sheikh, & Yesavage, 1987; Yesavage, 1982; Yesavage, Sheikh, Friedman, & Tanke, 1990). The memory training generally consisted of teaching participants imagery mnemonics for remembering names, faces, and lists, or teaching them methods to improve concentration and organizational techniques to improve recall. Yesavage (1982) found that benefits from training varied as a function of degree of dementia (as classified by the Mini-Mental State Examination); those individuals classified as mildly demented demonstrated some improvement, whereas those with more severe impairment did not benefit from training. In a case study of one patient with primary degenerative dementia, the researchers found that training gains were maintained 1 month after training (Hill et al., 1987). Finally, Yesavage and colleagues (1990) found that subtle cognitive impairment affected an individual's ability to learn more complex mnemonics. The findings from these studies suggest that individuals with mild cognitive impairment or dementia are still able to benefit from cognitive training interventions.

Our primary aim in the current study was to examine whether cognitive training effects were predictive of subsequent mental status as evaluated through neuropsychological assessment and clinician ratings. As a result of the design of the training intervention within the Seattle Longitudinal Study (SLS), we were able to address several specific questions. The SLS intervention involved training both on inductive reasoning and spatial orientation. First we examined whether training on reasoning versus spatial orientation was differentially predictive of later mental status. Previous literature has reported an association between both abstract reasoning and spatial orientation abilities and cognitive impairment; however, prior research has focused primarily on level of functioning on these abilities rather than cognitive reserve capacity as represented in cognitive training effects. The previous work of M. M. Baltes and colleagues (M. M. Baltes, Kuhl, & Sowarka, 1992; M. M. Baltes & Raykov, 1996) indicated that training effects on inductive reasoning were predictive of cognitive impairment. In a second series of questions, we examined whether the prediction of mental status varied by length of time between initial training and assessment of mental status; we considered three time intervals (approximately 14 years, 7 years, and 1 year prior to assessment). We considered two forms of cognitive reserve. That is, we studied both average magnitude of raw change in reasoning and spatial performance and the reliable training gain at the level of the individual in relation to later mental status.

Methods

Participants

Participants were 302 members (172 women and 130 men) of the SLS who were involved in the training phase of the SLS in 1998. The SLS is a longitudinal study of adult cognitive development, with participants recruited from their membership in the Group Health Cooperative of Puget Sound, a health maintenance organization (see Schaie, 2005 for a complete study description). All study participants had been involved in the SLS training study, including the 1998 training wave, and had undergone neuropsychological assessment within the SLS. The mean age of participants in 1998 was 76.62 years (SD = 6.82; range = 64–96); the mean educational level was 14.54 years (SD = 2.84; range = 7–20).

Neuropsychological Assessment and Mental Status Rating

Following the 1998 training wave, researchers assessed participants on an extended version of the Consortium to Establish a Registry for Alzheimer's Disease battery (Morris et al., 1993), including selected tests from the Revised Wechsler Adult Intelligence Scale (WAIS-R; Wechsler, 1981) and the Revised Wechsler Memory Scale (Wechsler, 1987; see also Cahn et al., 1995). Researchers reviewed participants' neuropsychological scores by using a screening algorithm of score cutoffs shown in previous research to be associated with cognitive dysfunction (Crum, Anthony, Bassett, & Folstein, 1993; LaRue, 1992; Spreen & Strauss, 1991).

The cutoff criteria for the selected tests are as follows: (a) Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975), score < 27; (b) Mattis Dementia Rating Scale (Mattis, 1988), score < 130; (c) Trail B (Reitan & Wolfson, 1985), score time > 180 seconds; and (d) an age-adjusted scaled score < 7 for any of the following tests: WAIS-R Vocabulary, WAIS-R Comprehension, WAIS-R Block Design, and WAIS-R Digit Symbol.

Two neuropsychologists reviewed the records of participants who met the algorithm's screening criteria. The neuropsychologists held consensus conferences to evaluate the mental status of these individuals. In the consensus conferences, they considered the scores on the neuropsychological tests, the tester's report of observed sensory limitations and current or previous health problems, educational level, and occupational status. They rated participants as (a) falling in the normal range, (b) being cognitively at risk (one or more cognitive scores below age norms but not meeting dementia criteria), or (c) showing evidence of probable dementia. Neuropsychologists had 90% agreement on the rating of participants' mental status.

Table 1 provides a description of the study sample, broken down by ability trained and mental status rating. Approximately 70% of the individuals in the sample were categorized as normal, 21% as cognitively at risk, and 9% as probably demented.

SLS Training Study Design

Researchers conducted three waves of training (1984, 1991, and 1998) within the SLS (Schaie & Willis, 1986; Willis & Schaie, 1986). At each wave, researchers recruited SLS participants for training who were aged 65 years and older and who had been in the SLS for 14 years or more prior to training. They assigned participants to training on one of two abilities, either inductive reasoning or spatial orientation, on the basis of their prior cognitive performance on these abilities. Researchers examined participants' performance on reasoning and spatial abilities (Thurstone, 1948) at three occasions prior to training (14 years, 7 years, and immediately before training, which was the initial training pretest). They assigned participants who had

Table 1. Description of the 1998 Study Sample: Training and Mental Status Groups

Mental Status Rating	Training Group	*n*	Age	Education	Reasoning		Spatial Ability	
					Pretest	Post-Test	Pretest	Post-Test
Cognitive nonrisk	Reasoning	105	75.52(6.27)	14.54(2.69)	47.18(6.77)	51.24(6.62)	47.57(6.98)	49.80(7.17)
	Spatial	107	75.28(6.61)	14.92(2.96)	48.32(7.62)	50.00(7.42)	46.79(7.40)	49.26(7.07)
	Total	212	75.40(6.43)	14.73(2.82)	47.75(7.22)	50.61(7.05)	47.18(7.18)	49.53(7.11)
Cognitive risk	Reasoning	27	78.63(7.04)	13.78(2.75)	42.59(6.26)	46.59(5.82)	43.74(5.88)	45.89(6.75)
	Spatial	37	78.76(6.82)	13.84(2.98)	41.03(6.77)	42.65(7.07)	43.92(9.04)	46.00(9.25)
	Total	64	78.70(6.86)	13.81(2.86)	41.69(6.56)	44.31(6.81)	43.84(7.81)	45.95(8.23)
Probable dementia	Reasoning	9	79.33(5.52)	13.89(2.31)	39.33(6.10)	40.11(6.94)	38.00(3.81)	39.89(4.34)
	Spatial	17	82.53(4.56)	15.29(2.80)	36.06(9.03)	37.71(9.62)	36.29(8.20)	38.59(7.54)
	Total	26	81.42(5.05)	14.81(2.68)	37.19(8.16)	38.54(8.72)	36.88(6.95)	39.04(6.55)
Total sample	Reasoning	141	76.36(6.50)	14.35(2.68)	45.80(7.04)	49.64(7.15)	46.23(7.09)	48.42(7.42)
	Spatial	161	76.84(6.88)	14.71(2.97)	45.35(8.74)	47.01(8.75)	45.02(8.48)	47.39(8.31)
	Total	302	76.62(6.82)	14.54(2.84)	45.56(7.98)	48.24(8.14)	45.59(7.87)	47.87(7.91)

Note: Table shows mean values, with standard deviations given parenthetically.

declined on only one ability to training on that ability. They randomly assigned participants who had declined on both abilities or remained stable on both abilities to ability training. The statistical criterion for reliable decline on spatial or reasoning ability was one standard error of measurement (SE) or greater (spatial ability = 6 raw points; reasoning = 4 raw points) below a participant's score 14 years prior to training (Dudek, 1979; Schaie & Willis, 1986). Hence, if participants' scores decreased by 1 *SE* or more over the 14-year period, they were categorized as having declined on that ability. Researchers maintained the same recruitment and selection procedures at each wave. After completion of training sessions, participants completed post-test assessment (within approximately 1 month after the pretest). In 1991, participants who were initially trained in 1984 received booster training on the same ability; in 1998, participants who were initially trained in 1984 or 1991 received booster training. A third wave of participants was trained for the first time in 1998. Booster training was identical in content to the initial training program.

Attrition

We conducted attrition analyses to compare the total sample initially trained at each wave (1984, 1991, and 1998) with the study sample. We conducted separate analyses for each wave. We used a multivariate analysis of variance to examine differences in age, education, reasoning pretest and post-test scores, and pretraining–post-training gain at time of initial training. We examined attrition for the total sample at each wave and by training group.

For the total sample in 1984 and 1991, current study participants were significantly younger ($p < .001$) and had higher reasoning pretest and post-test scores ($p < .001$) than did the total sample of individuals. Similar effects held when these participants were examined separately by training group. The current sample of individuals was younger and had higher pretest and post-test scores at the time of initial training. However, the participants in the current sample initially trained in 1998 did not differ in age or pretest and post-test scores from the total 1998 training sample.

Attrition effects associated with age and level of ability performance are to be expected. What is most important is that in no case did magnitude of training gain differ for the individuals in the study sample and the individuals in the total sample initially trained. Because training gain is one of the primary independent variables in the current study, these analyses suggest that the current study sample is representative of the initial training samples.

Measures

The primary dependent variable is mental status as defined by the neuropsychologists' ratings. Training group, training gain from pretest to post-test, age, and education were the primary independent variables or covariates. Training gain is of interest both at the time of initial training for the 1984 and 1991 waves, which indicates the long-term impact of initial training gain, and at the 1998 training wave, which indicates the proximal gain impact. The magnitude of training gain was of specific interest to us, because level of ability performance might be expected to vary across training waves, given age and cohort differences among the participants.

Inductive reasoning.—Inductive reasoning ability involves identifying patterns or rules and applying them to solve a problem. This involves a person's ability to recognize novel concepts or relationships and the ability to solve logical problems. We derived the cognitive factor score for inductive reasoning from the following measures: Primary Mental Abilities Reasoning (Thurstone, 1948), ADEPT Letter Series (Blieszner, Willis, & Baltes, 1981), Word Series (Schaie, 1985), and Number Series (Thurstone, 1962).

Spatial orientation.—Spatial orientation involves the ability to mentally rotate two- and three-dimensional objects. This ability requires a person to be able to visualize objects and to maintain the orientation of these objects when they are rotated in space. We used four measures to contribute to our spatial orientation factor score: Primary Mental Abilities Space (Thurstone, 1962), Object Rotation (Schaie, 1985), Alphanumeric Rotation (Schaie, 1985), and Cube Comparisons (Ekstrom, French, Harman, & Derman, 1976).

Results

We examined two key questions. First we examined whether long-term training effects (those measured in 1984 or 1991) were associated with subsequent mental status. Specifically, we

Table 2. Logistic Regression Analyses Predicting Probable Dementia: Reasoning Ability From Initial Training

	Step 1		Step 2		Reduced Model	
Variable	β	*SE*	β	*SE*	β	*SE*
Training group: reasoning or spatial	0.44	0.38	−0.79	0.78	0.34	0.32
Reasoning change: pretest to post- test	0.02	0.11	−0.00	0.14	0.04	0.10
Training wave: 1984 or 1991	−0.12	0.38	0.70	0.42	−0.03	0.32
Change × Training Group	−0.02	0.11	0.04	0.22		
Training Group × Training Wave	0.77*	0.38	−1.58*	0.77	0.61*	0.31
Change × Training Wave	0.10	0.11	−0.14	0.14	0.24*	0.10
Change × Training Group × Training Wave	−0.25*	0.11	0.50*	0.22		
Baseline age			−0.00	0.06		
Baseline education			0.13	0.10		

Notes: *SE* = standard error.
$*p < .05$; $**p < .01$; $***p < .001$.

addressed whether training occurring 14 or 7 years prior to mental status assessment was predictive of subsequently rated mental status. The second question focused on whether training effects in 1998, which were more proximal (within 1 year) to assessment of mental status, predicted subsequently rated mental status. We first examined both long-term and proximal training effects in terms of raw score training gain. In addition, we evaluated distal and proximal training effects at the level of the individual by the more stringent criterion of assessing reliable training improvement for a given participant.

Long-Term Training Effects and Mental Status

To address whether subsequent mental status varied as a function of initial training effects, we conducted a series of logistic regression analyses separately for the inductive reasoning and spatial orientation ability factor scores. We included training group (reasoning or spatial orientation) and initial training pretest-to-post-test change on ability (inductive reasoning or spatial orientation) as predictors (Step 1), with age and education at time of initial training (1984 or 1991) as covariates (Step 2). For parsimony, we used reduced models. Given the length of time between initial training (7 and 14 years) and neuropsychological assessment, we formed two mental status groups: (1) Those at risk or not at risk of cognitive impairment, and (2) probably demented. Prior research suggests that, at 14 and 7 years before assessment, the group defined as cognitively at risk would likely have been functioning within the normal range. We used logistic regression analyses to predict the probability that a participant would be rated as probably demented.

Long-term training effects for reasoning ability.—Results revealed that the full model was not significant: $\chi^2(5, 142) = 3.08$, $p > .05$. Baseline age, education, pretest-to-post-test change on inductive reasoning ability, and training group were not significantly associated with later mental status.

We conducted an additional analysis to determine whether mental status varied as a function of training wave (1984 or 1991; see Table 2). Thus, we added training wave as a predictor variable in Step 1. The first model (Step 1) was significant: $\chi^2(7, 142) = 14.71$, $p < .05$. Significant effects emerged for the Training Group × Wave of Initial Training interaction ($p < .05$), and for the three- way Training Group × Change in Reasoning Ability × Wave of Initial Training interaction ($p < .05$). The full model (Step 2) was not significant: $\chi^2(9, 142) = 16.56$, $p > .05$. Thus we examined the reduced model, retaining the main effects of training group, pretest-to-post-test change in reasoning ability, wave (1984 or 1991), and the Training Group × Wave and Training Group × Wave × Change in Reasoning Ability interactions: $\chi^2(5, 142) = 13.84$, $p < .05$. We used post hoc chi-square analyses to facilitate our interpretation of these interactions. Significantly more individuals first trained on spatial orientation in 1984 than individuals trained on reasoning ability in 1984 were later rated as probably demented: $\chi^2(1, 61) = 3.98$, $p < .05$. Thirty percent of individuals first trained on spatial orientation in 1984 were rated as probably demented, compared with less than 10% of reasoning trained individuals. For individuals trained on reasoning ability, irrespective of initial wave, there was not a significant difference in mental status rating: $\chi^2(1, 70) = 0.17$, $p > .05$.

The significant three-way interaction suggests that individuals trained on reasoning are less likely to be rated as probably demented than are individuals trained on spatial orientation. In addition, for those participants trained on reasoning ability, each 1-unit increase in reasoning gain from pretest to post-test is associated with a decreased likelihood of being rated as probably demented. Furthermore, individuals first trained on reasoning in 1984 were less likely to be rated as probably demented than those individuals first trained in 1991. This likelihood of being rated as not at risk or at risk of cognitive impairment increased with each 1-unit increase in raw pretest-to-post-test gain on reasoning. Thus, reasoning trained individuals who were later rated as probably demented did exhibit less initial pretest-to-post-test gain on reasoning ability, particularly those individuals trained in 1991. Therefore, the change in reasoning from pretest to post-test is more predictive of subsequent mental status when a person is evaluated at 7, opposed to 14, years prior to assessment. It is important to note that the results of this analysis are preliminary and must be interpreted with caution because of the small number of individuals in the probable dementia group.

Long-term training effects for spatial orientation ability.—The test of the full model for spatial orientation ability was not significant: $\chi^2(5, 142) = 6.98$, $p > .05$. The addition of the wave of initial training as a predictor variable also yielded a nonsignificant model [$\chi^2(9, 142) = 14.25$, $p > .05$; see Table 3]. The lack of a significant interaction with change on spatial orientation ability suggested that subsequent mental status did not vary as a function of training gain on spatial orientation occurring 7 or 14 years prior to assessment.

Proximal Training Effects and Mental Status

To address whether mental status varied as a function of the magnitude of 1998 (proximal) training gain, we used multinomial logistic regression analyses. Training group (reasoning or spatial orientation) and 1998 change on ability from pretest to post-test (reasoning or spatial orientation) were predictors, with age and education in 1998 as covariates. We used reduced models for parsimony. Because the mental status rating occurred

Table 3. Logistic Regression Analyses Predicting Probable Dementia: Spatial Orientation Ability From Initial Training

Variable	Step 1		Step 2		Reduced Model	
	β	*SE*	β	*SE*	β	*SE*
Training group: reasoning or spatial	0.43	0.34	0.41	0.34	0.27	0.27
Spatial ability change: pretest to post-test	−0.18	0.09	−0.18	0.10	−0.12	0.08
Training wave: 1984 or 1991	0.21	0.34	0.25	0.34	0.41	0.27
Change × Training Group	0.09	0.09	0.10	0.10		
Training Group × Training Wave	0.69*	0.34	0.66*	0.34	0.52	0.27
Change × Training Wave	−0.11	0.09	−0.09	0.10		
Change × Training Group × Training Wave	0.08	0.09	0.07	0.10		
Baseline age			−0.01	0.06		
Baseline education			0.13	0.10		

Notes: *SE* = standard error.
$^*p < .05$; $^{**}p < .01$; $^{***}p < .001$.

within 1 year of the 1998 training wave, we retained three mental status groups for these analyses: not at risk of cognitive impairment, cognitively at risk, and probable dementia. We used multinomial logistic regression analyses to predict the probability that a person would be rated as probably demented.

Proximal training effects for reasoning ability.—Descriptive analyses showed that participants rated as not at risk of cognitive impairment experienced the greatest magnitude of inductive reasoning training gains from pretest to post-test, followed by those participants categorized as being at risk; the participants in the probable dementia category experienced the lowest magnitude of gain. In terms of raw training gain from pretest to post-test, those participants with probable dementia had a previous gain of 0.10 *SD* on inductive reasoning. Participants rated as cognitively at risk experienced a 0.25 *SD* gain, and those rated as not at risk of cognitive impairment experienced a 0.40 *SD* gain, on inductive reasoning.

The test of the full multinomial logistic regression model (Step 2) was significant [$\chi^2(10, 302) = 48.21$, $p < .001$; see Table 4]. Age ($p < .01$) and the Training Group × Change in Reasoning Ability interaction ($p < .01$) emerged as significant. The reduced model eliminated education, but it retained all other main effects, interactions, and the covariate of age [$\chi^2(8, 302) = 43.38$, $p < .001$]. The Training Group × Change in Reasoning Ability interaction retained significance when we modeled the probability that a participant would be rated as probably demented to not at risk of cognitive impairment, and probably demented to cognitively at risk. Estimated odds ratios of the interaction suggest that individuals trained on spatial orientation had an increased likelihood of being rated as probably demented as opposed to being rated as cognitively at risk or not at risk. Moreover, the combination of being trained on reasoning ability and each 1-point increase in gain on reasoning ability from pretest to post-test was associated with a decreased likelihood that a participant would be rated as probably demented. There were no significant interactions when we conducted an additional multinomial logistic regression analysis to determine whether significant differences emerged among those individuals rated as being cognitively at risk compared with those who were rated as being not at risk of cognitive impairment.

We conducted an additional analysis to determine whether proximal training gain varied as a function of time of initial training (1984, 1991, and 1998). We added wave of initial training as a predictor variable in the first step of the model. The full model (Step 2) was significant: $\chi^2(26, 302) = 59.53$, $p < .001$. However, none of the higher order interactions with year of initial training reached significance.

Individual-level training gain and mental status.—With our next question we addressed whether mental status varied as a function of the proportion of individuals in the reasoning group who showed reliable training gain. We defined reliable gain as that above 1 *SE*. We ran a series of chi-square (χ^2) analyses. Results from the chi-square analyses indicated that there was a significant effect for the not at risk of cognitive impairment versus probably demented comparison, $\chi^2(1, 114) = 4.69$, $p < .05$, but not for the not at risk versus at risk comparison, $\chi^2(1, 132) = 0.15$, $p > .05$. For the 1998 reasoning training sample, approximately 45% of the participants experienced reliable gain at the individual level on inductive reasoning

Table 4. Multinomial Logistic Regression Analyses Predicting Probable Dementia: Reasoning Ability From 1998 Training

Variable	Step 1		Step 2		Reduced Model	
	β	*SE*	β	*SE*	β	*SE*
Comparison of probable dementia with cognitive nonrisk						
Training group (reasoning or spatial)	−0.40	0.24	−0.38	0.25	−0.38	0.25
1998 reasoning change: pretest to post-test	0.11	0.07	0.13	0.08	0.12	0.08
Change × Training Group	−0.20**	0.07	−0.21**	0.08	−0.21**	0.08
1998 age			−0.15***	0.04	−0.15***	0.04
1998 education			−0.06	0.08		
Comparison of probable dementia with cognitive risk						
Training group (reasoning or spatial)	−0.26	0.27	−0.22	0.27	−0.24	0.27
1998 reasoning change: pretest to post-test	0.11	0.08	0.12	0.09	0.11	0.09
Change × Training Group	−0.21*	0.08	−0.21*	0.08	−0.22*	0.09
1998 age			−0.08*	0.04	−0.07	0.04
1998 education			−0.16	0.08		

Notes: *SE* = standard error.
$^*p < .05$; $^{**}p < .01$; $^{***}p < .001$.

ability. Of those participants categorized as not at risk of cognitive impairment, 49% showed reliable training gain; 44% of individuals rated as at risk showed reliable gain. Of those individuals categorized as probably demented, only 11% showed reliable gain. Chi-square analyses indicated that the proportion of not at risk and at risk individuals showing reliable gain did not differ, whereas a significantly smaller proportion of individuals with probable dementia showed reliable gain.

Proximal training effects as a function of initial versus booster training.—The 1998 sample consisted of two different groups of individuals: those first trained in 1998, and those who received booster training in 1998 (first trained in 1984 or 1991). Of the 302 individuals in the 1998 study, 68 were first trained in 1984, 81 were first trained in 1991, and 153 were first trained in 1998. Thus, there were fairly equal numbers of individuals who were first trained in 1998 versus those who were booster trained in 1998. To determine whether the interaction of magnitude of training gain and mental status varied for first time versus booster training, we used two-step multinomial logistic regression analyses. We included training group (reasoning or spatial orientation), 1998 pretest-to-post-test change in reasoning ability, and training occasion (initial versus booster) in Step 1. We added age and education in 1998 in Step 2. The full model was significant: $\chi^2(18, 302) = 52.68$, $p < .001$. When comparing booster versus initial training, we found that neither the main effect nor any of the interactions were significant. These findings suggest that the association of training gain to mental status did not differ as a function of booster versus initial training.

Individual-level gain: Booster versus initial training in 1998.—The proportion of individuals trained on reasoning and showing reliable gain was compared for those booster trained versus first trained in 1998. Of those individuals first trained on reasoning in 1998 and categorized as not at risk of cognitive impairment ($n = 58$), 48% experienced reliable gain on reasoning; 50% of those booster trained and categorized as not at risk ($n = 48$) experienced reliable gain on reasoning ability. For individuals initially trained in 1998 and classified as cognitively at risk ($n = 13$), 54% achieved a significant (*SE*) gain, whereas 36% of those booster trained in 1998 and classified as cognitively at risk ($n = 14$) experienced reliable gain. The higher proportion of significant gain for the 1998 cognitively at risk group is likely due to lower baseline levels; these individuals had more room to improve than the participants who were not at risk of cognitive impairment. Finally, none of the individuals first trained in 1998 and classified as probably demented ($n = 1$) showed reliable gain; of those booster trained in 1998 and classified as probably demented ($n = 8$), only 13% ($n = 1$) exhibited reliable gain. Note that none of the chi-square tests revealed significant differences in mental status as a function of booster status.

Proximal training effects for spatial orientation ability.—Multinomial logistic regression analyses for the spatial orientation factor score yielded only a significant main effect for age [$p < .01$; $\chi^2(10, 302) = 35.16$, $p < .001$]. The addition of wave (1984, 1991, and 1998) to the first step of the model yielded a significant model [$\chi^2(26, 302) = 64.09$, $p < .001$]; however, the three-way Training Group × Training Wave × Change in Spatial orientation interaction was not significant.

Discussion

Our aim in the current study was to examine whether distal or proximal cognitive training effects were predictive of subsequent cognitive status. Only magnitude of reasoning training gain was associated with subsequent mental status. Training effects occurring 14 years prior to mental status ratings (trained in 1984) indicated that those individuals subsequently rated as probably demented did not differ in magnitude of distal training gain on reasoning ability. However, training effects 7 years prior to mental status ratings (individuals trained in 1991) indicated that those individuals subsequently rated as probably demented experienced less training gain on reasoning ability. Training effects at 1 year prior to mental status ratings differed among the three mental status groups.

The current study supports and extends prior research in several ways. The distal cognitive training effects for inductive reasoning ability support longitudinal prospective dementia studies that found a different level of performance up to 22 years prior to diagnosis (Elias et al., 2000; Linn et al., 1995). Our study findings extend prospective studies in that experimental effects of reasoning training interventions were predictive of mental status. The current findings also support prior research that abilities other than memory have shown preclinical deficits that are predictive of later dementia (Albert & Moss, 2002; Bäckman et al., 2005; Schaie, 2005). Reasoning is one ability that has shown preclinical deficits both in prospective dementia studies and now in experimental intervention studies. This study builds on prior intervention work by M. Baltes (Baltes et al., 1992; Baltes & Raykov, 1996) and Yesavage (Hill et al., 1987; Yesavage, 1982; Yesavage et al., 1990). Whereas the prior intervention work focused only on a concurrent association between training gain and mental status, this study also examined a lagged relation between training gain and mental status. Our study indicates that the magnitude of training gain differs by group up to 7 years prior to mental status assessment.

The study findings also contribute to literature on cognitive reserve and risk factors for dementia. Prior work on cognitive reserve has been primarily observational, showing an association between self-reports of cognitive engagement activities and reduced risk of cognitive impairment (Bäckman et al., 2004; Katzman, 1993; Scarmeas et al., 2001). The current study suggests that the individual's plasticity or ability to enhance cognitive reserve as represented in training improvement is associated with level of risk of cognitive impairment. Thus, the magnitude of gain from training could serve as an assessment tool for cognitive decline. The risk of cognitive impairment is associated with a diminished magnitude of enhancing cognitive reserve. The current study suggests that cognitive training programs may contribute to the enhancement of older adults' levels of cognitive reserve by involvement in mentally stimulating activity; additional cognitive activity may serve as a protective factor even for those individuals with preclinical cognitive decline. Further research, both descriptive and experimental, is needed to clarify the role of cognitive stimulation, including cognitive training, and cognitive reserve.

There are several alternative explanations for why training gains on reasoning but not spatial ability were predictive of subsequent mental status. Similar to reasoning, spatial ability exhibits a relatively early age-related decline, which becomes more pronounced in those individuals aged 75 years and older (Libon et al., 1994; Wahlin, Bäckman, Wahlin, & Winblad, 1993). However, reasoning ability is associated with the frontal cortex, which has been linked to cognitive deficits in older adulthood, whereas spatial ability utilizes the parietal lobe. Within the neuropsychological literature, reasoning is considered to be a component of executive functioning. In addition, in many neuropsychological batteries, including the battery used in the SLS, reasoning ability is more closely related to some measures of executive function, whereas mental rotation ability is less well represented. Finally, in the SLS training studies, a greater magnitude of training and maintenance effects has been demonstrated for reasoning ability, increasing the likelihood of an association with subsequent mental status. Thus, [illegible]

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