

## Effects of Cognitive Training on Change in Accuracy in Inductive Reasoning Ability

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**We investigated cognitive training effects on accuracy and number of items attempted in inductive reasoning performance in a sample of 335 older participants ( $M = 72.78$  years) from the Seattle Longitudinal Study. We assessed the impact of individual characteristics, including chronic disease. The reasoning training group showed significantly greater gain in accuracy and number of attempted items than did the comparison group; gain was primarily due to enhanced accuracy. Reasoning training effects involved a complex interaction of gender, prior cognitive status, and chronic disease. Women with prior decline on reasoning but no heart disease showed the greatest accuracy increase. In addition, stable reasoning-trained women with heart disease demonstrated significant accuracy gain. Comorbidity was associated with less change in accuracy. The results support the effectiveness of cognitive training on improving the accuracy of reasoning performance.**

AS INDIVIDUALS age, there are normative age-related cognitive declines that occur. The earliest declines are usually associated with fluid intelligence such as reasoning and verbal memory (Singer, Verhaeghen, Ghisletta, Lindenberger, & Baltes, 2003). Fluid intelligence is essential for older adults to meet the demands of their daily lives, such as performing instrumental activities of daily living (Lawton, 1982) and other cognitively demanding tasks. To better understand the impact of these normative declines on fluid abilities, in the current study we investigated the nature of the effects of cognitive training on inductive reasoning. Specifically, we examined whether training enhancement on fluid ability could be attributed to an increase in accuracy, or whether training effects were primarily associated with an increased number of reasoning items attempted. In addition, we examined the differential training effects as a function of gender, prior cognitive status, and chronic disease.

Inductive reasoning is an important ability to study experimentally as well as descriptively because it is associated with higher order executive functioning, and is considered one of the "pure" markers of fluid intelligence within a psychometric approach to mental abilities. As a fluid ability, it is vulnerable to earlier age-related declines. Thus, determining whether cognitive training differentially enhances a specific aspect of reasoning performance may contribute to greater understanding of the source of efficacy of the training for older adults. Prior cognitive intervention research has reported significant improvement in older adults' cognitive performance immediately after a brief cognitive intervention (Bächman, 1989; Ball et al., 2002; Baltes, Dittman-Kohli, & Kliegl, 1986; Willis, 1987; Yesavage, Lapp, & Sheikh, 1989). More specifically, training interventions on inductive reasoning abilities have been found to have a positive impact on individual's cognitive functioning (Ball et al., 2002; Baltes, Sowarka, & Kliegl, 1989; Calero & Garcia-Berben, 1997; Schaie & Willis, 1986; Willis & Nesselroade, 1990). Furthermore, training has also been found to be effective

through individual and collaborative training conducted independently (of a trainer) in the participant's home (Saczynski, Margrett, & Willis, 2004). Thus, even though inductive reasoning ability is susceptible to age-related declines, intervention research (both trainer-based and self-directed) has demonstrated that training can have a positive impact.

Although training has been demonstrated to be effective, there are two questions that have received relatively little attention. First, what aspects of performance on the target ability change with training improvement? Second, who profits from training, or what person characteristics predict or are associated with training improvement? Prior research on training interventions has concentrated on the effects in terms of total score (e.g., the number of correct answers). However, focusing findings on a summary score overlooks the specific aspects of performance that may be changing as a function of training.

We sought to investigate two hypotheses regarding the mechanisms underlying cognitive training improvement. One hypothesis is that, as a result of training, individuals are increasing the number of test items that they attempt to answer. Thus, the training effect is primarily due to an increased speed of responding to reasoning test items, which would result in a greater number of attempted items. Alternatively, individuals may be answering a greater proportion of items correctly, even if there was no increase in the number of items they attempted to answer. Hence, the training effect is primarily due to an increase in accuracy. Saczynski and colleagues (Saczynski, Willis, & Schaie, 2002) found that increased strategy use as a result of reasoning training was associated with greater gains on the reasoning ability factor score. Because the use of strategies is related to level of expertise, it can be inferred that the gains in reasoning ability were associated with an increase in accuracy.

Our second question in this study focused on furthering our understanding of the underlying factors or personal characteristics that affect training outcomes. Age, education, prior

cognitive status (stable or decline), gender, and chronic disease constitute factors that may be influential. Although the magnitude of change may vary by age and education, gains still have been observed in groups differing in age (Ball et al., 2002; Willis & Nesselroade, 1990) and education (Baltes et al., 1989; Calero & Garcia-Berben, 1997). It should be noted that younger older adults have demonstrated greater training gains in these studies.

Consideration of the impact of additional characteristics, such as health, is also important when gauging training efficacy. Due to increased longevity, many older adults will live with one or more chronic diseases in their later years. Thus, considering the potential impact of chronic disease on cognitive training is relevant. In prior research, diabetes mellitus, hypertension, heart disease, cerebrovascular disease, and osteoarthritis have each demonstrated negative associations with level of cognitive ability and rate of cognitive change. In several longitudinal studies, researchers have documented the relation of diabetes mellitus and lower cognitive function in old age while controlling for age, education, and gender (Arvanitakis, Wilson, Bienias, Evans, & Bennett, 2004; Fontbonne, Ducimetiere, Berr, & Alperovitch, 2001; Ryan, 2001). Many researchers have also shown the negative associations between cognitive performance and hypertension (Elias, D'Agostino, Elias, & Wolf, 1995; Hertzog, Schaie, & Gribbin, 1978; Raz, Rodrigue, & Acker, 2003; Waldstein et al., 1996). However, Morris and colleagues (2002) found a slight inverted U-shaped relation with blood pressure levels and cognitive functioning on memory, speed, and general cognitive ability. The inclusion of other cardiovascular risk factors such as stroke, heart disease, hypertension, and diabetes amplified this relationship. Gruber-Baldini (1991) found that individuals with osteoarthritis had lower functioning and steeper rates of decline on the abilities of inductive reasoning, spatial orientation, and verbal meaning. Finally, research on cardiovascular disease has also established a negative relationship with cognitive ability (Morris et al., 2002; Verhaeghen, Borchelt, & Smith, 2003). Thus, with few exceptions, the presence of chronic disease tends to be associated with lower levels of cognitive ability. Despite this relationship, there is very limited research on the impact of chronic disease on training gains.

Our first major aim in the current study was to determine if cognitive training on reasoning abilities improves the number of items attempted or the accuracy component of inductive reasoning performance in older participants of the Seattle Longitudinal Study (SLS). Participants trained on spatial orientation served as the comparison group for examining changes in attempts and accuracy on reasoning performance. If training gains are primarily due to an increase in accuracy, then this will provide support for training on the strategies employed in the SLS training.

Our second aim in this study was to examine predictors of cognitive training gain, in particular, the impact of chronic disease on training gain. We investigated whether change in accuracy or number of items attempted on reasoning tasks varies by prior cognitive status (stable or decline on reasoning ability), gender, or chronic disease. The identification of person characteristics associated with differential training outcomes may provide important information for more individualized training programs.

## METHODS

### *Participants*

The sample consisted of 335 older adults (186 women and 149 men) who had participated in the SLS in either 1991 ( $n = 159$ ) or 1998 ( $n = 176$ ). Training participants had participated in the SLS for at least 14 years prior to training and were at least 64 years of age at training. The mean age of the individuals in the training sample was 72.78 years (range = 64–94;  $SD = 6.25$ ); the mean level of education was 14.63 years (range = 7–20;  $SD = 2.76$ ). For the two abilities trained, 150 individuals were trained on inductive reasoning (age,  $M = 72.26$ ,  $SD = 5.62$ ; education,  $M = 14.43$ ,  $SD = 2.75$ ) and 185 were trained on spatial orientation (age,  $M = 73.19$ ,  $SD = 6.71$ ; education,  $M = 14.79$ ,  $SD = 2.76$ ).

### *SLS Training Study Design*

We based the participants' assignment to treatment group, inductive reasoning or spatial orientation training, on their prior performance on the Primary Mental Ability (PMA) reasoning and space tests (Thurstone, 1948; see Schaie & Willis, 1986 for a discussion of training design). Our statistical definition for decline was one standard error of measurement (that is, 1 *SE*) or greater (Space test = 6 raw points; Reasoning test = 4 raw points) from the score 14 years prior to training (Dudek, 1979; Schaie & Willis, 1986). If the participant's score on reasoning or space had decreased by 1 *SE* or more over the 14 years prior to training, then we considered the participant to have declined on that ability; we defined participants with less than 1 *SE* change as stable on that ability. We assigned participants declining on only one ability to training on that ability (the ability that had experienced decline). If the participants had declined or remained stable in both abilities, we randomly assigned them to a training group. See Table 1 for descriptive information on the sample, separated by treatment group and change status (stable or decline) on reasoning ability.

### *Training Programs*

The inductive reasoning and spatial orientation training focused on content and strategies unique to the target ability. The design of the two training programs was similar in that after baseline assessment, within a 2-week period, participants completed five 1-hr training sessions in their homes. We randomly assigned the participants to a trainer so that each trainer had approximately equal numbers of stable and decline participants in each training program.

*Inductive reasoning training.*—Inductive reasoning involves an individual's ability to recognize novel patterns and to effectively use these patterns to solve similar problems. Inductive reasoning is important for older adults because it has been shown to be a significant correlate of performance on tasks of daily living, such as interpreting labels on medicine bottles or household goods (Willis, 1987; Willis & Schaie, 1986). Experimenters taught participants to identify pattern-description rules and use them to solve subsequent problems through modeling, feedback, and practice procedures. The practice problems had the same pattern rules, but they were not identical to test items.

Table 1. Total Sample Descriptive Information by Training Group and Prior Cognitive Status (N = 335)

Sample Information	Reasoning Training			Spatial Orientation Training			Total		
	Stable	Decline	Total	Stable	Decline	Total	Stable	Decline	Total
N	94	56	150	155	30	185	249	86	335
Age	71.63 (5.45)	73.32 (5.78)	72.26 (5.62)	72.67 (6.33)	75.90 (7.99)	73.19 (6.71)	72.28 (6.02)	74.22 (6.70)	72.78 (6.25)
Education	14.32 (2.84)	14.60 (2.61)	14.43 (2.75)	14.85 (2.80)	14.50 (2.61)	14.79 (2.76)	14.65 (2.82)	14.57 (2.60)	14.63 (2.76)
Reason A Pr	19.22 (4.87)	18.25 (5.07)	18.86 (4.95)	21.20 (5.18)	16.18 (5.13)	20.39 (5.48)	20.45 (5.15)	17.53 (5.16)	19.70 (5.30)
Reason A Pt	20.71 (5.05)	20.25 (5.64)	20.54 (5.26)	21.46 (5.68)	18.07 (6.18)	20.91 (5.88)	21.18 (5.45)	19.49 (5.89)	20.74 (5.61)
Reason omit Pr	2.10 (2.27)	2.55 (2.51)	2.27 (2.36)	1.80 (2.15)	1.78 (1.81)	1.80 (2.09)	1.91 (2.19)	2.28 (2.31)	2.01 (2.23)
Reason omit Pt	1.43 (1.47)	1.34 (1.94)	1.39 (1.65)	1.73 (1.78)	1.40 (1.96)	1.68 (1.81)	1.62 (1.67)	1.36 (1.93)	1.55 (1.75)
Reason right Pr	13.87 (5.75)	12.23 (4.64)	13.26 (5.40)	16.45 (6.27)	11.00 (4.91)	15.57 (6.38)	15.48 (6.19)	11.80 (4.74)	14.53 (6.06)
Reason right Pt	17.93 (5.56)	17.36 (5.77)	17.71 (5.63)	17.07 (6.47)	13.77 (6.30)	16.54 (6.54)	17.39 (6.15)	16.10 (6.17)	17.06 (6.17)
Reason wrong Pr	3.25 (2.80)	3.46 (2.78)	3.33 (2.78)	2.95 (2.83)	3.40 (2.11)	3.02 (2.72)	3.06 (2.82)	3.44 (2.55)	3.16 (2.75)
Reason wrong Pt	1.36 (1.33)	1.55 (1.39)	1.43 (1.35)	2.66 (2.50)	2.90 (2.29)	2.70 (2.46)	2.17 (2.22)	2.02 (1.86)	2.13 (2.13)
Change accuracy	2.76 (2.82)	3.47 (3.08)	3.02 (2.93)	0.25 (2.37)	1.49 (2.62)	0.45 (2.45)	1.20 (2.82)	2.78 (3.06)	1.60 (2.96)
Change speed	1.29 (2.97)	1.66 (2.62)	1.43 (2.84)	0.37 (2.75)	1.27 (2.03)	0.51 (2.66)	0.72 (2.86)	1.52 (2.42)	0.92 (2.77)

Notes: Pr = pretest (prior to training); Pt = post-test (after training); A = attempts. Stable and Decline refer to cognitive status within the 14 years prior to training. The criterion of one standard error of measurement was used to designate participants as stable or having declined.

*Spatial orientation training.*—Spatial orientation involves an individual’s ability to mentally rotate abstract figures in either a two- or three-dimensional object space. This ability is important for older adults because certain everyday situations require the ability to visualize different types of directions. For the PMA spatial orientation test, participants must be able to identify which of the six drawings present is a correct (not mirror image) rotation of the target drawing. Each practice problem was developed to represent the angle of rotation identified in the task analysis (45°, 90°, 135°, 180°, 225°, 270°, and 315° of rotation). To simulate test questions, we had participants practice with common everyday figures. Rotating items manually, rotating items mentally, generating names for abstract figures, and focusing on two or more features of the figure during rotation were the strategies emphasized in training. We chose all of these strategies because they had been identified in prior descriptive research on mental rotation ability (Cooper, 1975; Cooper & Shepard, 1973; Egan, 1981; Kail, Pellegrino, & Carter, 1980).

**Measures**

*Dependent variables.*—We administered the PMA inductive reasoning and spatial orientation measures as part of the larger cognitive battery at pretest and post-test. The inductive reasoning measure consists of 30 test items with a 6-min time limit. We derived four component scores for this measure: number of correctly answered items, number of incorrectly answered items, number of omitted items, and total number of items attempted (sum of right answers and wrong answers). The means and standard deviations presented in Table 1 demonstrate that participants were not performing at floor or ceiling level, suggesting that improvement from training was possible. The dependent variables in this study are pretest-to-post-test changes in accuracy and change in number of items attempted on the inductive reasoning measure.

*Change in accuracy.*—We computed an accuracy score for the baseline reasoning measure as the proportion of attempted answer choices marked correctly (reason correct/reason attempts). We computed an expected accuracy score at post-

test, assuming that level of accuracy remained constant across the two occasions. The expected accuracy score is the proportional accuracy at baseline (reason correct pretest/reason attempts pretest) multiplied by the number of items attempted at post-test. We computed the pretest-to-post-test accuracy change score as the observed correct post-test responses minus the expected accuracy score at post-test. The use of expected accuracy to calculate the accuracy change score corrects for increased accuracy that is simply due to attempting a different number of items, thus providing a more precise representation of accuracy change.

*Change in attempts.*—We computed the change in attempted items by subtracting the change in accuracy score (already described) from the observed change score of correct responses (reason correct post-test – reason correct pretest). In this way we account for the change in number of items attempted per unit time while taking into account accuracy changes.

*Independent variables.*—We included age and education at pretest as covariates. The predictor variables were gender, prior cognitive status (stable or decline on inductive reasoning ability), training group (reasoning, spatial orientation), and chronic disease status. We obtained the demographic variables of age, education, and gender from the Life Complexity Inventory (Gribbin, Schaie, & Parham, 1980).

We examined the influence of five chronic diseases on training effects in this study: diabetes, hypertension, heart disease, cerebrovascular disease, and osteoarthritis. We recruited participants in the SLS through their membership in a health maintenance organization, and medical records of participants’ health care, including illnesses or medical conditions identified and treated in outpatient and hospital visits, were available. We coded diseases according to the codes provided in the eighth or ninth edition of the *International Classification of Diseases* (ICD-8 or ICD-9; the eighth edition was used until 1984, and the ninth edition was used thereafter; see U.S. Public Health Service, 1968). See the Appendix for ICD-8 and ICD-9 disease codes. For each chronic disease, we used a dichotomous variable indicating presence or absence of the disease during the 14-year period (14 years prior to training

and training interval). That is, we examined chronic diseases for exhibited a greater magnitude of accuracy change than did

(1984–1998). Prevalence rates for our sample were as follows:

0% of the individuals had diabetes, 46% had hypertension, 40%

*Inductive reasoning estimate      Answers for the invasion*

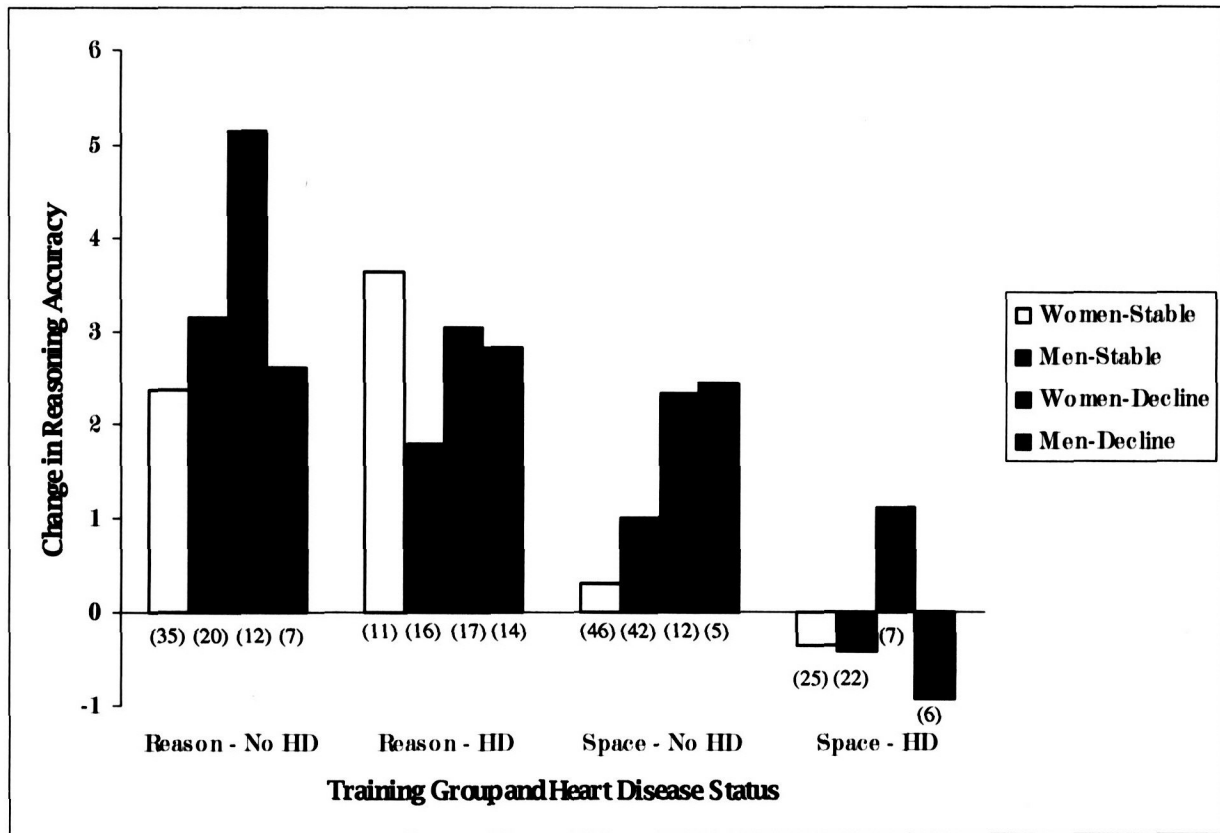


Figure 1. Change in reasoning accuracy by training group, heart disease (HD) status, prior cognitive status, and gender. (Note that  $N = 297$ ; the number of participants in each condition is shown in parentheses.)

post hoc analyses using Tukey's honestly significant difference for unequal sample sizes. In all post hoc comparisons for the significant four-way interaction, greater accuracy gain was shown by the reasoning-trained group (compared with the space-trained group); for those who declined on reasoning prior to training; by women; and for those with no HD diagnosis.

Figure 1 presents the change in accuracy for the various groups represented in the four-way interaction. The largest gains in accuracy were shown for the two groups of women trained on reasoning. The greatest magnitude of gain was exhibited by women trained on reasoning who had declined in the previous 14 years and did not have a diagnosis of HD. Notably, women trained on reasoning who had a diagnosis of HD and had not declined prior to training showed comparable gain with men and women with no HD diagnosis and who had not declined prior to training. In contrast, men and women in the space comparison group with a prior HD diagnosis and who had shown stability on reasoning prior to training actually demonstrated a decline in accuracy within the brief interval from pretest-to-post-test. It is important to note that the results from these analyses should be interpreted with caution because of the small cell sizes present when all grouping variables are incorporated.

*Inductive reasoning attempts.*—Neither the main effect of HD diagnosis nor any interactions with the additional grouping variables reached statistical significance with or without the inclusion of covariates for number of attempts.

*Impact of comorbid conditions.*—Although four of the five chronic diseases investigated did not significantly impact change in reasoning accuracy or attempts when investigated individually, we examined whether comorbidity had an effect. Approximately 18% of the individuals in the sample had none of the chronic diseases we investigated, whereas 37%, 26%, and 19% had one, two, or three or more conditions, respectively. We combined individuals with between three and five conditions into one group for the purposes of analyses, because the proportion of individuals with four or five chronic diseases was small. A 2 (training group)  $\times$  2 (gender)  $\times$  2 (prior cognitive status)  $\times$  4 (comorbidity) ANCOVA revealed that comorbidity significantly interacted with training group, gender, and prior cognitive status for change in accuracy,  $F(3, 261) = 3.48, p = .017, \eta^2 = 0.038$ . The greatest magnitude of gain was exhibited by reasoning-trained women who had declined prior to training and had no incidence of chronic disease. Comorbidity was not influential for number of items attempted.

**DISCUSSION**

In the current study we sought to investigate the aspects of inductive reasoning ability most responsive to training as well as the person characteristics, such as chronic disease, associated with training gain. Results indicated that although both accuracy and number of items attempted on reasoning tasks

were affected by training, a greater magnitude of change was evident for accuracy. Prior to the inclusion of chronic disease, only training group (reasoning training), prior cognitive status, and education were associated with greater positive change in accuracy. Decline in cognitive status and lower education were also associated with greater change in attempts. With the addition of HD status, the interaction of training group, gender, prior cognitive status, and chronic disease was associated with change in accuracy but not change in number of attempts.

In regard to the aspects of inductive reasoning ability most responsive to training, we examined two hypotheses regarding the role of attempts and accuracy. The primary effect of training was due to increased accuracy, suggesting that the reasoning-trained participants not only answered more items as a function of training but also specifically answered more items correctly. This current study supports and extends prior research by Saczynski and colleagues (2002) on the effectiveness of increased strategy use. Within the SLS training study, Saczynski and colleagues found that strategy use was associated with increased pretest-to-post-test gain in inductive reasoning scores. Our study extends these findings, because training gain can primarily be attributed to improved accuracy. Thus, training on the strategies employed in the SLS contributes to improved accuracy on inductive reasoning ability.

Our second objective in the current study was to investigate person characteristics associated with change in accuracy and number of items attempted on reasoning performance. The significant education covariate and the main effect of prior cognitive status support previous research findings. Lower functioning individuals (specifically those with lower education), and those functioning at a lower baseline level as a result of decline in ability, experienced a greater magnitude of change in accuracy as a result of training than did higher functioning individuals (Schaie & Willis, 1986; Willis & Nesselrode, 1990). In addition, although older adults of all ages have evidenced benefits from cognitive training, younger age has been associated with a greater magnitude of change (Ball et al., 2002; Willis & Nesselrode, 1990). In the current study, age was only influential for changes in number of attempts and not for accuracy, reiterating that older adults of all ages can and do benefit from cognitive training.

The additional person characteristic investigated, chronic disease, is a unique contribution to the literature. Few studies have examined the impact of chronic disease on cognitive training outcomes, and much of the prior literature on the relation between health and cognition has depended on self-report. Because of the design of the SLS and the recruitment through a health maintenance organization, we assessed the incidence of chronic disease through medical records rather than self-report. Therefore, to contribute further to the cognitive training literature, we included chronic disease as a longitudinal predictor.

Findings from the current study revealed the impact that HD has on improving accuracy through cognitive training. First, the main effect of HD demonstrated that those individuals with no diagnosis prior to training showed greater gain in accuracy. However, the four-way interaction suggests that the impact of HD may be moderated by gender and prior cognitive status. Reasoning-trained women without HD who had declined in the 14 years prior to training experienced the greatest magnitude of change in accuracy. This is consistent with prior research

demonstrating that individuals showing prior decline have more room for improvement.

Older women with HD who had remained stable also demonstrated a significant magnitude of change. There are several factors that could contribute to an understanding of this finding. Women tend to develop HD at a later age than men do (Rossouw, 2002) and may be at an earlier stage in the disease, thus having more reserve capacity (than older men) to profit from training. Although these women had HD at the time of training, the negative cumulative effects of HD may not have been manifested in their cognitive performance. In addition, there are gender differences in life expectancy (Hooyman & Kiyak, 2002). Men with or without HD may be closer to death (or in terminal decline) than women. It must be emphasized that these findings apply to accuracy, not to attempts in relation to reasoning performance.

There was not a training effect for accuracy or attempts associated with the other four chronic diseases, that is, hypertension, osteoarthritis, cerebrovascular disease, and diabetes. There are possible explanations. Cardiovascular disease is the leading cause of death for adults (American Heart Association, 2001), and thus a greater number of participants had HD than diseases such as diabetes or cerebrovascular disease. The strongest relationships between cognition and disease have been shown for HD. Research on the relationship between hypertension and cognitive change is contradictory (Elias et al., 1995; Elias, Robbins, Elias, & Streeten, 1998), but HD has consistently been shown to have a negative effect on cognition. In addition, diabetes has demonstrated a negative relationship with cognitive ability, but these effects are typically observed long term as a result of the cumulative impact of the disease (Arvanitakis et al., 2004; Fontbonne et al., 2001; Ryan, 2001). The healthy nature of the individuals in the SLS sample may also have contributed to limited associations between disease and training effects. However, it should be highlighted that comorbidity was associated with less gain in accuracy. Thus, the cumulative effects of multiple chronic diseases in various stages on cognitive training and plasticity may be an important avenue for future research.

There are limitations to the present study that must be acknowledged. The individuals in the sample consisted primarily of independently functioning Caucasian persons from a geographically restricted area. Participants were screened on the basis of reports from the individual's physician to ensure that they did not suffer any known physical or mental disabilities that would interfere with their participation in the study. Furthermore, each participant must have participated in the SLS for at least 14 years prior to the current study. Finally, although chronic disease was present in our sample of older adults, the majority of individuals were unburdened by comorbid chronic disease. All of these factors led to a select sample, which limits the generalizability of the results.

Findings from this study support future research in the area of cognitive intervention and the gains associated with it. These results have demonstrated that improved accuracy is the primary mechanism attributable to producing training gain; this provides evidence regarding the utility of training on strategies, such as those used in the SLS, to increase accuracy in inductive reasoning ability. Engaging in cognitive training to maintain, remediate, or improve inductive reasoning ability in

older adulthood can contribute to sustained independence. Further highlighting the relevance of inductive reasoning, fluid ability has been linked to everyday problem solving in daily life (Willis, Jay, Diehl, & Marsiske, 1992; Willis & Marsiske, 1991; Willis & Schaie, 1986).

One of the main themes of cognitive intervention studies is to understand the plasticity of cognitive declines associated with the aging process so that interventions can be implemented to address these declines. The current study provided evidence regarding possible responsiveness to cognitive interventions for older participants both with and without chronic disease. This serves as a first step toward determining how modifiable the impact of chronic disease on cognitive function in later life may be, and how chronic disease may affect plasticity. Much epidemiological research emphasizes the cumulative impact of chronic disease on cognitive ability. Thus, more research should examine responsiveness to training at different stages of these chronic diseases, and the impact of multiple chronic diseases on training gain. By understanding these processes, future researchers could investigate if training interventions are effective in delaying the negative aspects associated with chronic disease and cognitive decline.

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Appendix

International Classification of Disease Codes of Chronic Conditions

Diagnosis	ICD-8 Codes	ICD-9 codes
Diabetes		
Diabetes mellitus (adult onset)	250	250
Hypertensive disease	400–404	401–405
Malignant hypertension	400	401
Essential benign hypertension	401	401.1
Hypertensive HD	402	402
Hypertensive renal disease	403	403
Hypertensive HD and renal disease	404	404
Heart disease	410–429	410–429
Ischemic HD	410	410

