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PATTERNS OF COGNITIVE CHANGE IN INDUCTIVE REASONING ABILITY IN THE SEATTLE LONGITUDINAL STUDY: COVARIATES AND CLINICALLY MEANINGFUL OUTCOMES

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ABSTRACT

The purpose of the current study was to examine variability in the rate of change in inductive reasoning ability in older adults. Although prior research has recognized the interindividual variability in rate of cognitive change, identification of distinct groups of cognitive trajectories and profiles for these trajectories are needed. This study investigated the distinct cognitive trajectories present in three samples with varying levels of participation in structured cognitive activity. The association of health behaviors, chronic diseases, cognitive reserve and cognitive style with distinct cognitive change trajectories was also examined. Finally, the long-term outcomes for health severity, mental status, everyday problem solving, and mortality were investigated as a function of trajectory group, training group and training gain.

A sample of 422 individuals who participated in the Seattle Longitudinal Study for a minimum of 14 years and were at least 57 years of age at the baseline assessment were used in the current study. At baseline, participants had a mean age of 63.54 years and a mean education level of 14.42 years. The total sample was analyzed as three subsamples: nontrained (N=181), reasoning trained (N=118), and space trained (N=123). Nagin Mixture Modeling was employed to determine the optimal number and shape of the trajectories for the three subsamples, as well as the impact of the covariates. Analysis of covariance, Chi-square, and logistic regression analyses were utilized to investigate the clinically meaningful outcomes. Results indicated that there was significantly variability in reasoning ability over the 14-year period in each of the three samples. Those trained on inductive reasoning ability performed at comparable levels throughout the entire 14-year period, while those trained on spatial orientation ability demonstrated linear decline

trajectories differing as a function of level. The nontrained sample showed the most variability in terms of trajectory shape. Thus, these findings suggest that structured cognitive activity is helpful for the maintenance of inductive reasoning ability in older adults exhibiting normative age-related decline.

Investigation of the covariates revealed that cognitive style, particularly psychomotor speed and motor-cognitive flexibility, were consistently associated with trajectory group membership in each of the three samples. Individuals demonstrating higher levels of inductive reasoning ability throughout the 14-year period had higher levels of cognitive style at the final occasion of measurement compared to their lower functioning peers. In addition, cognitive reserve, specifically level of education and occupational status, were associated with trajectory group membership in the nontrained and reasoning trained samples. Individuals with higher levels of inductive reasoning ability had higher levels of educational and occupational attainment. These findings suggest that individuals with higher levels of inductive reasoning ability are able to adapt and respond to changes in the environment more readily, and have higher levels of cognitive reserve (as evidenced by educational and occupational levels).

Finally, everyday problem solving was the outcome most consistently associated with trajectory group membership and training group. Individuals with higher levels of inductive reasoning ability, both through trajectory group membership, and training on inductive reasoning ability, demonstrated higher levels of everyday problem solving ability. This suggests that inductive reasoning is a particularly salient cognitive ability to consider in the study of everyday problem solving.

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CHAPTER 1

Introduction

The main purpose of the current study is to examine variability in rates of cognitive change in inductive reasoning ability in older adulthood. In addition, the association of individual level variables and clinically meaningful outcomes with the different cognitive change trajectories are of interest.

Three major questions will be considered. The first question will explore the differential groups of trajectories present in three samples with varying levels of exposure to structured cognitive activity (nontrained, reasoning trained, and space trained samples). The second question will investigate the differential impact of four domains of covariates on the different trajectory groups. Specifically, chronic disease, health behaviors, cognitive reserve and cognitive style will be examined as covariates. Finally, the long-term outcomes of the different trajectory groups will be explored. Mortality, mental status, everyday problem solving, and health severity will be examined as long-term outcomes.

As individuals age, normative changes in cognitive ability are often expected. On average, beginning in the mid-60s, adults may experience normative age-related decline in fluid abilities involving abstract reasoning and speeded responses (Schaie, 1996). However, it is important to recognize that there are vast interindividual differences in rate of change as a function of both environmental and individual factors. Twin studies have even found evidence suggesting the increased impact of environment in comparison to genes on cognitive performance with age (Johansson, Hofer, Allaire, Maldonado-Molina, Piccinin, Berg et al., 2004; Reynolds, Finkel, McArdle, Gatz, Berg, & Pedersen, 2005).

Due to the vast interindividual variability in rate of cognitive change present in the older adult population, there is growing recognition of the need to identify groups of individuals with different change trajectories and to develop profiles of these trajectories. Determining subgroups of trajectories is important for eventually understanding the impact of differential cognitive change on everyday life. Individual levels of plasticity and reserve capacity also impact the magnitude of cognitive change in older adulthood (Baltes, 1987; Kliegl & Baltes, 1987; Kliegl, Smith, & Baltes, 1986). Engagement in activities such as cognitive training programs can serve to exercise older adults' levels of plasticity, in turn impacting their cognitive trajectories (Ball et al., 2002; Schaie& Willis, 1986; Willis & Nesselroade, 1990). Numerous researchers have demonstrated the modifiability of fluid performance, specifically inductive reasoning, in non-demented older adults (Baltes, Kliegl, & Dittmann-Kohli, 1988; Blieszner, Willis, & Baltes, 1981; Hayslip, 1989; Schaie & Willis, 1986; Willis & Schaie, 1986). Thus, investigation of the groups of cognitive trajectories as a function of structured cognitive activity is of interest.

Examination of the domains associated with different trajectories of cognitive change is meaningful in order to provide descriptive information regarding what individual level variables are most influential in rate of cognitive change. Prior research has demonstrated that the four covariates included in this study are associated with normative age-related cognitive change. The negative impact of chronic diseases such as diabetes, hypertension, heart/cerebrovascular disease, and osteoarthritis on cognitive ability has been well documented (Anstey & Christensen, 2000; Arvanitakis, Wilson, Bienias, Evans & Bennett, 2004; Elias, D'Agostino, Elias & Wolf, 1995; Gruber-Baldini, 1991; Ryan, 2001). Practicing positive or proactive health behaviors such as exercise (Blumenthal & Gullette, 2002; Clarkson-Smith & Hartley, 1989; Colcombe & Kramer, 2003), diet (Correa Leite, Nicolosi, Christina, Hausner, & Nappi, 2001; Morris, Evans, Bienias, Tangne, & Wilson, 2004), and medical and dental check-ups (Belloc & Breslow, 1972) have shown positive associations with cognitive ability. Protective factors such as higher levels of educational and/or occupational attainment (Cagney & Lauderdale, 2002; Gilleard, 1997; Lee Kawachi, Berkman & Grodstein, 2003), and engagement in cognitively stimulating activities (Hultsch, Hertzog, Small, & Dixon, 1999; Lang, Rieckmann, & M. Baltes, 2002) have demonstrated positive associations with cognitive change. Finally cognitive style, or the ability to adapt and respond to changes, has been positively associated with inductive reasoning ability in prior research (Schaie 1984; 1996; 2004). Investigating these domains already associated with level and/or rate of cognitive change will provide meaningful information on the degree to which these variables differentially impact the various cognitive change trajectories.

Finally, much of the training research has demonstrated the efficacy of the training on proximal measures to the ability trained. However, research on transfer to more clinically meaningful outcomes, such as problem solving, mental status, health severity, and mortality is limited. Prior research has demonstrated associations between level of fluid or inductive reasoning ability and health severity (Chodosh, Seeman, Keeler, Sewall, Hirsch, Guralnik, & Reuben, 2004; Kavanaugh & Knapp, 2002), mental status (Raykov, Baltes, Neher, & Sowarka, 2002; Yesavage, 1982), everyday problem solving (Allaire & Marsiske 1999; 2002; Willis & Marsiske, 1991), and mortality (Smits, Deeg, Kriegsman, & Schmand, 1999; Wilson, Beckett, Cienias, Evans, & Bennett, 2003). However, because not all older adults were exposed to training or benefited equally from cognitive training, investigating the impact of varying levels of structured cognitive activity and cognitive trajectories, training group, and training gain is necessary. This will provide information on the practical, real-world, and long-term implications of individual cognitive activity, structured global cognitive activity, and targeted cognitive training.

CHAPTER 2

Review of the Literature

Although normative age-related declines in cognitive functioning in older adults occur, many older adults are able to live independently in the community. One of the most critical cognitive abilities in the maintenance of independence is inductive reasoning ability. Many of the instrumental activities of daily living associated with the maintenance of independence (IADLs; Lawton & Brody, 1969) involve inductive reasoning ability. Not all individuals living independently experience the same rate of cognitive change in inductive reasoning ability, and individuals also vary in the level of cognitive ability prior to the onset of decline. This variability in reasoning functioning results in individuals having developmental trajectories that vary in slope and/or level. Profiling these distinct developmental trajectories of inductive reasoning ability is an important first step towards studying the covariates and outcomes associated with the different trajectories. A major aim of this study is to examine variability in cognitive change trajectories, specifically those for inductive reasoning ability.

This review of the literature will address four major issues related to inductive reasoning ability in adulthood. First, the construct of inductive reasoning ability will be considered both with regard to a psychometric approach to intelligence and secondly with regard to executive functioning which is based on a neuropsychological approach to cognition. Second, the literature on developmental cognitive change in older adulthood, including variability in rates of change, non-normative rates of change, and the impact of plasticity and reserve capacity on rates of change will be reviewed. Third, several individual-level characteristics associated with change in inductive reasoning ability will be considered. Cognitive training status, chronic diseases, health behaviors, cognitive reserve/engagement, and cognitive flexibility are the domains that will be examined in relation to different change trajectories of inductive reasoning ability. Finally, the relation of four clinically meaningful outcomes, everyday problem solving ability, mental status, health severity, and mortality to different change trajectories and to training status will be studied.

Reasoning Ability in Older Adulthood

The construct of inductive reasoning is represented in various approaches to the study of cognitive functioning. In this section, the construct of inductive reasoning is considered from two major approaches, a psychometric abilities perspective and in relation to neuropsychological assessment. Within a psychometric approach, inductive reasoning is viewed as one of the most important abilities in the broader domain of fluid intelligence.

Inductive Reasoning: A Psychometric Ability

The basic cognitive abilities comprising the psychometric perspective have been referred to as the "building blocks" of competence in a continuum from basic cognitive ability to complex tasks associated with everyday competence (Allaire & Marsiske, 1999; Willis, 1996). Inductive reasoning involves the ability to recognize, understand, and analyze novel concepts and to use these skills to solve subsequent problems. This requires identifying patterns or rules and applying these rules to solution of a problem (Schaie, Willis, Hertzog, & Schulenberg, 1987; Sternberg, 1988). Verbal meaning, inductive reasoning, numeric ability, spatial orientation, and word fluency are the five psychometric abilities associated with a Thurstonian approach to psychometric intelligence (Schaie, 1996; Thurstone, 1948). From a hierarchical perspective, these abilities can be conceptualized as involving two second-order domains of fluid and crystallized intelligence (Cattell, 1971; Horn & Hofer, 1992) or, more recently described as, the mechanics and pragmatics of intelligence (Baltes, Dittman-Kohli, & Dixon, 1984). Basic cognitive operations are encompassed under the fluid-like mechanics of intelligence including the perception of relationships, classification, and logical reasoning. In contrast, the crystallized pragmatics can be understood as the kind of knowledge and information that cultures offer about the world and human affairs, and that developing individuals acquire as they participate in culture-based socialization.

A Neuropsychological Perspective: Executive Functioning and Reasoning Ability

A neuropsychological approach to the study of cognitive functioning also involves study of reasoning processes. From a neuropsychological approach, the construct of executive functioning captures some of the same processes as the fluid ability of inductive reasoning within a psychometric approach (Baddeley, 1990; Shallice, 1982; Temple, 1997; Woodruff-Pak, 1997). Executive functioning refers to capacities that enable a person to engage successfully in complex, purposeful, everyday tasks. It involves the ability to carry out and regulate goal-directed behaviors in order to interact in a socially appropriate manner (Lamar, Zonderman, & Resnick, 2002; Rabbitt, 1997). Examples of executive functioning include dealing with novelty, initiation, planning, problem solving, working memory, self-monitoring (i.e., inhibition), and conscious goal-directed behavior (Rabbitt, 1997). Although executive functioning ability is important for most problems encountered in daily life, its importance is particularly pertinent for situations involving novel information. In these instances, planning and implementing strategies, adjusting behavior based on feedback, inhibiting inappropriate or irrelevant behaviors and/or information, and maintaining vigilance are the behaviors that result in successful outcomes and solutions (Bryan & Luszcz, 2000).

Rate of Cognitive Change in Fluid Abilities

Much prior research has focused on determining what constitutes the normative rate of cognitive change in fluid ability in later adulthood. Three areas related to study of cognitive change will be considered: (1) variability in rate of normative cognitive change, (2) variation in rates of cognitive change with cognitive impairment, and (3) the relevance of plasticity and reserve capacity in the consideration of cognitive change.

Variability in rate of cognitive change in fluid abilities. Fluid abilities involve processes such as reasoning, concept formation, and problem solving and are typically assessed by measures of abstract reasoning, figural relations, memory, and speed (Cattell, 1963; 1968; 1971; Horn, 1970; 1976; 1978). Decline in the psychometric abilities associated with fluid intelligence is evident with increasing age with reliable change first noted in the sixties (Finkel, Reynolds, McArdle, Gatz, & Pedersen, 2003; Hickman, Howieson, Dame, Sexton, & Kaye, 2000; Schaie, 1996; Singer, Verhaeghen, Ghisletta, Lindenberger, & Baltes, 2003).

Normative change in fluid abilities such as inductive reasoning and spatial orientation has been extensively studied within the Seattle Longitudinal Study (SLS). Schaie (1996) reported longitudinal data from the SLS that showed gain in fluid abilities, including inductive reasoning ability, in early adulthood, stability in middle adulthood, followed by gradual decline from the 60's through the 80's. In addition to the findings of

Schaie, Singer and colleagues (2003) studied longitudinal change in perceptual speed, memory, and fluency over 6 years in a sample of individuals aged 70 to 100 years. They found that individuals in their 70's showed less dramatic rates of decline than individuals in their 80's or 90's, especially for perceptual speed. In a study of twin pairs aged 80 years and older, Johansson and colleagues (2004) studied rate of cognitive change over a 6-year period. They found older age was consistently associated with increased rates of decline on all abilities measured, including the fluid abilities of inductive reasoning, perceptual speed, visuospatial ability, and memory. Wilson and colleagues (2002) studied older Catholic clergy members for up to six years. Their assessment of cognitive ability included a general measure of cognitive function (the Mini Mental Status Exam; MMSE; Folstein, Folstein & McHugh, 1975), and measures of episodic, semantic, and working memory. Wilson et al. (2002) found that although the rate of change accelerated with age, there was still significant individual variability in rate of cognitive change at all ages.

The research reported above indicates a general pattern of normative decline in fluid abilities with increasing age. However, research on interindividual variability suggests that wide individual differences in patterns of normative decline exist. In an investigation of interindividual variability in rates of cognitive change in individuals aged 70 years and older, Christensen et al. (1999) demonstrated that there was an increase in interindividual variability in change scores associated with the fluid abilities of memory, spatial functioning, and speed as a function of increasing age. Similarly, MacDonald, Hultsch, and Dixon (2003) examined performance variability in reaction time, perceptual speed, working memory, fluid reasoning, episodic memory, and crystallized verbal ability in individuals aged 55 to 89 years over a 6-year period. Results regarding variability were consistent with those of Christensen and colleagues (1999) in that the old-old group (aged 75 to 89 years) demonstrated less consistent performance in cognitive ability over successive measurement occasions. Degree of inconsistency over the three occasions of measurement was predictive of cognitive change for all abilities measured. In addition, individuals with lower levels of cognitive ability were more likely to have higher levels of inconsistency. Overall, various studies report similar findings regarding normative rates of cognitive change. However, these studies also note the considerable variability among individuals in level and rate of decline for fluid ability. This suggests that different patterns of normative cognitive change in older adulthood exist, and that further study of these different trajectories of change is needed.

Rates of cognitive change in cognitively impaired individuals. To understand the full range of variability in cognitive functioning, it is informative to compare rate of normative change with rate of decline in impaired individuals. The normative rates of cognitive change suggest gradual decline rather than rapid deterioration of fluid ability, but the onset of cognitive impairment alters the normative pattern. The normative rates of cognitive decline are exacerbated in the presence of cognitive impairment. Research has demonstrated that those who become cognitively impaired exhibit steeper rates of decline, even after years of a normative cognitive trajectory (Rubin, Storandt, Miller, Kinscherf, Grant, Moris, & Berg, 1998; Teri, McCurry, Edland, Kukull, & Larson, 1995). In addition, those with lower baseline levels of cognitive ability have been found to progress and exhibit the symptomology of cognitive impairment more rapidly. For those with initially higher levels of ability, the symptomology associated with cognitive impairment may not manifest until later, but the pathology is still present. Once a critical threshold of symptoms of cognitive impairment is evident, there is precipitous decline in cognitive ability.

Plasticity and reserve capacity. Although cognitive abilities, particularly the fluid abilities, demonstrate normative decline with increasing age, there is also evidence for plasticity and cognitive reserve. Plasticity refers to the amount of gain possible on a developmental trajectory through increased activity or exposure to an activity. Behavioral interventions are an experimental procedure for studying plasticity. Hence, one's range of plasticity is an example of reserve capacity. One's optimal potential is referred to as "reserve capacity" which focuses on the range and conditions of plasticity (Kliegl & Baltes, 1987). Reserve capacity is based on the assumption that one's potential often exceeds one's performance, with performance referring to the routine level at which an individual performs in his/her daily life. Test results usually represent one's normative level of performance given that people normally do not push themselves to their limits when performing everyday tasks. Baltes and colleagues (Baltes, 1987; Kliegl & Baltes, 1987; Kliegl, Smith, & Baltes, 1986) examined individuals' cognitive reserve potential by putting individuals under conditions that maximized their performance level, thus providing an estimate of reserve capacity. This strategy of testing the range of latent reserve capacity was termed "testing the limits." Baltes and colleagues tested this concept in the Berlin Aging study with memory training on the strategy of Method of Loci. They attempted to maximize individuals' performance by increasing the speed of presentation and increasing the number of words to be recalled. Results indicated that age differences were magnified under speeded conditions. Both younger and older adults raised their level of performance under speeded conditions; however, the mean difference in performance of young and old was greater under stressed conditions than normal testing conditions. Hence, attempting to maximize older adults' performance through increasingly speeded conditions is not an optimal approach to assess plasticity and reserve capacity. However, it is still important to consider that although older adults' performance on cognitive batteries may decline with age, their actual capacity to utilize these abilities in daily life is higher.

Summary: The Construct of Reasoning Ability and Developmental Change

The brief overview indicates that reasoning ability is broadly defined and included in the conceptualization of several different approaches to the study of cognition (psychometric abilities, fluid ability, and neuropsychology). Overall, the reviewed research has suggested that older adults experience normative age-related decline on inductive reasoning ability beginning in the sixties. There is also evidence of interindividual variability in level and rate of change. Additionally, the onset of cognitive impairment can alter the normative cognitive trajectory, resulting in an accelerated rate of decline in fluid ability. While the reviewed research has suggested considerable variability in both level of functioning and rate of decline, there has been limited research on profiling different trajectories of decline in fluid ability, including inductive reasoning. A major aim of this study is to contribute to the identification of individual differences in trajectories of change.

Person Characteristics and Change in Fluid Ability

Important in the investigation of patterns of change trajectories of inductive reasoning ability is identification of variables associated with the differential trajectories. Additionally, determining what individual variables are most salient for trajectory group membership will lead to greater understanding of the mechanisms underlying the different trajectories. The literature on associations between individual variables and level and change in fluid ability will be reviewed.

Cognitive training. The prior section on cognitive reserve has suggested that older individuals maintain at least some degree of plasticity in their abilities and can benefit from cognitive interventions. Participation in cognitive training programs is voluntary, and can thus be considered an individual or person variable. Cognitive training programs involve brief but intense periods of intellectual stimulation. Most of the cognitive training research has focused on training on fluid abilities such as reasoning or memory. This research has suggested that older individuals can significantly improve their performance on the ability trained. In the few training studies such as the SLS in which there is prior longitudinal data on subjects, there is evidence that training can partially remediate normative age-related decline on the ability trained.

Older adults trained in inductive reasoning ability have demonstrated gains as a result of the training program (Ball et al., 2002; Baltes, Sowarka, & Kliegl, 1989; Calero & Garcia-Berben, 1997; Schaie & Willis, 1986; Willis & Nesselroade, 1990). Ball and colleagues (2002) demonstrated the efficacy of reasoning training in a large randomized clinical trial. In addition to initial training effects, booster sessions were beneficial for the maintenance of the reasoning training effects. Willis and Nesselroade (1990) also demonstrated the efficacy of booster sessions in maintaining some of the effects of reasoning training. In a training study conducted in the context of the Seattle Longitudinal Study, Schaie and Willis (1986) conducted cognitive training with individuals with known prior cognitive status. Individuals were classified as having remained stable or declined as assessed by Thurstone's (1949) Reasoning and Space Primary Mental Abilities test over the 14-year period prior to training. Those who had declined on either ability were trained on that ability. The rest of the individuals were randomly assigned to one of two training groups, reasoning and spatial orientation. In addition to finding evidence of immediate training gain in both the reasoning and space training groups, 40% and 62% (respectively) of participants who had declined on the target ability achieved remediation of their cognitive ability level 14-years prior.

Reasoning training gains have also been accomplished with individuals of varying educational levels (Baltes et al., 1989; Calero & Garcia-Berben, 1997). Baltes and colleagues (1989) found comparable training gains for the tutor and self-guided figural relations training. The individuals in this study were highly educated. Calero and Garcia-Berben (1997) also found comparable training gains for self and tutor-guided inductive reasoning training programs. However, their sample included low-educated individuals; ninety-six percent of the sample had only completed elementary school.

These studies have shown that young-old, old-old, and very old adults are all capable of achieving gains of roughly comparable magnitudes, although level of ability varies by age/cohort. There has been no evidence of differential age effects for maintenance of training gains. Although training gains of the greatest magnitude are observed at immediate posttest, delayed follow-up assessment up to two and even seven years (Schaie, 1996) post-training has revealed that older adults are still performing above their pretest levels. In addition, regardless of age, older adults have been able to achieve comparable cognitive training gains for tutor and self-guided training programs.

Summary: Cognitive Training. Many cognitive training programs have demonstrated their effectiveness in improving individuals' level of fluid intelligence, specifically reasoning ability. Training programs have been efficacious for individuals with varying demographic characteristics. Thus, it does appear that the effects of cognitive training programs demonstrate considerable plasticity in older adults. In addition, because the cognitive training programs have helped older adults remediate some of the normative declines experienced, this suggests that participation in cognitive training programs may at least temporarily alter the normative cognitive trajectory of age-related decline.

Chronic Disease. Studying the impact of chronic diseases on the rate of cognitive change is essential when studying older adults due to the co-occurrence of chronological and biological aging. As the body experiences changes at the cellular level, increased incidence of chronic disease is common. Because older adults must live with chronic diseases for many years, it is important to consider the impact these diseases may have on cognitive functioning and everyday life. The current review will focus on four major categories of diseases, non-insulin dependent diabetes mellitus, hypertensive disease, heart/cerebrovascular disease, and osteoarthritis.

Diabetes. Non-insulin dependent diabetes mellitus is a chronic disease that is more prevalent in the population of adults over the age of 60. Ryan (2001) and colleagues have suggested that age of onset of diabetes may be an important factor for determining the influence on cognitive functioning. Specifically, he, along with his colleagues, suggested that younger age of onset may lead to lower risk of cognitive dysfunction. Several longitudinal studies 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; Elias et al., 1997; Fontbonne, Ducimetiere, Berr, Alperovitch, 2001; Ryan, 2001). Cross-sectional studies have also suggested that individuals with diabetes mellitus score lower on measures of cognitive ability (Bent, Rabbitt, & Metcalfe, 2000; Ryan, 2001). Most of the studies on the relation between diabetes mellitus and cognitive ability have focused primarily on fluid ability, memory, executive functions, and general cognitive ability. Research has demonstrated that of the abilities investigated, speed, memory, and attention abilities are among those impacted by diabetes mellitus in older adulthood (Arvanitakis et al., 2004; Fontbonne et al., 2001; Ryan, 2001). Elias and colleagues (1997) found that the duration of diabetes was associated with poorer performance on verbal memory and abstract reasoning abilities. Desmond, Tatemichi, Paik, and Stern (1993) also found that presence of diabetes was associated with lower scores on abstract reasoning.

There has been research on the relationship between diabetes mellitus in older adulthood and risk of cognitive dysfunction, such as cognitive impairment, dementia, or Alzheimer's disease. In a cross-sectional study of individuals over the age of 65, Sinclair Girling, and Bayer (2000) found that diabetics had a greater prevalence of cognitive dysfunction, measured by the Mini Mental State Examination and the clock-drawing test (Sunderland, Hill, Mellow, Lawlor, et al., 1989). Bruce, Harrington, Davis, and Davis (2001) found that at a three-year follow-up, there was a higher rate of dementia in older adults over the age of 70 with diabetes. Finally, Ott, Stolk, van Harskamp, Pols, Hofman, and Breteler (1999) also found that the presence of diabetes nearly doubled the risk of dementia. Furthermore, in addition to a 65% increased risk of developing Alzheimer's disease in the presence of diabetes, Arvanitakis et al. (2004) found that although individuals with diabetes mellitus had lower baseline cognitive scores on measures of general cognition, memory, perceptual speed, and visuospatial ability, they did not experience an increased rate of decline compared to their non-diabetic counterparts, except for perceptual speed. Ott and colleagues (1999) and Bent and colleagues (2000) found that although older adults with diabetes mellitus scored lower on measures of cognitive functioning, diabetics that managed their disease through drugs, as opposed to diet, tended to perform poorer than the diabetics that managed the disease primarily through diet. However, it is important to consider that individuals using medications may have had a more severe stage of diabetes.

The reviewed literature suggests that diabetes mellitus in older adulthood does impact cognitive function, and may increase the risk of cognitive decline. The longitudinal and cross-sectional research has suggested that older adults with diabetes mellitus tend to score lower on measures of cognitive ability at baseline and follow-up assessments. Less research has focused on the rate of cognitive decline associated with diabetes. From the reviewed research, it is evident that those with diabetes mellitus may have lower levels of cognitive ability at baseline, similar to those with lower levels of reserve capacity. Thus, the increased risk of cognitive impairment may operate through the same mechanism as those with lower levels of cognitive reserve, mainly earlier manifestation of the clinical symptomology. Although much research has focused on fluid abilities generally, Elias and colleagues (1997) found that the cumulative effects of diabetes impacted reasoning ability. Thus, the cognitive abilities impacted by diabetes mellitus in older adulthood may vary as a function of duration. Furthermore, the cumulative impact may differentially affect rate of change in inductive reasoning ability.

Hypertension. Another chronic disease that is common in elderly individuals is elevated blood pressure or hypertension. This is the most common chronic condition other than arthritis. Many researchers have documented the negative associations between cognitive performance and levels of blood pressure (Anstey & Christensen, 2000; Elias, Elias, & Wolf, 1995; Elias, Robbins, Elias, Streeten, 1998), and specifically hypertension (Elias, D'Agostino, Elias, & Wolf, 1995; Hertzog, Schaie, & Gribbin, 1978; Raz, Rodrigue, & Acker, 2003; Waldstein, Jennings, Ryan, Muldoon, Shapiro, Polefrone, Fazzari, & Manuck, 1996). In a meta-analysis, Anstey and Christensen (2000) found that level of blood pressure was associated with change in mental status, speed, memory, and visuospatial ability in older adults. When specifically investigating hypertension, Saxby et al. (Saxby, Harrington, McKeith, Wesnes, & Ford, 2003) found that individuals with untreated hypertension scored lower on measures of speed, executive functioning, episodic memory and working memory when compared to their normotensive (individuals with normal levels of blood pressure) peers.

There is ample evidence suggesting a negative relation between hypertension and cognitive functioning in older adulthood. Elias and colleagues (2001) stated that hypertension has a negative dose-response relationship with cognitive performance; specifically increased blood pressure levels are associated with accelerated rates of cognitive decline on measures of memory, executive function, and speed (Elias, D'Agostino, Elias, & Wolf, 1995; Elias, Robbins, Elias, & Streeten, 1998). Their prior research demonstrated that a linear relationship between cardiovascular risk factors and cognitive ability was even stronger when considering the long-term risk of cognitive decline. In a twenty-year longitudinal study, Kilander, Nyman, Boberg, Hansson, and Lithell (1998) found that diastolic blood pressure measured at age 50, was a significant predictor of lower cognitive performance on the MMSE and a measure of attention and task-switching at age 70. Concurrent blood pressure levels at age 70 were predictive of cognitive performance as well.

There is also evidence of the cumulative effects of elevated blood pressure and the impact on reasoning ability. Raz, Rodrigue, and Acker (2003) found that fluid ability performance, specifically fluid reasoning, decreased with longer duration of hypertension in a group of adults aged 30 – 77 years. Additionally, they found evidence that hypertension impacts the areas of the brain most vulnerable to aging, the white matter hyperintensities (WMH) responsible for executive functioning abilities. Findings from a 3-year longitudinal study of individuals over the age of 70 suggested that elevated blood pressure may have contributed to the higher rate of dementia found in individuals with diabetes mellitus (Bruce et al., 2001). Thus, as with diabetes, the reviewed research suggested that hypertension negatively impacts cognitive functioning in older adulthood.

Heart/Cerebrovascular Disease. Cardiovascular disease (CVD) is the leading cause of death for adults (American Heart Association, 2001). There are a number of risk factors for CVD. Several of these risk factors also increase the risk for cerebrovascular disease. Elias and colleagues (Elias, Elias, Robbins, Wolf, & D'Augostino, 2001) provided a comprehensive review of the risk factors for CVD and subsequent effects on cognitive functioning. These researchers cited blood pressure level and hypertension, diabetes, cigarette smoking, total cholesterol, low density lipoprotein cholesterol, high density lipoprotein cholesterol, age and obesity to be among the risk factors for CVD. Most research on CVD and cognitive functioning includes several of these aforementioned risk factors. Elias et al. (2001) emphasized the importance of considering multiple risk factors, stating that the risk of lowered cognitive functioning is directly related to the number of cardiovascular risk factors present. This suggests that the presence of one or more risk factors may accelerate the normative rate of cognitive decline.

The cross-sectional literature has demonstrated that there is a relationship between cardiovascular risk factors and lower levels of cognitive function. Morris, Scherr, Hebert, Bennett, Wilson, Glynn, and Evans (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 CVD, stroke, heart disease, hypertension, and diabetes amplified this relationship. Fahlander et al. (2000) also demonstrated that cardiovascular symptoms were associated with poorer cognitive performance on measures of episodic memory, verbal fluency, and visuospatial skill.

Longitudinal investigations have provided evidence suggesting the negative cumulative effects of cardiovascular risk factors on cognitive ability. In a six-year longitudinal study, Hassing and colleagues (2002) found that when controlling for stroke and markers of CVD, lower performance on visuospatial ability, episodic memory, and speed was still predictive of mortality. However, this relationship was not present for crystallized knowledge and inductive reasoning, suggesting that the presence of cardiovascular risk factors, specifically stroke and markers of CVD, alter the relationship between level of cognitive ability and mortality. Verhaeghen, Borchelt, and Smith

(2003) found that individuals who had cardiovascular risk factors at baseline were more likely to have lower cognitive scores on perceptual speed, episodic memory, fluency, and knowledge four years later than those who developed the risk factor(s) throughout the study or those who never developed risk factors. This suggests that the impact of cardiovascular risk factors on cognitive ability is not immediate, but rather cumulative. Elias et al. (1998) also found evidence for the cumulative effects of cardiovascular risk factors on cognitive ability. Using an average level of blood pressure was demonstrated to be a better predictor of cognitive ability compared to baseline blood pressure level alone.

Cross-sectional and longitudinal studies have produced mixed findings regarding the differential impact of cardiovascular risk factors on individuals of varying ages. Cross-sectional studies have suggested that older individuals show less cognitive impairment on mental status, numeric ability, and working memory measures as a result of blood pressure level and stroke when compared to their younger counterparts (total sample aged 70 to 103; Zelinski et al., 1998). In individuals aged 75 to 96 years of age, Fahlander et al. (2000) found that cardiovascular symptoms accounted for more of the age-related variance in episodic and visuospatial ability than in verbal ability. However, in a longitudinal study, Elias et al. (1998) demonstrated that there was not an age by blood pressure level or an age by hypertension interaction for verbal ability, visualization performance, memory span, or speed. Controlling for systolic blood pressure levels did account for more age-related variance than any other indicator of blood pressure level. Elias et al. (1995) found that age increased the odds of poor performance more than blood pressure in older adults (aged 55 to 88 years).

Although the percent of variance in cognitive ability accounted for in the cardiovascular risk factors was very small (usually less than 1%), the implications are still clinically meaningful; the impact is large enough to result in statistically significant rates of cognitive decline. Individuals with cardiovascular risk factors typically have lower cognitive scores. The evidence from Verhaeghen and colleagues (2003) and Elias et al. (1998) suggested that the impact of the risk factors is not immediate, but rather accumulates over time.

Osteoarthritis. Although there is a high prevalence of osteoarthritis in the older adult population, there is limited research on the association between osteoarthritis and rate of change in cognitive ability. Through latent growth curve analysis, Gruber-Baldini (1991) found that individuals with osteoarthritis had lower functioning and greater rates of decline on the abilities of inductive reasoning, spatial orientation, and verbal meaning. However, logistic regression analyses indicated that the onset of significant decline on inductive reasoning ability was later. Gruber-Baldini (1991) also investigated whether the effects of arthritis differed as a function of age of onset. Latent growth modeling indicated that individuals with arthritis before age 60 had lower levels and experienced greater decline on inductive reasoning ability than those individuals with arthritis after age 60. Thus, despite the limited research on the association between osteoarthritis and cognitive change, the reviewed literature suggests that osteoarthritis negatively impacts reasoning ability. Furthermore, it appears that the cumulative effects of the duration of osteoarthritis impact rate of change on inductive reasoning ability.

Summary: Chronic diseases. The four chronic disease categories reviewed revealed several common themes. First, diabetes mellitus, hypertension, heart/cerebrovascular disease, and osteoarthritis each demonstrated negative associations with level of cognitive ability and cognitive change. Presence of the chronic disease was consistently associated with lower levels of cognitive ability. Second, despite the fact that few studies investigated the cumulative effects of the chronic diseases on cognitive ability, those that did found that the cumulative impact of each of the chronic diseases was more deleterious with increased duration. Finally, although most of the studies reported controlled for or excluded individuals with comorbid conditions, the literature acknowledged that it is usually unlikely that any one of these chronic diseases exists in the absence of any other disease in older adults. Most older adults have comorbid conditions, thus comorbid conditions need to be incorporated when investigating rate of cognitive change.

Health Behaviors. Health behaviors consist of risk or preventative behaviors that influence an individual's health (Kirscht, 1983). Although the impact of health behaviors on cognitive ability has not been widely studied, research in this area is growing due to investigation of behaviors such as exercise, diet, and disease management. Exercise, diet, food preparation, and medical and dental check-ups have been identified in the literature as critical behaviors for prevention or health maintenance. These are the five health behaviors that will be reviewed.

Food Consumption and Preparation. In general, a healthier diet has been found to be positively associated with cognitive ability in older adulthood (Correa Leite, Nicolosi, Christina, Hauser, & Nappi, 2001; La Rue, Koehler, Wayne, Chiull, Haaland, & Garry, 1997; Ortega, Requijo, Andres, Lopez-Sobaler, Quintas, Redondo, Navia, & Rivas, 1997). Specifically, higher intake of carbohydrates and potassium, fruits and vegetables, and lower intake of saturated fats have been found to be associated with better general cognitive scores in older women aged 59 – 85 years (Brownbill & Ilich, 2004). In a 6-year longitudinal study of individuals over the age of 65, Morris and colleagues (Morris, Evans, Bienias, Tangney, & Wilson, 2004) found that intake of larger amounts of saturated and transunsaturated fat was associated with cognitive decline in general cognitive ability, memory, perceptual speed and attention. Intake of monounsaturated and polyunsaturated fats was inversely related to cognitive performance. In the Rotterdam Study, Bonarek, Barberger-Gateau, Letenneur, Deschamps, Iron, Dubroca, et al (2000) found that high intake levels of saturated fat were associated with an increased risk of dementia.

The impact of caffeine on cognitive ability has also been investigated. Overall, the results have suggested that caffeine has neither a positive nor a negative impact on the rate of cognitive change with age (Hameleers, van Boxtel, Hogervorst, Riedel, Houx, Buntinx, & Jolles, 2000; Schmitt, Hogervorst, Vuurman, Jolles, & Riedel, 2003; Smith, Brice, Nash, Rich, & Nutt, 2003; van Boxtel, Schmitt, Bosma, & Jolles, 2003). In a 6-year longitudinal study of individuals aged 24 to 81 years, van Boxtel and colleagues (2003) found evidence for a small, but significant association between caffeine intake and complex motor speed. However, they concluded that the effects of caffeine intake are minimal and will not result in attenuation of age-related cognitive decline. Hameleers and colleagues (2000) also reported a lack of evidence for caffeine counteracting the effects of cognitive aging in individuals aged 24 to 81 years.

Exercise. A health variable that has received considerably more attention in recent decades is physical fitness (Blumenthal & Gullette, 2002; Clarkson-Smith &

Hartley, 1989; Emery & Blumenthal, 1991; Shay and Roth, 1992). Research has sought to not only investigate the relation between level of physical fitness and cognitive ability, but more recently has examined the efficacy of exercise training programs on cognitive ability (Colcombe & Kramer, 2003). To measure level of physical fitness some researchers have relied exclusively on self reported activity levels. However, most researchers also employ objective criterion or measures to determine fitness level.

Summary articles have stated that the consensus of cross-sectional research indicates older exercisers perform better on cognitive assessments than older non-exercisers (Blumenthal & Gullette, 2002; Emery & Blumenthal, 1991). Research conducted on the relation between fitness level and cognitive ability has indicated that although an association is present, it varies by ability. Shay and Roth (1992) found the older "fit" individuals (aged 60 – 73 years) performed better on visuospatial ability than their less fit peers. Clarkson-Smith and Hartley (1989) demonstrated that the high exercise group was more physically fit and performed superior on the tasks of reasoning, working memory, and reaction time.

Overall, longitudinal studies concurred that physical fitness provides some protective benefit from cognitive decline. Baseline fitness level was found to be associated with two-year (Albert, Jones, Savage, Berkman, Seeman, Blazer, & Rowe, 1995) and six-year changes (Barnes, Yaffe, Satariano, & Tager, 2003) in cognitive ability. In both studies, lower baseline levels of fitness were associated with greater detrimental cognitive change. Laurin, Verreault, Lindsay, MacPherson, and Rockwood (2001) demonstrated a dose-response effect between level of exercise and five-year predictions of cognitive impairment. Individuals rated as normal at the five-year follow-up were more likely to have reported higher levels of exercise at baseline than the individuals rated as cognitively impaired but not demented (CIND), or suffering from dementia or Alzheimer's disease. In addition, individuals who had died before the follow-up had similar exercise levels to the individuals with CIND, dementia, or Alzheimer's disease.

Thus, maintaining physical fitness throughout older adulthood does appear to impact cognitive ability; physically fit older adults tend to have higher baseline levels of cognitive ability suggesting elevated levels of reserve capacity. The literature suggests that physical or aerobic fitness does provide a protective benefit for the onset of cognitive decline (Albert et al., 1995; Barnes et al., 2003; Laurin et al., 2001). Although it is unclear whether physical fitness can slow the normative cognitive trajectory of decline, it can provide protective effects for the onset of cognitive impairment.

Medical and Dental Check-ups. The benefits of preventative health behaviors are not limited to young individuals. Preventative health behaviors have a cumulative effect on health (Belloc & Breslow, 1972) regardless of age. Belloc and Breslow (1972) concluded that older individuals who have practiced persistent positive health behaviors during their lifespan could have the same health status as individuals that are thirty years younger than themselves. Due to the cumulative effects, it may be relevant to consider duration of health behaviors to obtain a more accurate estimate of positive and negative effects. Engagement in medical check-ups serves as a preventative measure against onset or increase in severity of chronic disease such as heart disease (Almeida & Flicker, 2001; Rabbitt, Watson, Donlan, McInnes, Horan, Pendleton, & Clauge, 2002; Seeman, McEwen, Rowe, & Singer, 2001), chronic obstructive pulmonary disease (Fioravanti, Nacca, Amati, Buckley, & Bisetti, 1995; Incalzi, Gemma, Marra, Muzzolon, Capparella, & Carbonin, 1993), diabetes (Jackson-Guilford, Leander, & Nisenbaum, 2000; McCarthy, Lindgren, Mengeling, Tsalikian, & Engvall, 2002), and pneumonia (Iwamoto, Shimizu, Ami, Yoneda, Imamura, & Takasaki, 2000; Medina-Walpole & McCormick, 1998). All of these conditions can negatively affect cognitive competence. With proper health care utilization, the diagnosis and management of these diseases could possibly prevent or delay negative cognitive changes.

Summary: Health Behaviors. The reviewed research on health behaviors supports the idea that engagement in protective health behaviors such as a nutritional diet, regular exercise, and preventative medical check-ups is associated with positive effects on cognitive ability. In contrast, lack of engagement in protective health behaviors by means of a poor diet, lack of exercise, and absence of regular medical check-ups, is associated with a negative impact on cognitive ability.

Cognitive Reserve. Cognitive reserve or reserve capacity as mentioned above, reflects an individual's range of plasticity, one's potential compared to normal level of functioning (Kliegl & Baltes, 1987). Several lifestyle variables have been reported to impact an individual's cognitive reserve including education, occupation, and leisure activities (Hultsch et al., 1993; Hultsch, Hertzog, Small, & Dixon, 1999; Lang, Rieckmann, & M. Baltes, 2002; Snowdon, Kemper, Mortimer, Greiner, Wekstein, & Markesbery, 1996). These various components of lifestyle may all impact the rate of cognitive change in adulthood. The current discussion of lifestyle will primarily focus on cognitive activity, education, and occupation.

Cognitively demanding activity. The various activities individuals engage in on a day-to-day basis comprise a sizable portion of their lifestyle. Activities can encompass a variety of domains including physical, intellectual, and social activities. When investigating the rate of cognitive change in older adulthood, researchers have been interested in the impact of activities associated with one's lifestyle. The perspective that has driven the majority of this research stems from Schooler's (1987) environmental complexity model. His model asserts that the environment includes both stimulus and demand characteristics. Complex environments include a diverse array of stimuli from which individuals must problem solve and adapt. Thus, individuals who engage in a variety of activities requiring a diverse array of cognitive skills should demonstrate greater maintenance of those abilities than individuals in less complex environments. This hypothesis is similar to the idea of "use it or lose it." The use it or lose it adage suggests that age-related cognitive changes can be moderated by types of activity in one's lifestyle, particularly cognitive activity. Thus, if tasks or activities related to certain cognitive abilities are not incorporated into one's lifestyle, he/she may "lose" or decline on this ability since it is not being used.

In general the research on activity has focused on current levels of activity, or a recollection of activity over the past couple years (Hultsch et al., 1999; MacKinnon et al., 2003; Wilson et al., 2002). Measurement of activity levels is predominantly achieved through self-report on the frequency of participation during the past week, month, or on a regular basis. Some researchers have also asked participants to rate how cognitively demanding they perceive an activity to be (Salthouse et al., 2002). The studies that contain the greatest diversity of activities assessed include activities categorized as physical, self-maintenance (related to instrumental activities of daily living), social, hobbies, home maintenance, passive information processing, novel information processing, and sleep (Hultsch et al., 1993; Hultsch, Hertzog, Small, & Dixon, 1999; Lang, Rieckmann, & M. Baltes, 2002).

Research has demonstrated that activities considered to be “intellectually stimulating” or those that involve information processing demonstrate the highest associations with cognitive ability (Hultsch et al., 1993; Hultsch et al., 1999; Wilson, Bennett, et al., 2002; Wilson, Mendes de Leon, Barnes, Schneider, Bienias, Evans, & Bennett, 2002). Hultsch and colleagues (1999) found that higher levels of tasks involving processing of novel information were associated with less substantial changes in working memory over a 6-year period. Individuals with lower baseline levels of activity were more likely to experience subsequent declines in crystallized and memory abilities (Hultsch et al., 1993; Mackinnon, Christensen, Hofer, Korten, & Jorm, 2003). In spite of the documented relationship between cognitive activity and cognitive performance, research has not demonstrated that cognitive activity mediates or moderates age-related cognitive change (Hultsch et al., 1999; Salthouse, Berish, & Miles, 2002).

Levels of cognitive activity decrease with increasing age on average (Hultsch et al., 1999; Mackinnon et al., 2003; Menec, 2003; Salthouse et al., 2002; Wilson, Bennett et al., 2002; Wilson, Mendes de Leon et al., 2002). Research by Salthouse and colleagues (2002) on individuals aged 20 to 91 years demonstrated that older age was associated with increased cognitive demands for watching television, but decreased demands for playing chess or attending class. Thus, more cognitive resources or mental energy was required for information processing associated with watching television. However, it is important to note that this was a cross sectional study, thus the differences present could be at least partially due to cohort differences as well as age differences. Salthouse et al. (2002) also found that older adults reported spending fewer hours in activities they rated as more cognitively demanding. In a 7-year longitudinal study of individuals aged 70 to 93 years, Mackinnon et al. (2003) found that a decrease in cognitive activity was correlated with decreases in cognitive performance on memory, speed, and crystallized abilities. Hultsch et al. (1999) reported that during a 6-year period, young-old and old-old adults spent fewer hours on self maintenance, hobbies, and novel information processing activities (aged 55 to 86 years) than they had 6 years prior. Furthermore, the old-old exhibited a steeper rate of decline in hobbies and novel information processing activities. The most extensive findings on the differential impact of cognitive activity on cognitive performance are from a cross-sectional study conducted by Hultsch and colleagues (1993). The interactions with age and activity indicated that activity was a stronger predictor of cognitive performance in older age.

Cognitive activity levels have also been investigated in relation to cognitive impairment. Cognitively impaired individuals engage in lower levels of activity (Menec, 2003). However, this finding is not surprising since individuals with lower baseline levels of cognitive ability tend to also have lower baseline levels of activity. In two separate 4-year longitudinal studies that employed two different samples, Wilson and colleagues (Wilson, Bennett et al., 2002; Wilson, Mendes de Leon et al., 2002) found that for every one point increase in cognitive activity (based primarily on information processing), there was a significant reduction in the risk for Alzheimer's disease, with a reduction of 64% in the biracial community sample (Wilson, Bennett et al., 2002), and 33% in the Religious Orders Study sample (Wilson, Mendes de Leon et al., 2002). This research suggests that participation in cognitively stimulating activities may serve as a protective factor for impeding the onset of Alzheimer's disease. However, it is important to consider that the directionality of the relationship between cognitively stimulating activity and cognitive impairment is still being investigated; it is unclear whether cognitive activity impacts cognitive impairment or whether cognitive impairment impacts cognitive activity.

Cognitive activity level is an important predictor of cognitive ability throughout older adulthood. Research has shown that beginning in old-old age, the rate of decline in information processing activity accelerates. In addition, activity levels are powerful predictors of cognitive performance in several domains for the old-old.

Education and Occupation. Extensive research has also been conducted on the relation between educational and occupational attainment and cognitive ability in later adulthood (Snowdon, Kemper, Mortimer, Greiner, Wekstein, & Markesbery, 1996; Stern, Albett, Tang, & Tsai, 1999; Tuokko, Garrett, McDowell, Silverberg, & Kristjansson, 2003). This line of research is derived in part from the cognitive reserve literature and the lifestyle activity literature. Based on the findings from that literature, individuals with higher levels of educational and occupational attainment would be expected to be exposed to more cognitive complexity and be more prone to engage in cognitively stimulating activities for a sizable portion of their adult lives. This would likely result in a higher reserve capacity when entering old age. Thus, pathology may progress for a longer time before the symptoms of cognitive impairment are manifest.

Higher educational attainment is considered a protective effect for the onset of cognitive decline and dementia (Cagney & Lauderdale, 2002; Gilleard, 1997; Lee Kawachi, Berkman & Grodstein, 2003). Although the specific mechanism of this effect is not known, higher education is often associated with higher socioeconomic status, better health (Albert, Jones, Savage, Bernman, Seeman, Blazer et al., 1995; Lee et al., 2003), and possibly even greater dendritic growth resulting in greater "brain reserve (Katzman, 1993; Stern, 2002).

Snowdon and colleagues (Snowdon, Kemper, Mortimer, Greiner, Wekstein, & Markesbery, 1996) studied writing samples of nuns that were produced in young adulthood (aged 18 to 32 years). These same individuals were given a cognitive assessment in older adulthood (aged 75 to 87). The results indicated that cognitive function in later adulthood was associated with idea density, which is a reflection of education, vocabulary, and general knowledge, and environmental complexity in young adulthood. Furthermore, individuals who exhibited lower idea density in young adulthood were more likely to have lower cognitive ability in older adulthood. In a five-year longitudinal assessment, Stern, Albert, Tang, and Tsai (1999) found that individuals with higher educational and occupational attainment had a steeper rate of progression of deteriorating cognitive ability in Alzheimer's disease. This suggests that due to a higher baseline level of functioning, pathology may have progressed undiagnosed before the symptoms were outwardly present. Thereafter, the decline was steeper. Finally, Tuokko and colleagues (Tuokko, Garrett, McDowell, Silverberg, & Kristjansson, 2003) categorized individuals as high or low functioning based on level of education, occupational attainment, and estimated premorbid IQ. In a five-year assessment, Tuokko et al. found high functioning individuals were less likely to be cognitively impaired. However, the high functioning individuals that did become cognitively impaired throughout the duration of the study showed a more rapid rate of decline.

Summary: Cognitive reserve/engagement. In summary, participation in cognitively stimulating activities is associated with higher levels of cognitive ability in older adulthood. The mechanism of this effect may be that individuals with higher educational and/or occupational attainment and those who engage in cognitively stimulating activities have higher levels of reserve capacity in older adulthood.

Cognitive Style. Behavioral rigidity and flexibility has been associated with cognitive ability in adulthood. Schaie (1984; 1996; 2004) examined the relationship between three flexibility factors, attitudinal flexibility, motor-cognitive flexibility, and psychomotor speed, and fluid ability in the context of the Seattle Longitudinal Study. Motor-cognitive flexibility represents an individual's ability to adapt to a change in stimuli or inhibit a response to stimuli. Attitudinal flexibility involves an individual's self-reported tolerance to unpredictability, ambiguity, and sudden changes. Psychomotor speed involves the speed an individual responds to familiar stimuli.

Investigation of the concurrent relationships by age revealed that the association between reasoning ability and motor-cognitive flexibility positively increased with age, as did the relationship with attitudinal flexibility, and psychomotor speed. Attitudinal flexibility and psychomotor speed exhibited a slight decrease in association with reasoning ability in the last age group (81 years). Similar associations were maintained at the latent ability level. Thus, inductive reasoning ability had the strongest concurrent relationship with both motor-cognitive flexibility and psychomotor speed.

There were several associations found through cross-lagged correlations. At a 7-year interval, inductive reasoning demonstrated a causal association with psychomotor speed. This relationship was retained at the 14-year interval, and a causal association with attitudinal flexibility also emerged. At the 35-year interval, an association between reasoning and motor-cognitive flexibility emerged, and this was retained at the 42-year interval. The crossed-lagged correlations suggested that the causal relationship was from inductive reasoning ability to the cognitive style factors.

Thus, this research demonstrates that flexibility is related to fluid ability, specifically inductive reasoning ability, throughout the lifespan. The positive associations found indicate that individuals with higher levels of flexibility, particularly psychomotor speed and motor-cognitive flexibility also have higher levels of inductive reasoning ability. This suggests that individuals with higher levels of inductive reasoning ability more quickly respond to familiar and unfamiliar changes in the environment, and have more self-reported tolerance for these changes.

Clinically Meaningful Outcomes and Fluid Ability

Everyday Problem Solving

Everyday competence or problem-solving involves the ability to complete or solve the tasks and problems associated with daily life, including novel situations and problems encountered in daily life (Berg, Klaczynski, Calderone, & Strough, 1994; Diehl, Willis, & Schaie, 1995; Marsiske & Willis, 1995). Although maintaining the ability to complete activities associated with daily life is pivotal for an independent lifestyle, there is wide individual variability in the manner in which these activities are approached.

Prior research has demonstrated a link between cognitive ability and everyday problem-solving. Due to the complexity of problem-solving in everyday activities, several basic cognitive abilities are involved in the process of solving a problem. For example, Willis and colleagues (Willis & Marsiske, 1991; Willis & Schaie, 1986) found that over half of the variance in older adults' performance on everyday tasks could be accounted for by mental ability performance. Additionally, both fluid and crystallized abilities accounted for everyday task performance, with a somewhat greater proportion of the variance accounted for by fluid ability. Willis, Jay, Diehl, and Marsiske (1992) found that fluid ability at the first assessment occasion predicted everyday task performance seven years later. These findings supported their hypothesis that level of functioning on basic mental abilities is a significant antecedent of performance on everyday tasks assessed by objective measures. Research by Allaire and Marsiske (1999, 2002) supports the finding that everyday cognition can be partially accounted for by a set of underlying, basic cognitive abilities. Since most everyday tasks involve multiple basic abilities, everyday tasks are cognitively complex. Hence, individuals that experience decline on one or more cognitive abilities may experience increasing difficulty performing the tasks essential in daily life. Alternatively, if individuals participate in cognitive training programs to at least partially remediate the cognitive declines experienced, they may be able to prolong maintenance of the abilities necessary for functioning in daily life.

Mental Status

There has been research on the association between fluid ability and mental status. Raykov, Baltes, Neher, and Sowarka (2002) conducted a study to detect risk of dementia. Two approaches to the diagnosis of dementia were compared. The first was the Stodrandt et al. (1984) approach. This approach utilizes the abilities involved in logical memory, trailmaking, word fluency, and mental control to discriminate between normal and pathological aging. The second approach was based on assumptions underlying cognitive plasticity. This approach usually involves intervention or training procedures that focus on learning potential. The cognitive plasticity approach involved assessment of practice or learning using figural relations tests, which assess fluid ability. Results indicated support for the cognitive plasticity approach. Initial and post-training performance on figural relations tests was predictive of cognitive status (as measured by the Structured Interview for the Diagnosis of Dementia; SIDAM). These findings suggest that the magnitude of change as a function of training varied by cognitive status (or risk for dementia).

The effectiveness of cognitive interventions in demented or possibly demented older adults has not been as extensively studied as in nondemented elderly. Oswald, Rupprecht, Gunzelmann, and Tritt, (1996) conducted a 9-month intervention on a sample of community-dwelling older adults. The three training conditions were memory training, competence training, and psychomotor training. There were also two combined training groups: combined competence and psychomotor training, and combined memory and psychomotor training. Results indicated that for the combined psychomotor and memory training group, there was a reduction in the symptoms of dementia.

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 the participants imagery mnemonics for remembering names, faces, and lists, and/or methods to improve concentration and organizational techniques to improve recall. The findings from these studies suggest that individuals with mild cognitive impairment or dementia are still able to benefit from cognitive training interventions.

Health Severity

As mentioned previously in the review of chronic diseases, disease comorbidity is common in older adulthood. Due to comorbidity, older adults typically utilize more health services, and therefore have higher total health care costs. Several different measures have been derived in an attempt to estimate health severity. The chronic disease score (CDS) is a measure based on prescription medications (Clark, Von Korff, Saunders, Baluch, & Simon, 1995; Von Korff, Wagner, & Saunders, 1992). The medications are mapped onto classes, and then onto chronic disease categories, and finally assigned weights based on expert judgment. The CDS has been found to predict mortality and health care resource utilization (Clark et al., 1995; Von Korff et al., 1992). Recent research has demonstrated that a count of medication use is most predictive of health care utilization charges, while diagnosis-based measures (the ACGs and the Charlson comorbidity index) are more predictive of one-year mortality (Perkins, Kroenke, Unutzer, Katon, Williams, Hope, & Callahan, 2004). It should be noted that the authors concluded that the current comorbidity measures are only poor to moderate predictors of actual costs or mortality (Perkins et al., 2004).

Research has demonstrated an association between individuals functioning at a lower level of cognitive ability and higher health care costs (Kavanaugh & Knapp, 2002). Chodosh and colleagues (Chodosh, Seeman, Keeler, Sewall, Hirsch, Guralnik, & Reuben, 2004) found that individuals functioning at a high level at baseline, followed by a decline in cognitive function over a 3-year period were more likely to be hospitalized. Walsh and colleagues (2003) found that even after controlling for health and functional status, lower cognitive functioning had an impact on outpatient services, but not hospitalization. Although this finding is somewhat counter to that of Chodosh and colleagues, the general finding is the same: individuals functioning at a lower cognitive level tend to utilize more health services than those functioning at a higher level. Finally, in a study of out-of-pocket expenditures made by cognitively impaired individuals and their families, the expenses significantly increased as cognitive impairment increased from no dementia, to mild/moderate dementia, to severe dementia (Langa, Larson, Wallace, Fendrick, Foster, Kabeto, Weir, Willis, & Herzog, 2004). In summary, this research suggests that lower cognitive functioning is associated with higher health care expenditures.

Mortality

Researchers have suggested that there may be a terminal drop or abrupt decline in cognitive ability several years before death. Several researchers have found evidence that declines in crystallized abilities were related to an increased likelihood of impending mortality (Berg, 1987; Bosworth & Schaie, 1999; Johansson et al., 2004). Bosworth and Schaie (1999) concluded that the rates of decline in fluid ability were normative, and not especially informative about impending mortality. Others have found that this relationship is only evident in individuals over the age of 70 years (Anstey, Luszcz, Giles, & Andrews, 2001; Deeg, Hofman, & Van Zonneveld, 1990). Smits, Deeg, Kriegsman, and Schmand (1999) found that five measures of cognitive function, general cognitive functioning, information processing speed, fluid intelligence, learning, and proportion retained, were predictive of mortality in individuals aged 55 to 85 years. Wilson, Beckett, Bienias, Evans, and Bennett (2003) found that declines in episodic memory, semantic memory, working memory, perceptual speed, and visuospatial ability were apparent between 3 and 6 years prior to death. Finally, additional researchers have not found evidence of any relationship between cognitive decline and mortality (Hassing et al., 2002; Small, Fratiglioni, von Strauss, & Backman, 2003). Evidence of terminal drop varies as a function of the abilities studied, the population investigated, and the duration of the follow-up of the study. In a meta-analysis, Bosworth and Siegler (2002) suggested that the discrepant findings could be due to researchers neglecting to consider the impact of health and disease on the relationship between cognitive change and mortality.

SUMMARY AND IMPLICATIONS

Although there is normative decline with age, there are wide individual differences in rate and onset of decline. There is a need for further study on subgroups of individuals showing different profiles of cognitive change or different trajectories of change. The preceding review of the literature suggests that there is interindividual variability in rates of cognitive change, and that differences in ability level may contribute to different trajectories. In addition, the research found that there are relationships between chronic disease, health behaviors, cognitive reserve/engagement, and cognitive style and rate of cognitive change in inductive reasoning ability. However, the impact of these multiple factors on the probability of trajectory group membership still needs to be investigated. Further research will reveal what factors distinguish the developmental trajectories. Moreover, investigation of the associations between these covariates and the trajectory groups will provide the field with more information on the associations between health behaviors, cognitive disease, cognitive reserve, cognitive engagement and inductive reasoning ability in general.

In addition, the impact of cognitive training programs on the cognitive trajectories needs to be investigated. Research has documented the efficacy of training programs in remediating cognitive decline, but the impact on the subgroups of trajectories needs to be investigated. By determining the different trajectory groups as a function of training status (nontrained, reason train, space train), the impact of targeted cognitive training (reasoning training sample), organized/structured cognitive activity (space training sample), and individual activity (nontrained sample) will be better understood.

Finally, more research needs to focus on clinically meaningful outcomes of training. Investigation of the association between the different subgroups of trajectories and the clinically meaningful outcomes will provide important descriptive information to the field. Thus, the current study will seek to identify distinct developmental trajectories of inductive reasoning ability in older adults, as well as the covariates associated with these trajectories. The association of clinically meaningful outcomes to these various change trajectories will be considered, particularly in the context of trajectory group membership, training status, training group and training gain.

CHAPTER 3
Statement of Problem

The primary purpose of this study was to examine differential patterns of cognitive change in inductive reasoning ability in participants in the Seattle Longitudinal Study. Three broad questions will be addressed. The first will identify patterns of cognitive change in inductive reasoning ability over a 14-year period in three samples (nontrained, reason trained, and space trained). Specifically, the number of distinct cognitive change trajectories will be determined. The second question will investigate the association of person level variables with the different patterns of cognitive change in inductive reasoning ability for each sample. The third question will focus on the impact of the different change trajectories and cognitive training on a number of "clinically meaningful" outcomes. In the current study, clinically meaningful outcomes will refer to outcomes that reflect the maintenance or extension of cognitive and/or physical independence of older individuals.

For each of the three major questions, the specific issues that will be examined are outlined below.

I. Differential trajectories of cognitive change in inductive reasoning ability.

A. What sub-groups representing distinctive patterns of cognitive change in inductive reasoning ability can be identified in the nontrained sample?
B. What sub-groups representing distinctive patterns of cognitive change in inductive reasoning ability can be identified in the reasoning training sample?
C. What sub-groups representing distinctive patterns of cognitive change in inductive reasoning ability can be identified in the space training sample?

The three samples (nontrained, reason trained, and space trained) were investigated separately because determining whether the trajectory groups differed as a function of organized cognitive activity in the form of training programs was of interest. Although most individuals experience normative rates of decline in fluid abilities beginning in the mid-60's (Finkel et al., 2003; Hickman et al., 2000; Schaie, 1996; Singer et al., 2003), there is wide individual variability in rate of cognitive change (Christensen et al., 1999). In addition to individual variability in normative rates of cognitive change, research has demonstrated that those who become cognitively impaired exhibit steeper rates of decline, even after years of a normative cognitive trajectory (Rubin et al., 1998; Teri et al., 1995). Furthermore, participation in cognitively stimulating activities has been found to be associated with higher levels of cognitive ability (Ball et al., 2002; Calero & Garcia-Berben, 1997; Hultsch et al., 1999; Schaie & Willis, 1986; Wilson, Bennett, et al., 2002), therefore contributing to maintenance of ability level. Thus, there are at least two trajectories that are hypothesized to be present in the data, one representing normative age-related cognitive decline, and one representing maintenance of ability. However, these trajectories will likely look different in each of the three samples due to the variable impact of participation in training. For example, in the reasoning training sample, these two trajectories should demonstrate the least substantial decline (in comparison to the other two samples) because training was on the ability of interest. These trajectories may appear to be more similar in the space training and nontrained groups since neither experienced training on the outcome ability of interest (reasoning ability). If differences are present among these hypothesized trajectories in the space training and nontrained groups, it will likely be due to the organized cognitively stimulating activity received by the space training group.

Differences in level of ability are likely to impact the sub-groups of trajectories for all three samples. For example, individuals with lower levels of reserve capacity, and/or lower levels of education typically have lower levels of cognitive ability at baseline (Kliegl & Baltes, 1987; Snowdon et al., 1996; Stern et al., 1999; Tuokko et al., 2003). Those with lower levels of ability at baseline will likely exhibit a different trajectory than those with higher levels of ability at baseline, regardless of training status. Individuals with higher levels of reserve capacity as a result of higher levels of education, occupational attainment, or engagement in intellectually stimulating activities have been found to have higher levels of cognitive ability at baseline (Hultsch et al., 1993; Hultsch et al., 1999; Snowdon et al., 1996; Stern et al., 1999; Wilson, Bennett, et al., 2002; Wilson, Mendes de Leon, et al., 2002).

Two of the samples (reason trained and space trained) participated in the cognitive training programs with initial training occurring between occasions 2 and 3 and booster training occurring between occasions 4 and 5. Some trained participants exhibited decline on the ability trained within the fourteen years prior to training and other individuals were stable across the fourteen years prior to training. Thus, the variations in stability status for these two samples will likely contribute to different trajectories reflecting variability in both slope and intercept. Cognitive training has been found to remediate ability to at or near pre-decline levels for approximately 40% of those experiencing prior decline (Nesselroade, 1990; Schaie & Willis, 1986). Much research has established that older adults trained in inductive reasoning ability have demonstrated gains as a result of the training program (Ball et al., 2002; Baltes et al., 1989; Calero & Garcia-Berben, 1997; Schaie & Willis, 1986; Willis & Nesselroade, 1990). Therefore, most individuals trained on inductive reasoning ability, should exhibit a different pattern of trajectories than the nontrained or space trained groups. In summary, several trajectories of cognitive change in inductive reasoning ability are hypothesized in this study.

II. What individual level variables are associated with the various cognitive change trajectories for inductive reasoning?

A. Confirmatory factor analysis on the covariates.

Due to the large number of possible covariates that will be included, a confirmatory factor analysis will be performed to validate a 4-factor structure. The occasion of measurement for the covariates will be Time 5 (1991 for the 1984 replicate; 1998 for the 1991 replicate).

The hypothesized 4 domains of covariates include chronic diseases, health behaviors, cognitive reserve/engagement and cognitive style. Prior research has demonstrated associations between cognitive ability and each of these four domains. The variables described below are hypothesized to be indicators for the four domains. The factor structure will be confirmed on the three samples (nontrained, reasoning trained, and space trained) as a whole.

Chronic Diseases. The chronic disease domain will be represented by hypertensive disease, heart/cerebrovascular disease, diabetes, and osteoarthritis. Prior research has demonstrated associations between cognitive ability and cardiovascular disease (Fahlander et al., 2000; Zelinski et al., 1998), hypertension

(Elias et al., 2001; Morris et al., 2002; Zelinski et al., 1998), and diabetes (Bruce et al., 2001; Trento et al., 2004; Zelinski et al., 1998). In the cited research, presence of these chronic diseases has been associated with lower levels of fluid ability functioning. The research on the association between osteoarthritis and cognitive ability is extremely limited. Gruber-Baldini (1991) found that individuals with arthritis had lower levels and more negative change in inductive reasoning ability. These four chronic diseases are among the chronic diseases most common in the older population, and display incidence rates of at least 10% in the SLS sample.

Health Behaviors. The health behavior domain will include exercise, food consumption, food preparation, and dental and medical check-ups. Research has shown that physical or aerobic fitness does provide a protective benefit against the onset of cognitive decline (Barnes et al., 2003; Blumenthal & Gullette, 2002; Laurin et al., 2001). There are multiple pathways by which these health behaviors may impact cognitive functioning. For example, food consumption can contribute to obesity, heart disease (Ornish, Scherwitz, Billings, Brown, Gould, Merritt, Sparler, Armstrong, Ports, Kirkeeide, Hogeboom, & Brand, 1998), and diabetes (Chandalia, Garg, Lutjohann, von Bergmann, Grundy, & Brinkley, 2000), all of which are associated with lower levels of cognitive ability (Correa Leite et al., 2001; La Rue et al., 1997; Ortega et al., 1997). Finally, engagement in regular medical check-ups serves as a preventative measure against onset or increase in severity of chronic disease such as heart disease (Almeida & Flicker, 2001; Rabbitt et al., 2002; Seeman et al., 2001), chronic obstructive pulmonary disease (Fioravanti et al., 1995; Incalzi et al., 1993), diabetes (Jackson-Guilford et al., 2000; McCarthy et al., 2002), and pneumonia (Iwamoto et al., 2000; Medina-Walpole & McCormick, 1998).

Cognitive Reserve/Engagement. The cognitive reserve/engagement domain will include education level, occupational status, income, and two activity factors (fitness and education/culture). Participation in cognitively stimulating activities has been found to result in maintenance of higher levels of working memory, crystallized ability, and processing in older adulthood (Hultsch et al., 1993; Hultsch et al., 1999; Menec, 2003; Wilson, Bennett, et al., 2002; Wilson, Mendes de Leon, et al., 2002). Additionally, individuals with higher levels of educational and/or occupational attainment tend to have higher levels of reserve capacity and to engage in cognitively stimulating activities in older adulthood, therefore providing a protective effect. Individuals functioning at a higher level have an increased likelihood of pathology existing prior to the manifestation of the symptoms of cognitive impairment (Snowdon et al., 1996; Stern et al, 1999; Tuokko et al., 2003).

Cognitive Style. Finally, the cognitive style domain will be represented by: motor cognitive flexibility, attitudinal flexibility, and psychomotor speed. Motor-cognitive flexibility represents an individual's ability to adapt to a change in stimuli or inhibit a response to stimuli (Schaie, 1984; 1996; 2004). Attitudinal flexibility involves an individual's self-reported tolerance to unpredictability, ambiguity, and sudden changes. Psychomotor speed involves the speed at which an individual responds to familiar stimuli. These three variables have been found to be associated with fluid ability performance and inductive reasoning is one of the most pure indicators of fluid ability (Schaie, 1984; 1996; 2004).

B. What domains are most discriminative for the various cognitive change trajectories in each of the three samples (nontrained, reason trained, space trained)?

Although it is anticipated that the factors will have some impact on all the cognitive trajectories, the degree to which each is hypothesized to discriminate among the trajectories is variable. Based on the literature, it is hypothesized that the presence of chronic disease will be most discriminative of trajectories representing steep decline trajectories and/or low levels of functioning. In contrast, higher levels of the cognitive reserve factor will likely be more discriminating for the groups with higher initial levels and those that maintained a high level of functioning and/or individuals that benefited from cognitive training. However, research has also demonstrated that although the manifestation of symptomology of cognitive impairment is delayed in individuals with higher levels of reserve, once the pathology has progressed, the declines thereafter tend to be steeper.

No specific hypotheses regarding differential impact as a function of the three samples are hypothesized. Each sample includes individuals with varying levels of ability, thus multiple trajectory groups are expected for each sample. To a certain extent, all four factors may impact trajectory group membership to produce varying degrees of discrimination in the three samples. Moreover, the covariates may influence trajectory group membership in such a way that profiles associated with various trajectories of cognitive change could be suggested. For example, individuals who engage in poor health behaviors may have lower cognitive reserve, a more rigid cognitive style, and may therefore be more likely to have increased incidence of chronic diseases, all of which would contribute to lower levels of cognitive ability. Alternatively, individuals who engage in cognitively stimulating activities and positive health behaviors, have a more flexible cognitive style, and have fewer chronic diseases may be more likely to have higher levels of cognitive ability. Based on the reviewed literature, health behaviors and chronic diseases, and health behaviors and cognitive engagement are hypothesized to be associated with group membership. In particular, the influence of health behaviors and cognitive engagement is hypothesized because individuals who engage in more cognitively stimulating activities are typically more highly educated, and thus more likely to engage in protective health behaviors.

III. Association of cognitive change trajectories and cognitive training effects with clinically meaningful outcomes.

Four measures of clinically meaningful outcomes will be examined in this study, everyday problem solving, mental status ratings, health severity (total health care expenditures), and mortality. First the association between each of the cognitive change trajectories identified in question 1 and each of the clinical outcomes will be examined in the three samples. Second, the association of the clinical outcomes with training status, training group, and magnitude of training effects will be examined.

A. What is the association between each of the cognitive change trajectory types and clinical outcomes in each of the three samples?

Based on prior research, it is hypothesized that the individuals with higher levels of inductive reasoning ability or those that maintain relative stability will also have higher scores on everyday problem solving (Willis et al.,1992), a decreased likelihood of mortality (Smits et al.,1999; Wilson et al., 2003), lower disease severity (Perkins et al., 2004), and a decreased risk of dementia (Rubin et al., 1998; Teri et al., 1995). This is hypothesized across the three samples. Along a similar hypothesis, individuals with lower levels of inductive reasoning ability or those that experience steeper rates of decline will likely have lower scores on everyday problem solving (Willis et al.,1992), increased risk of mortality (Smits et al.,1999; Wilson et al., 2003) and cognitive impairment (Rubin et al., 1998; Teri et al., 1995), and have higher disease severity (Perkins et al., 2004).

B. Does training status (intervention versus no intervention) differentially impact the clinically meaningful outcomes?

Specifically, training status (trained versus nontrained) will be examined as the primary predictor of these outcomes. Because prior research has demonstrated that participation in cognitive training programs is beneficial for older adults regardless of age, gender, or education (Ball et al., 2002; Baltes et al., 1989; Calero & Garcia-Berben, 1997; Schaie & Willis, 1986; Willis & Nesselroade, 1990), it is hypothesized that the trained individuals will likely demonstrate more positive long-term outcomes than the non-trained individuals. Individuals in the training programs were exposed to additional practice on either spatial orientation or inductive reasoning ability. It is hypothesized that engagement in these programs will yield higher everyday problem solving skills, lower incidence of probable dementia, fewer total dollars of health expenditures, and fewer incidences of mortality in comparison to the non-trained individuals. Prior research has suggested that everyday problem-solving or everyday cognition is composed of a set of underlying, basic cognitive abilities, all of which may be drawn upon to solve novel or familiar tasks of daily living (Allaire & Marsiske, 1999; 2002). In addition, Willis and colleagues (1992) found that fluid ability at the first assessment occasion predicted everyday task performance seven years later. Thus, individuals with higher levels of fluid ability performance tended to have higher levels of problem-solving ability. Trained individuals should have boosted their abilities (specifically the ability trained) in comparison to their nontrained counterparts.

As stated previously, individuals with higher levels of cognitive ability tend to have higher levels of cognitive reserve (Kliegl & Baltes, 1987), which often contributes to delaying the marked decline in cognitive ability due to pathology. Because individuals trained typically experience some remediation of the decline experienced in cognitive ability, the training therefore contributes to the maintenance of a higher level of cognitive ability. Thus, trained individuals will likely have at least a slightly delayed manifestation of the symptoms of probable dementia when compared to the controls.

Because it is hypothesized that trained individuals will have higher levels of cognitive ability in comparison to the non-trained controls, the trained individuals are also hypothesized to have lower health expenditure costs and lower rates of mortality. Researchers have found that level of cognitive ability is predictive of mortality (Hassing et al., 2002; Smits et al., 1999). In studies of mortality, surviving individuals were younger, more educated, had better cognitive scores, cited fewer chronic conditions, were less likely to have had a stroke, heart attack, congestive heart failure, and had less accelerated rates of decline in crystallized ability and episodic memory (Hassing et al., 2002; Small et al., 2003).

C. Do training group (reason/space train) and training gain differentially impact these clinically meaningful outcomes?

Of the clinically meaningful outcomes to be investigated in this study, it is hypothesized that gain on ability trained will only differentially contribute to everyday problem solving ability and mortality because prior research (Anstey et al, 2001; Deeg et al., 1990; Willis et al., 1992; Willis & Marsiske, 1991; Willis & Schaie, 1986) has demonstrated a positive relation between level of cognitive ability and problem solving and mortality. Furthermore, specific to training group, the only hypothesized difference is for everyday problem solving. It is hypothesized that those reasoning trained participants that experienced gain will likely have higher levels of problem solving ability than the space trained group. The rationale for this hypothesis lies in the definitions of inductive reasoning, spatial orientation, and problem solving ability. Inductive reasoning ability involves identifying patterns or rules and applying them to solve a problem. Everyday competence or problem-solving involves the ability to complete or solve the tasks and problems associated with daily life, including novel situations and problems encountered in daily life. Spatial orientation requires the ability to mentally rotate two and three-dimensional objects. Thus, inductive reasoning training will likely demonstrate a greater impact on problem solving ability than spatial orientation training. No other outcomes regarding different training groups are hypothesized.

CHAPTER 4

Methods

Participants

All participants were community dwelling adults from the Seattle, Washington area who were recruited into the Seattle Longitudinal Study (SLS) through their membership in the Group Health Cooperative of Puget Sound, a health maintenance organization. See Table 1 for design of the study for Questions 1 and 2. Five occasions of measurement were included: Time 1 (7 years prior to training), Time 2 (Pretest 1 immediately prior to first training occasion), Time 3 (Posttest 1 immediately following the first training occasion), Time 4 (Pretest 2 immediately prior to the second training occasion), and Time 5 (Posttest 2 immediately after the second training occasion).

Table 1 Measurement occasions to be used for Questions 1 and 2

Replicate	7 years prior to training	Initial Training		7 years post training	
	T1	T2	T3	T4	T5
1984					
Trained	1977	Pre training 1984 pre	Post training 1984 post	Booster 1991 pre	Booster 1991 post
Nontrained	1977	1984 pre	1984 post	1991 pre	1991 post
1991					
Trained		Pre training 1991 pre	Post training 1991 post	Booster 1991 pre	Booster 1991 post
Nontrained	1984	1991 pre	1991 post	1998 pre	1998 post

Questions 1 and 2 Sample

The total sample consisted of 422 individuals who participated in the SLS for a minimum of 14 years and who were at least 57 years of age at the baseline occasion (T1: 1977 for the 1984 replicate; 1984 for the 1991 replicate). See Table 2 for descriptive information by training status, training group, and replicate. Mean age at baseline was 63.54 years of age (Range = 57-80; SD = 4.97). Mean education level was 14.42 years

Table 2 Demographic characteristics (mean(standard deviation)) for the Nagin modeling samples by replicate and training status

	7 Years Prior (T1)	First Training Occasion (T2)	7 Years Post-training (T4)
1984 Replicate			
Trained (N=142)			
Age	63.70(4.98)	70.70(4.98)	77.70(4.98)
Education	14.17(2.95)	14.17(2.90)	14.18(2.88)
Space Train (N=69)			
Age	63.88(4.89)	70.88(4.89)	77.88(4.89)
Education	14.28(3.05)	14.28(3.03)	14.36(3.03)
Reas Train (N=73)			
Age	63.53(5.09)	70.53(5.09)	77.53(5.09)
Education	13.93(2.86)	13.94(2.77)	13.99(2.74)
Nontrained (N=42)			
Age	64.38(5.04)	71.38(5.04)	78.38(5.04)
Education	13.68(3.07)	13.68(3.02)	13.74(3.08)
Total (N=184)			
Age	63.86(4.99)	70.86(4.99)	77.86(4.99)
Education	14.07(2.97)	14.00(2.92)	14.07(2.92)
1991 Replicate			
Trained (N=99)			
Age	63.28(4.66)	70.44(4.66)	77.29(4.66)
Education	14.58(2.90)	14.60(2.85)	14.76(2.97)
Space Train (N=54)			
Age	63.72(5.07)	70.72(5.07)	77.72(5.07)
Education	14.70(3.17)	14.70(3.08)	14.89(3.24)
Reas Train (N=45)			
Age	62.76(4.11)	70.11(4.11)	76.76(4.11)
Education	14.39(2.58)	14.48(2.58)	14.61(2.65)
Nontrained (N=139)			
Age	63.28(5.17)	70.28(5.17)	77.28(5.17)
Education	14.69(2.79)	14.69(2.74)	14.82(2.82)
Total (N=238)			
Age	63.28(4.95)	70.35(4.95)	77.28(4.95)
Education	14.68(2.83)	14.68(2.78)	14.80(2.88)
TOTAL Sample			
Trained (N=241)			
Age	63.53(4.85)	70.60(4.85)	77.53(4.85)
Education	14.28(2.87)	14.31(2.88)	14.41(2.93)
Space Train (N=123)			
Age	63.81(4.95)	70.81(4.95)	77.81(4.95)
Education	14.44(3.04)	14.47(3.05)	14.59(3.13)
Reas Train (N=118)			
Age	63.24(4.74)	70.37(4.74)	77.24(4.74)
Education	14.11(2.75)	14.15(2.70)	14.23(2.71)
Nontrained (N=181)			
Age	63.54(5.15)	70.54(5.15)	77.54(5.15)
Education	14.39(2.83)	14.44(2.83)	14.57(2.91)
Total (N=422)			
Age	63.54(4.97)	70.57(4.97)	77.54(4.97)
Education	14.42(2.91)	14.42(2.86)	14.48(2.92)

(Range = 6-20; SD = 2.91). The individuals trained on reasoning had a mean age of 63.24 years (Range = 57-78; SD = 4.74), and a mean education level of 14.11 years (Range = 7-20; SD = 2.75). The space trained individuals had a mean age of 63.81 years (Range = 57-78; SD = 4.95), and a mean education level of 14.44 years (Range = 8-20; SD = 3.04). The nontrained individuals had a mean age of 63.54 years (Range = 57-80; SD = 5.15), and a mean education level of 14.39 years (Range = 6-20; SD = 2.83). At the final occasion of measurement, Time 5, mean age for the total sample was 77.54 years of age (Range = 71-94; SD = 4.97). Mean age for the reasoning trained sample at Time 5 was 77.24 years (Range = 71-92; SD = 4.74). The space trained sample had a mean age of 77.81 years (Range = 71-92; SD = 4.95), and the mean age for the nontrained sample was 77.54 years (Range = 71-94; SD = 5.15).

Since the sample in the current investigation included three groups (reason train, space train, nontrained) and two replicates, it was necessary to determine if the subsamples differed from each other. Multivariate analysis of variance (MANOVA) was used to test for differences in age, education, and reasoning baseline score (T1). Results indicated that there were no significant differences as a function of training status, replicate, or the training status by replicate interaction.

1984 Replicate. The 1984 replicate included 184 individuals. Mean age at baseline was 63.86 years of age (Range = 57-80; SD = 4.99). Mean education level was 14.07 years (Range = 8-20; SD = 2.97). The reasoning trained individuals had a mean age of 63.53 years (Range = 57-78; SD = 5.09), and a mean education level of 13.93 years (Range = 7-20; SD = 2.86). The individuals trained on spatial orientation had a mean age of 63.88 years (Range = 57-78; SD = 4.89), and a mean education level of 14.28 years (Range = 8-20; SD = 3.05). The nontrained individuals had a mean age of 64.38 years (Range = 57-80; SD = 5.04), and a mean education level of 13.68 years (Range = 8-20; SD = 3.07). At the final occasion of measurement, mean age for the total 1984 replicate was 77.86 years of age (Range = 71-94; SD = 4.99). Mean age was 77.53 years (Range = 71-92; SD = 5.09) for the reasoning trained sample, 77.88 years (Range = 71-94; SD = 4.89) for the space trained sample, and 78.38 years (Range = 71-94; SD = 5.04) for the nontrained sample.

Since this replicate was composed of reasoning trained, space trained, and nontrained individuals, it was necessary to determine whether there were group differences in age, education, and reasoning score at baseline. MANOVA was employed. Results indicated that there were no significant differences among the three groups in the 1984 replicate for age, education, or reasoning score at baseline.

1991 Replicate. The 1991 replicate contained 238 individuals with a mean age at baseline of 63.28 years of age (Range = 57-80; SD = 4.95) and a mean education level of 14.68 years (Range = 6-20; SD = 2.83). The individuals trained on reasoning had a mean age of 62.76 years (Range = 58-77; SD = 4.11), and a mean education level of 14.39 years (Range = 11-20; SD = 2.58). The space trained individuals had a mean age of 63.72 years (Range = 57-78; SD = 5.07), and a mean education level of 14.70 years (Range = 8-20; SD = 3.17). The nontrained individuals had a mean age of 63.28 years (Range = 57-80; SD = 5.17), and a mean education level of 14.69 years (Range = 6-20; SD = 2.79). At the final occasion of measurement, Time 5, mean age for the total 1991 replicate was 77.28 years of age (Range = 71-94; SD = 4.95). Mean age for the reasoning training sample at Time 5 was 76.76 years (Range = 71-92; SD = 4.11). Mean age for the space training sample at Time 5 was 77.72 years (Range = 71-92; SD = 5.07), and mean age for the nontrained sample was 77.28 years (Range = 71-94; SD = 5.17).

Again, because this replicate was composed of reasoning trained, space trained and nontrained individuals, it was necessary to determine whether there were group differences in age, education, and reasoning ability at baseline. Results of the MANOVA indicated that there were no significant differences between the reason trained, space trained, and nontrained samples in the 1991 replicate.

Attrition Analysis. It was necessary to conduct an attrition analysis to determine whether individuals that returned 7 years (T4, T5) post initial training differed from those who did not return. Attrition analyses were conducted by training status (reason train, space train, nontrain), by replicate, and by training status and replicate. A series of MANOVAs were used to determine whether there were differences in age, education, and reasoning score at baseline, as well as reasoning pretest at initial training.

1984. For the reasoning trained group in the 1984 replicate, results indicated that individuals who returned 7 years post training (N=73) were significantly younger (p <

0.05), and had higher scores at initial training reasoning pretest ($p < 0.05$) than the initial sample (N=110). For the individuals trained on spatial orientation in the 1984 replicate, results indicated that individuals who returned 7 years post training (N=69) were significantly younger ($p < 0.05$) than the initial sample (N=119). For the nontrained group in the 1984 replicate, results indicated that individuals who returned 7 years post training (N=42) were significantly younger ($p < 0.01$), and had higher reasoning scores at initial training reasoning pretest ($p < 0.01$) than then initial sample (N=201). In the total 1984 replicate, results indicated that individuals who returned 7 years post training (N=184) were significantly younger ($p < 0.001$), more highly educated ($p< 0.05$) and had higher reasoning scores at baseline ($p < 0.001$) and at the initial training reasoning pretest ($p < 0.001$) than the initial sample (N=430).

1991. For the reasoning trained group in the 1991 replicate, results indicated that individuals who returned 7 years post training (N=45) were significantly younger ($p < 0.01$), and had higher reasoning scores at initial training reasoning pretest ($p < 0.05$) than the initial first trained in 1991 sample (N=80). For those trained on spatial orientation in the 1991 replicate, results indicated that individuals who returned 7 years post training (N=54) were significantly younger ($p < 0.05$), and had higher reasoning scores at initial training reasoning pretest ($p < 0.05$) than the initial first trained in 1991 sample (N=93). For the nontrained group in the 1991 replicate, results indicated that individuals who returned 7 years post training (N=139) were significantly younger ($p < 0.001$), had higher levels of education ($p < 0.05$), and had higher reasoning scores at baseline ($p< 0.001$) and at initial training reasoning pretest ($p < 0.001$) than the initial sample (N=290). In the total 1991 replicate, results indicated that individuals who returned 7 years post training (N=239) were significantly younger ($p < 0.001$), more highly educated ($p< 0.05$) and had higher reasoning scores at baseline ($p < 0.001$) and at the initial training reasoning pretest ($p < 0.001$) than the initial sample (N=463).

Total. For the total reasoning trained group across replicates, results indicated that individuals who returned 7 years post training (N=118) were significantly younger ($p < 0.001$), and had higher reasoning scores at baseline ($p < 0.05$) and initial training reasoning pretest ($p < 0.001$) than the initial sample (N=190). For the total space trained group across replicates, results indicated that individuals who returned 7 years post training (N=123) were significantly younger ($p < 0.01$), and had higher reasoning scores at initial training reasoning pretest ($p < 0.05$) than the initial sample (N=212). For the total nontrained group across replicates, results indicated that individuals who returned 7 years post training (N=181) were significantly younger ($p < 0.001$), had higher levels of education ($p < 0.001$), and had higher reasoning scores at baseline ($p < 0.001$) and at initial training reasoning pretest ($p < 0.001$) than the initial sample (N=449). In the total sample across replicates, results indicated that individuals who returned 7 years post training (N=422) were significantly younger ($p < 0.001$), more highly educated ($p < 0.01$) and had higher reasoning scores at baseline ($p < 0.01$) and at the initial training reasoning pretest ($p < 0.001$) than in the parent sample (N=842).

Question 3 Sample

Although the sample sizes varied depending on the specific clinical outcome, the largest sample size was utilized for this sample description. See Table 3 for complete descriptive information. The total sample consists of 1203 individuals who were at least 64 years of age at the baseline occasion (1984 for the 1984 replicate; 1991 for the 1991 replicate). Mean age at baseline was 72.73 years of age (Range = 64-95; SD = 6.43), and mean education level was 13.87 years (Range = 4-20; SD = 3.03). The trained individuals had a mean age of 73.09 years (Range = 64-95; SD = 6.51), and a mean education level of 14.13 years (Range = 6-20; SD = 2.96). Those trained on spatial orientation had a mean age of 73.02 years (Range = 64-95; SD = 6.32), and a mean education level of 14.13 years (Range = 4-20; SD = 3.03). The reasoning trained group had a mean age of 73.16 years (Range = 64-93; SD = 6.73), and a mean education level of 14.13 years (Range = 7-20; SD = 2.90). The nontrained individuals had a mean age of 72.54 years (Range = 64-93; SD = 6.38), and a mean education level of 13.73 years (Range = 4-20; SD = 3.05).

1984 Replicate. The 1984 replicate includes 640 individuals. Mean age at baseline was 73.50 years of age (Range = 64-95; SD = 6.61), and mean education level was 13.32 years (Range = 4-20; SD = 3.08). The trained individuals had a mean age of 72.79 years (Range = 64-95; SD = 6.43), and a mean education level of 13.87 years (Range = 6-20; SD = 2.98). Individuals trained on spatial orientation had a mean age of 72.80 years (Range = 64-95; SD=6.23), and a mean education level of 13.83 years

Table 3 Demographic characteristics (mean, standard deviation) for the clinically meaningful outcomes sample by replicate, training status, and training group

	N	Age	Education
1984 Replicate			
Trained	229	72.79(6.43)	13.87(2.98)
Space	119	72.80(6.23)	13.83(3.09)
Reason	110	72.79(6.67)	13.92(2.86)
Nontrained	411	73.89(6.68)	13.00(3.10)
Total	640	73.50(6.61)	13.32(3.08)
1991 Replicate			
Trained	178	73.47(6.61)	14.46(2.92)
Space	95	73.31(6.45)	14.51(2.92)
Reason	83	73.65(6.83)	14.41(2.95)
Nontrained	385	71.10(5.72)	14.49(2.80)
Total	563	71.85(6.11)	14.48(2.84)
TOTAL Sample			
Trained	407	73.09(6.51)	14.13(2.96)
Space	214	73.02(6.32)	14.13(3.03)
Reason	193	73.16(6.73)	14.13(2.90)
Nontrained	796	72.54(6.38)	13.73(3.05)
Total	1203	72.73(6.43)	13.87(3.03)

(Range = 6-20; 3.09). Individuals trained on inductive reasoning ability had a mean age of 72.79 years (Range=64-92; SD = 6.67), and a mean education level of 13.92 (Range = 7-20; SD = 2.86). The nontrained individuals had a mean age of 73.89 years (Range = 64-93; SD = 6.68), and a mean education level of 13.00 years (Range = 4-20; SD = 3.10).

1991 Replicate. The 1991 replicate contained 563 individuals with a mean age at baseline of 71.85 years of age (Range = 64-93; SD = 6.11) and a mean education level of 14.48 years (Range = 6-20; SD = 2.84). The trained individuals had a mean age of 73.47 years (Range = 64-93; SD = 6.61), and a mean education level of 14.46 years (Range = 7-20; SD = 2.92). Those trained on spatial orientation had a mean age of 73.31 years (Range = 64-88; SD = 6.45), and a mean education level of 14.51 years (Range = 8-20; SD = 2.92). The reasoning training group had a mean age of 73.65 years (Range = 65-93; SD = 6.83), and a mean education level of 14.41 years (Range = 7-20; SD = 2.95). The nontrained individuals had a mean age of 71.10 years (Range = 64-88; SD = 5.72), and a mean education level of 14.49 years (Range = 6-20; SD = 2.80).

Design and Procedure

Training Study

Classification of participants into training groups. Participants trained in 1984 or 1991 were classified as having remained stable or declined on the Thurstone (1934) Primary Mental Ability (PMA) Inductive Reasoning and Spatial Orientation measures over the fourteen years prior to training participation (1970-1984 for those trained in 1984; 1977-1991 for those trained in 1991). The statistical criterion for reliable decline on space or reasoning ability was one standard error of measurement or greater (Reasoning = 4 raw points; Space = 6 raw points) below their score fourteen years prior to training (Schaie & Willis, 1986; Dudek, 1979).

Assignment of Participants. Participants were assigned to training on inductive reasoning or spatial orientation based on their classification status. Individuals that experienced decline on only one ability were assigned to the training program for the ability that demonstrated decline. Participants who either declined or remained stable on both target abilities were randomly assigned to the reasoning or space training programs.

Procedure. A pretest-posttest control group design was used. The training programs consisted of five one-hour sessions of training on the target ability, which usually took place in the participant's home. Middle-aged trainers who had prior experience working with older adults conducted the training sessions. Following the training sessions, participants completed the posttest battery of measurements, which was identical to those measures administered at the pretest. The pretest served as the 1984 or 1991 longitudinal assessment for the participants. Booster training sessions were conducted 7-years post initial training (1991 for those initially trained in 1984; 1998 for those initially trained in 1991). These training sessions included the same amount of training sessions and training material as initial training.

Training programs

Inductive reasoning. Inductive reasoning involves the ability to recognize, understand, and analyze novel concepts and to use these skills to solve subsequent problems. This requires identifying patterns or rules and applying them to the problem. There were four major pattern description rules that participants were taught to identify: repeats, next, skips, and backward next. Participants learned to identify the rules and solve the problems through modeling, feedback, and practice procedures. The participants were encouraged to use strategies such as reading aloud, making tick marks to indicate skips, making slashes to separate repetitions, and underlining repeats to identify and solve the pattern. The practice problems utilized similar rules, but had different content from the actual items on the test. Once participants identified patterns, the trainers instructed them how to identify a series within the pattern by following the rule. Training sessions involved practicing the patterns and problems, and discussing them afterwards. The cognitive skills used in inductive reasoning tasks are important in daily life for everyday problem solving (e.g., modifying quantities in a recipe, determining medication dosages, or interpreting bus schedules).

Spatial orientation. Spatial orientation involves the ability to visualize and mentally manipulate two or three-dimensional objects in space. This ability requires both speed and accuracy. Participants must be able to identify which of six drawings can be rotated to look like the target drawing. The practice problems developed represented the angles of rotation identified in the task measure (45, 90, 135, 180, 225, 270, and 315 degree angles). Cognitive strategies to facilitate solving these problems included developing concrete terms for the various angles, manually rotating the figures prior to mental rotation, practicing mental rotation with familiar objects prior to applying this to abstract figures, generating names for the abstract items, and focusing on two or more features of the figure during rotation. The cognitive skills used in spatial orientation are important in daily life (e.g., reading a map or interpreting floor plans).

Measures

The measures that represented the dependent and independent variables for the samples are described below.

Question 1 and 2 Variables

See Table 4 for information on the measures that will be used for the Nagin Mixture Modeling in Questions 1 and 2.

Dependent Variable: Inductive Reasoning. In 1977, only the PMA inductive reasoning ability t-score was available. Since 1984, the longitudinal cognitive assessment has involved two testing sessions involving 20 cognitive tests measuring 6 cognitive abilities at the construct level (Schaie, 1996). For training participants, the pretest served as the longitudinal assessment battery; the posttest involved the same battery given at pretest. The cognitive ability battery is composed of multiple measures of six cognitive abilities, inductive reasoning, spatial orientation, numeric facility, verbal comprehension, perceptual speed, and verbal memory. The factor scores were computed and standardized across the total sample at the first occasion of measurement (1984). The six-ability factor structure was developed in previous research (Schaie, Dutta, & Willis, 1991). Only the inductive reasoning ability factor will be used in this study.

Inductive Reasoning. Inductive reasoning ability involves identifying patterns or rules and applying them to solve a problem. This involves the ability to recognize novel concepts or relationships and the ability to solve logical problems. The cognitive factor score for inductive reasoning is derived from the following measures: Primary Mental Abilities Reasoning, ADEPT Letter Series, Word Series, and Number Series. Each test score was computed by summing the number of correct responses.

Table 4 Description of measures to be used for Question 1

Measure	N	Score Range	Time Limit	Score Used
DEPENDENT VARIABLE				
Inductive Reasoning				
PMA Reasoning	421	1-30	6 minutes	# correct
ADEPT Letter Series	421	1-20	4.5 minutes	# correct
Word Series	421	1-30	6 minutes	# correct
Number Series	421	1-15	4.5 minutes	# correct
COVARIATES				
Chronic Disease				
Diabetes	399	0-14	-	years with disease
Hypertension	399	0-14	-	years with disease
Heart/cerebrovascular disease	399	0-14	-	years with disease
Osteoarthritis	399	0-14	-	years with disease
Health Behaviors				
Health Behaviors Questionnaire				
Smoking	380	31-54	-	Factor score total
Alcohol consumption	380	23-72	-	Factor score total
Food consumption	380	1-61	-	Factor score total
Food preparation	380	20-66	-	Factor score total
Exercise	380	35-61	-	Factor score total
Seat-belt use	380	19-54	-	Factor score total
Dental care	380	21-68	-	Factor score total
Medical Check-ups	380	30-67	-	Factor score total
Cognitive Style				
Test of Behavioral Rigidity	413			
Capitals Test	413	1-100	5 minutes	Scale totals
Opposites Test	413	1-120	6 minutes	Scale totals
TBR Questionnaire	413	1-75	-	Scale totals
Cognitive Reserve/Engagement				
Life Complexity Inventory		-	-	
Education	421	6-20	-	years of education
Occupation	421	0-9, 55, 66, 77, 88	-	Occupational status
Income	421	-2 - +2	-	z-score income
Communication Activity	406	38-62	-	factor score total
Education/Culture Activity	406	39-70	-	factor score total
Fitness Activity	406	38-67	-	factor score total
Household Activity	406	38-75	-	factor score total
Social Activity	406	38-84	-	factor score total
Solitary Activity	406	40-69	-	factor score total

To complete the Primary Mental Abilities (PMA) Inductive Reasoning (Thurstone, 1948), participants must identify the pattern in a series of letters and report the letter that comes next in the series. The measure consists of 30 test items, and participants must complete the items within 6 minutes.

ADEPT Letter Series (Blieszner, Willis, & Baltes, 1981) parallels the inductive reasoning measure from the PMA (Thurstone, 1948), but includes additional pattern description rules. Participants identify the pattern for the letter series and report the letter that comes next in the series from five letter choices. It has 20 test items, and participants are limited to 4.5 minutes to complete the measure.

In the Word Series measure (Schaie, 1985) items involve the same pattern as for the PMA inductive reasoning measure (Thurstone, 1948) except word series rather than letter series are included. Participants must identify which word, such as the month or day of the week, comes next in the series. The measure consists of 30 items, and participants have 6 minutes to complete it.

The Number Series test (Thurstone, 1962) involves a series of numbers and participants must identify the number that would appear next in the series. The measure is comprised of 20 items with 4.5 minutes allotted for completion.

The inductive reasoning factor score was used for all time points beginning with 1984. The factor score tends to be more stable because error is controlled. For those individuals that have 1977 as the first occasion of measurement, the PMA inductive reasoning ability t-score was used.

Inductive reasoning score estimation. The five occasions of measurement included in this study include two posttest occasions. Participants that participated in the training study had both pre and posttest measurements. Individuals that did not participate in the training (nontrained) did not have observed posttest measurements. Thus, it was necessary to generate predicted posttest scores for these individuals. Because the space training group served as the control group for those trained on reasoning ability, the pre-to-posttest improvement observed in the space training group served as a model for generating estimated posttest scores for the non-trained individuals. Using reasoning pretest as the only predictor of reasoning posttest in the space trained group yielded regression weights that were then applied to all individuals that lacked an observed posttest. This procedure was carried out for individuals lacking 1984, 1991 and/or 1998 reasoning posttest data.

Question 2: Covariate Domains

Prior to investigating the covariates associated with the patterns of cognitive change, it was necessary to conduct a confirmatory factor analysis (CFA) on the variables used as covariates of cognitive change in inductive reasoning ability. The purpose of the CFA was to confirm the hypothesized four-factor structure. The four factors that the CFA attempted to confirm were the following: chronic disease, health behaviors, cognitive reserve, and cognitive style.

Chronic Disease. Since participants in the SLS were recruited through their membership in a HMO, all participants' health care records including illnesses/medical conditions requiring medical care and treatment were available. Four chronic diseases were of interest in this study: **diabetes, hypertensive disease, heart/cerebrovascular disease,** and **osteoarthritis**. See Table 5 for the Internal Classification of Disease (ICD) 8 and ICD 9 codes associated with these chronic diseases. A cumulative index was created to represent the number of years (0 to 14) that individuals were diagnosed with each of the four chronic diseases. The years of chronic disease assessment were 1977 through 1991 for the 1984 replicate, and 1984 through 1998 for the 1991 replicate.

Health Behaviors. The Health Behaviors Questionnaire was first administered as a mail survey in 1993. In the 7^{th} wave (1998) of the SLS, the HBQ was included as part of the homework packet. Eight health behavior domain scores can be derived from this measure (Maier, 1995). The health behavior domains are the following: smoking, alcohol consumption, food consumption, food preparation, exercise, seat-belt use, dental care, and medical checkups. The **Smoking** domain represents the amount of cigarettes, cigars, and/or pipes smoked per day. **Alcohol consumption** assesses the number of glasses of wine, bottles/cans of beer, and drinks containing hard liquor drank per week. **Food consumption** is composed of the following: consumption of caffeinated beverages, and beef, egg yolk, and other meat in an average day. **Food preparation** includes the following behaviors: how often individuals eat butter, read sodium labels, buy low sodium products, cook low sodium, read fat labels, buy low fat products, and cook without butter. **Exercise** is composed of hours and frequency of physical exercise per

Table 5 Internal 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 heart disease	402	402
Hypertensive renal disease	403	403
Hypertensive heart and renal disease	404	404
Heart/Cerebrovascular disease	410-438	410-438
Ischemic heart disease	410-414	410-414
Acute myocardial infarction	410	410
Other acute and subacute forms of IHD	411	411
Chronic ischemic heart disease	412	414
Angina pectoris	413	413
Asymptomatic ischemic heart disease	414	414.9
Other forms of heart disease	420-429	420-429
Acute pericarditis, nonrheumatic	420	420
Acute and subacute endocarditis	421	421
Acute myocarditis	422	422
Chronic disease of pericardium, nonrheumatic	423	423
Chronic disease of endocardium	424	424
Cardiomyopathy	425	425
Pulmonary heart disease	426	415-417
Symptomatic heart disease	427	428
Other myocardial insufficiency	428	429
Ill-defined heart disease	429	429
Cerebrovascular disease	430-438	430-438
Subarachnoid hemorrhage	430	430
Cerebral hemorrhage	431	431
Occlusion of precerebral arteries	432	433
Cerebral thrombosis	433	434
Cerebral embolism	434	434.1
Transient cerebral ischemia	435	435
Acute but ill-defined cerebrovascular disease	436	436
Generalized ischemic cerebrovascular disease	437	437.1
Other and ill-defined cerebrovascular disease	438	437
Osteoarthritis	713	715

week. **Seat-belt use** is an assessment of how often seat belts are used when driving in town and driving on the highway. **Dental care** includes frequency of teeth brushing, flossing, and regular dental check-ups. **Medical check-ups** include vision, hearing, physical, cholesterol, and colon/rectal check-ups and flu shots. The 1993 factor scores on these health behavior variables were used for the 1984 replicate, and the 1998 factor scores were used for the 1991 replicate.

Cognitive Style. The Test of Behavioral Rigidity (TBR; Schaie, 1955, 1960; Schaie & Parham, 1975) was used to obtain the three measures of cognitive style. The three measures are motor-cognitive flexibility, attitudinal flexibility, and psychomotor speed. The TBR contains a capitals test, an opposites test, and finally a questionnaire. The capitals test contains two sections, one that requires individuals to copy a paragraph exactly as it appears (producing capital letters and lower case letters exactly as they appear in the stimulus paragraph), and a second section that requires individuals to copy the same paragraph substituting capital letters where lower case letters appear, and lower case letters where capital letters appear. A two and a half minute time limit is imposed for each section. A copying speed score is derived from the number of words correctly copied in the first section. An instructional set flexibility score is calculated as the ratio of the number of correctly copied words in the second section to those in the first section.

The opposites test includes three subsections, each with a two-minute time limit. The first section requires individuals to produce antonyms for the stimulus words. The second section requires the production of synonyms for the stimulus words. The final section requires the participants to produce both antonyms and synonyms depending on whether the word appears in capital or lower case letters. Three scores are produced from the opposites test. Associational speed is the sum of the correct responses from the first two subsections. Two associational flexibility scores are also derived. One score utilizes the ratio of incorrect responses, responses started incorrectly, and erasures to the number of correct responses in the third subsection. The second score utilizes the ratio of correct responses in the third subsection to one half the sum of the correct responses from the first two sections.

The TBR questionnaire contains 75 true/false items that assess rigidity-flexibility, social responsibility, and perseverative behavior.

From these three tests, motor-cognitive flexibility, attitudinal flexibility, and psychomotor speed scores can be derived. **Motor-cognitive flexibility** represents an individual's ability to adapt to a change in stimuli or to inhibit a response to stimuli. This factor score is derived from instructional set flexibility and the two associational flexibility scores (Motor cognitive flexibility = (0.25*instructional set flexibility) + (0.35*associational flexibility 1) + (0.40*associational flexibility 2)). **Attitudinal flexibility** involves an individual's self-reported tolerance to unpredictability, ambiguity, and sudden changes. This factor score is derived from the flexibility and rigidity items and the perseverative behavior scale of the TBR questionnaire (Attitudinal flexibility = (0.50*flexibility-rigidity) + (0.50*perseverative behavior)). **Psychomotor speed** involves the speed that an individual responds to familiar stimuli. This factor score is calculated from copying speed and associational speed (Psychomotor speed = (0.60*copying speed) + (0.40*associational speed)). These three variables were used to represent cognitive style.

<u>Cognitive Reserve/Engagement.</u>

Life Complexity Inventory (LCI; Gribbin, Schaie, & Parham, 1980). The LCI includes data related to demographic, lifestyle, activity, work, educational, and living characteristics of the study participants. Demographic variables included were age/cohort, years of education, income, and occupation.

The response choices for the income variable varied across measurement occasion. It was necessary to standardize this variable in order to ensure the comparability of income across occasion. After obtaining a frequency distribution of income across waves, a z-score transformation was applied to each wave in order to standardize across waves.

In addition, O'Hanlon (1993) developed six activity factors. The activity factors were derived from a list of 34 leisure activities based on the work of Lowenthal and colleagues (1975). Through both exploratory and confirmatory factor analyses, O'Hanlon found six activity factors, communication, education/culture, fitness, household, social, and solitary activities, with the associated factor weights. The activity scores were trimmed to be within three standard deviations of the mean for each variable, and were transformed using square root and logarithmic transformations (O'Hanlon, 1993).

Question 3 Variables: Clinically Meaningful Outcomes

See Table 6 for information on the measures that were used as clinically meaningful outcomes.

Everyday Problems Test (EPT). The Everyday Problems Test (EPT; Marsiske & Willis, 1995; Willis & Marsiske, 1991; Willis & Schaie, 1993) is an instrument designed to assess skills associated with performing the instrumental activities of daily living (IADLs; Lawton & Brody, 1969). The EPT consists of seven scales relevant to daily life including food preparation, medication use, telephone use, shopping and consumerism, financial management, housekeeping and transportation. This is an untimed paper and pencil task in which participants must choose the correct response from four choices. There were a total of 42 questions on this test. This test was first administered in 1998.

Consensus Ratings. The consensus ratings in this study were derived from a procedure rating the status of individuals that completed the neuropsychological battery. The first step in this process was a screening algorithm that utilized cutoff scores based on prior research (see Schaie, 2004 for specific cutoff criteria). In the second stage, two neuropsychologists examined the scores of the individuals that met the screening criteria of the algorithm. These two neuropsychologists then rated the individual as (1) normal, (2) "at risk" for dementia, (3) possible dementia, (4) probable dementia. For the purposes of this study, the consensus ratings were dichotomous. Two different groups were employed: 1) normal versus "at risk"/possible/probable dementia, and 2) normal/"at risk" versus possible/probable dementia. Because completion of the neuropsychological battery was necessary to achieve a consensus rating, ratings were only available for individuals that completed the neuropsych portion of the study.

Health Severity. Health severity is a single variable that is an estimate of the total annual health expenditures in dollars for each study participant. This score was derived by applying empirically estimated weights based on age group, sex, and medication use (Clark, Von Korff, Saunders, Baluch, & Simon, 1995).

Table 6 Description of measures to be used as clinically meaningful outcomes

Measure	Score Range	Score Used
Problem Solving		
Everyday Problems Test	0-42	# correct
Consensus Ratings	0-2	rating given
Health Severity		
Estimated total health expenditures	$232-$9424	estimated $ amount expended
Mortality	-	alive, dead

Mortality. Mortality data (up to 2003) was obtained for all individuals that have baseline data. The Social Security numbers that were provided in the LCI identified mortality status. The Social Security Death Index is located at http://www.ancestry.com.

CHAPTER 5
Results

Three broad questions were addressed in this study. The first question focuses on identification of discrete group trajectories of inductive reasoning ability over a 14-year period with five occasions of measurement. Second, covariates of these differential trajectories are examined. The third question investigates clinically meaningful outcomes of training up to 7 or 14 years after initial training. The clinically meaningful outcomes are examined as a function of differing cognitive change trajectories, training status (trained versus nontrained) and as a function of training gain (gain on ability trained).

Trajectories of Cognitive Change in Inductive Reasoning for Three Samples

Nagin Mixture Modeling was utilized to determine the optimal number of trajectories for each of the three samples (nontrained, reasoning trained, space trained). Separate analyses were run for the nontrained group, the reasoning training group, and the space training group. This procedure identified distinctive groups of trajectories within each sample and allowed different shapes of trajectories among the identified groups (Nagin, 1999). Nagin modeling identifies groups of trajectories such that the all trajectory groups significantly differ from one another at each occasion of measurement. Five occasions of measurement were utilized: Time 1 (7 years prior to training), Time 2 (Pretest 1 immediately prior to first training occasion), Time 3 (Posttest 1 immediately following the first training occasion), Time 4 (Pretest 2 immediately prior to the second training occasion), and Time 5 (Posttest 2 immediately after the second training occasion). Thus, each trajectory group identified in each of the three samples significantly differed from all other groups identified within that sample for each of the 5 occasions of measurement. (See Table 1 in Methods for a display of the occasions of measurement for each sample.) The Bayesian information criterion (BIC) was used as the basis for selecting of the model with the optimal number of groups. The BIC is a parsimonious criterion, tending to favor the fewest number of groups (Kass & Raftery, 1995). The model with the maximum (least negative) BIC value was chosen.

Change Trajectories for Nontrained (control) Group

Based on the BIC criterion (See Table 7), it was determined that a 5-group model best fit the data for the control group (BIC = -2634.22). Investigation of the 5-trajectory group model revealed that the trajectories were not all of the same form. Two quadratic, one cubic, and two linear trajectories yielded the best model fit (BIC = -2627.40). See Table 8 for descriptive information for the 5 trajectory groups. Tables 9 and 10 provide mean change scores from the 14-year period examined. See Figure 1 for a display of the trajectory shapes for each group.

Group 1

A quadratic trajectory best fit the model for Group 1 ($Y = 40.64 - 3.38(T) + 0.45(T^2)$). The negative slope indicated an overall decline over time. This group had the lowest average scores on reasoning ability across all five occasions. At all five occasions, reasoning scores for this group were significantly lower than all other groups ($p < 0.001$). Overall, this group experienced a similar magnitude of decline across the two longest intervals (7 years each; time 1 to time 2 and time 3 to time 4). Specifically, the greatest decline was experienced between times 1 and 2 ($p < 0.05$), and between times 3 and 4 ($p < 0.001$). There was evidence of a slight improvement or retest effect from pre-to-posttest for both the initial training ($p < 0.001$) and the booster training ($p < 0.001$) occasions, with slightly more improvement during the booster training occasion. The pre-to-posttest improvement was enough such that there was not evidence of a significant difference in level of reasoning ability between occasions 1 and 3 (the 7-year period including initial training) or occasions 3 and 5 (the 7-year period including booster training). The overall decline over the 14-year period was not statistically significant ($p = 0.05$). In comparison to the other nontrained groups, this group can be described as *low ability with the greatest initial (7 year) decline*. Approximately 14% of the sample had posterior probabilities that would place them in this group.

Group 2

For group 2, a quadratic trajectory best fit the model ($Y = 45.87 - 2.44(T) + 0.25(T^2)$). Again, the negative slope suggested an overall decrease in ability level over time. Approximately 29% of the sample was included in this group. The trajectories for groups 1 and 2 differed in two important ways: 1) Group 2 had a higher intercept, and

Table 7

Nagin Modeling Groups: Nontrained sample (N=181)

# of Groups	BIC
2	--2821.03528
3	-2724.11639
4	-2671.18838
5	-2634.21903
6	-2641.69031
7	-2647.35747
8	-2627.17283

Table 8

Means (standard deviations) for the 5-group model: Nontrained (Control) Sample

	Group 1	Group 2	Group 3	Group 4	Group 5
N	26	50	40	44	21
% membership	14.01	28.66	22.15	24.49	10.70
Equation	Y = 40.64 – 3.38(T) + 0.45(T^2)	Y = 45.87 – 2.44(T) + 0.25(T^2)	Y = 41.58 + 9.44(T) – 3.79(T^2) + 0.41(T^3)	Y = 54.41 – 0.78(T)	Y = 59.82 – 0.60(T)
Occasion 1	38.00(5.05)	43.84(4.44)	48.03(3.69)	53.75(2.50)	59.43(4.30)
Occasion 2	34.62(2.84)	41.04(2.31)	46.90(2.74)	51.82(2.37)	57.87(2.87)
Occasion 3	36.44(2.89)	42.91(2.29)	48.79(2.76)	53.70(2.38)	59.56(2.93)
Occasion 4	33.08(2.86)	38.28(2.51)	43.20(2.00)	49.45(2.36)	55.90(2.98)
Occasion 5	35.29(2.69)	40.33(2.46)	45.13(1.91)	51.13(2.24)	57.38(.04)

Note: Occasion 1 is 7 years prior to training. Occasion 2 is the first pretest immediately prior to the first training occasion. Occasion 3 is the first posttest immediately following the first training occasion. Occasion 4 is the second pretest immediately prior to the second training occasion. Occasion 5 is the second posttest immediately after the second training occasion.

Table 9

Reasoning change score means across the 14-year interval: Nontrained sample

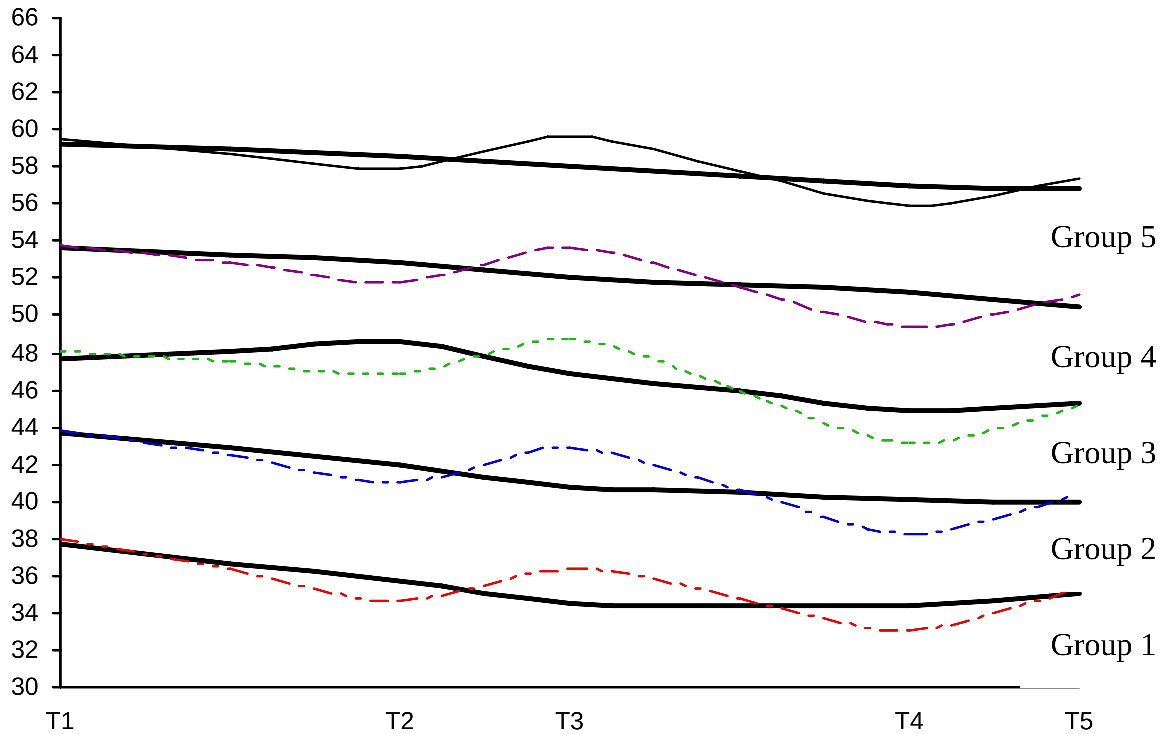
	Group 1	Group 2	Group 3	Group 4	Group 5
N	26	50	40	44	21
First 7 year interval	-3.38	-2.80	-1.13	-1.93	-1.86
(T1 to T2)	(6.23)	(5.08)	(3.64)	(3.14)	(3.61)
First pre-post	1.82	1.87	1.89	1.89	1.99
(T2 to T3)	(0.21)	(0.19)	(0.18)	(0.12)	(0.17)
Second 7 year	-3.36	-4.63	-5.59	-4.25	-3.65
interval (T3 to T4)	(3.23)	(3.73)	(4.06)	(3.15)	(3.87)
Second pre-post	2.21	2.05	1.93	1.67	1.48
(T4 to T5)	(0.42)	(0.26)	(0.13)	(0.13)	(0.25)
14 year interval	-2.71	-3.51	-2.90	-2.62	-2.05
	(6.28)	(5.39)	(4.60)	(3.40)	(3.78)

Table 10

Reasoning change score means for change associated with training: Nontrained sample

	Group 1	Group 2	Group 3	Group 4	Group 5
N	26	50	40	44	21
First training session	-1.56	-0.93	0.77	-0.05	0.13
interval (T1 – T3)	(6.28)	(5.03)	(3.59)	(3.12)	(3.51)
Second training session	-1.15	-2.59	-3.67	-2.58	-2.17
interval (T3 – T5)	(3.17)	(3.66)	(3.99)	(3.08)	(3.86)
14 year interval	-2.71	-3.51	-2.90	-2.62	-2.05
	(6.28)	(5.39)	(4.60)	(3.40)	(3.78)

Figure 1. Predicted and mean trajectories for the nontrained sample by trajectory group.



had consistently higher levels across time than group 1 ($p < 0.001$); 2) Group 1 had a steeper slope and a larger quadratic term indicating more rapid decline than group 2. Thus, as illustrated in Table 2, it appears that group 1 was lower functioning and exhibited a steeper and more dramatic rate of decline than group 2. On average, group 2 demonstrated less initial decline over the first 7-year period (time 1 to time 2), followed by a greater decline over the second 7-year period (time 3 to time 4) when compared to group 1. The decline evident in group 2 over the second 7-year period was about two times as much as the decline over the first 7-year period. However, there was still evidence of significant decline over the two 7-year periods ($p < 0.001$) and over the 14-year period ($p < 0.001$). Group 2 did demonstrate evidence of retest effects of similar magnitude at both training occasions ($p < 0.001$). The difference in level of reasoning ability from occasions 1 to 3 was not significant, suggesting that participants were functioning at a comparable level after the first training occasion as they were 7 years prior to training. However, the difference in level between occasions 3 and 5 was significant ($p < 0.001$), with participants performing at a higher level at time 3. Group 2 can be described as *low ability with the greatest overall (14 year) decline* for the 5 nontrained groups.

Group 3

A cubic-order trajectory best fit the model for Group 3, which encompassed approximately 22% of the sample ($Y = 41.58 + 9.44(T) – 3.79(T^2) + 0.41(T^3)$). The predicted equation suggests a slight increase over the first 7-year period (time 1 to time 2), followed by a decrease over the second 7-year period (time 3 to time 4), with a slight increase in the final one-month assessment (occasions 4 and 5). Overall, this group had higher mean scores across all occasions when compared to groups 1 and 2 ($p < 0.001$). Although on average there was decline over the initial 7- year period, the decline in this group was less compared to groups 1 and 2, and when taking into account the initial practice effect (time 2 to time 3), there was little evidence of decline. The change from occasion 1 to 3 was nonsignificant. Thus, group 3 participants were functioning at comparable levels at occasions 1 and 3. However, the decline over the second 7-year period was substantial ($p < 0.001$), and the decline over the entire 14-year period was significant ($p < 0.001$). The decline over the second 7-year period was almost five times as much as the decline over the first 7-year period and almost two times as much as the overall decline. Furthermore, the overall decline over the entire 14-year period was over two and a half times the decline of the first 7-year period. As with the previous two groups, there was evidence of retest effects of comparable magnitude coinciding with both training occasions ($p < 0.001$). Group 3 can be described as *average ability with relative stability over the first 7- year period followed by marked and the greatest decline of the 5 nontrained groups over the second 7-year period*.

Groups 4 and 5

Finally linear trajectories best fit Groups 4 (Y = 54.41 – 0.78(T)) and 5 (Y = 59.82 – 0.60(T)). Groups 4 and 5 had the highest mean scores across occasions; the means for group 5 were higher than those for group 4 ($p < 0.001$). However, both groups did exhibit significant decline over the first 7-year period ($p < 0.05$), the second 7-year period ($p < 0.001$), and the entire 14-year period ($p < 0.05$). For both groups, the decline over the second 7-year period was approximately twice as great as the decline over the first 7-year period. These two groups differed in intercept (group 5 had a higher intercept), and slope (group 4 had a steeper overall slope). Thus, group 4 exhibited a steeper rate of decline in comparison to group 5. Both groups displayed evidence of retest effects at initial and booster training occasions ($p < 0.001$). Groups 4 and 5 also both exhibited nonsignificant change in level from occasion 1 to 3, and significant decline in level of reasoning ability from occasions 3 to 5 ($p < 0.01$). Thus, despite the evidence of retest effects at booster training, this was not enough to counter the overall decline exhibited over the second 7-year period. In comparison to the other nontrained groups, group 4 can be described as the *high ability average group*. Group 5 can be described as the *high ability group with the least overall decline (14 year)*. Approximately 24% and 11% of the sample was included in groups 4 and 5 respectively. Overall, it appears that group 5 was the highest functioning and exhibited the least amount of decline of the five groups present in the nontrained sample.

Change Trajectories for the Reasoning Training Group

Investigation of the BIC values revealed that a 4-group model best fit the data for the reasoning training sample (BIC = -1830.34; see Table 11). The BIC value improved when different trajectory forms were permitted (BIC = -1817.41; Figure 2). Zero-order trajectories best fit three out of the four groups. Groups 1, 3, and 4 exhibited zero-order trajectories, thus, level of reasoning ability was the distinguishing factor amongst these groups. Group 2 exhibited a linear decline trajectory. See Table 12 for descriptive information on the 4 groups. Tables 13 and 14 contain descriptive information on the change score means for the 14-year period. Fit of the zero-order trajectories suggests that the training and booster training were successful in that individuals maintained their initial ability levels across the 14-year interval.

Group 1

A zero-order trajectory (Y = 38.20) best fit the data for group 1 (15% of the sample). This suggests that overall, across the five occasions, this group remained at the same ability level. There was not a significant difference in ability level between time 1 and time 5. Group 1 exhibited the lowest reasoning scores across occasions ($p < 0.001$). Over the first 7-year period, this group demonstrated decline ($p < 0.001$). However, there was evidence of a significant training effect. In general, participants scored significantly higher on inductive reasoning ability at occasion 3 compared to occasion 2 ($p < 0.001$). Furthermore, this training effect contributed to the nonsignificant change in level between occasions 1 and 3. There was a similar magnitude of decline over the second 7-year period (time 3 to time 4; $p < 0.001$). This suggests that there was little maintenance of ability as a result of initial training. After booster training, there was evidence of gain in performance ($p < 0.001$). However, group 1 experienced over twice the gain from initial training as compared to booster training. Moreover, there was a significant difference in level of reasoning ability from time 3 to time 5. Participants scored significantly higher at time 3 than time 5 ($p < 0.001$). Thus, despite the gains in reasoning ability as a result of booster training, these gains were not large enough to recover all the decline experienced. Group 1 can be described as *low ability with the greatest initial (7 year) decline* of the 4 reasoning trained groups. As suggested by the zero-order trajectory, there was no significant decline over the 14-year period.

Table 11

Nagin Modeling Groups: Reason Training Sample (N=118)

# of Groups	BIC
2	-1913.23796
3	-1854.84979
4	-1830.34273
5	-1832.46929
6	-1834.53796
7	-1839.57097
8	-1848.50913

Table 12

Means (standard deviations) for the 4-group model: Reason training sample

	Group 1	Group 2	Group 3	Group 4
N	18	38	46	16
% membership	15.17	33.58	37.59	13.66
Equation	Y = 38.20	Y = 46.88 – 0.59(T)	Y = 51.38	Y = 59.83
Occasion 1	40.11(3.48)	47.05(4.28)	52.11(4.24)	61.19(2.90)
Occasion 2	35.50(2.31)	43.29(3.41)	49.63(3.03)	57.63(2.94)
Occasion 3	41.06(3.56)	48.26(3.01)	54.13(2.60)	62.38(2.13)
Occasion 4	35.83(3.54)	41.16(2.95)	48.48(3.47)	57.00(2.76)
Occasion 5	38.22(4.28)	44.98(4.07)	52.35(3.14)	61.25(2.24)

Note: Occasion 1 is 7 years prior to training. Occasion 2 is the first pretest immediately prior to the first training occasion. Occasion 3 is the first posttest immediately following the first training occasion. Occasion 4 is the second pretest immediately prior to the second training occasion. Occasion 5 is the second posttest immediately after the second training occasion.

Table 13

Reasoning change score means across the 14-year interval: Reasoning training sample

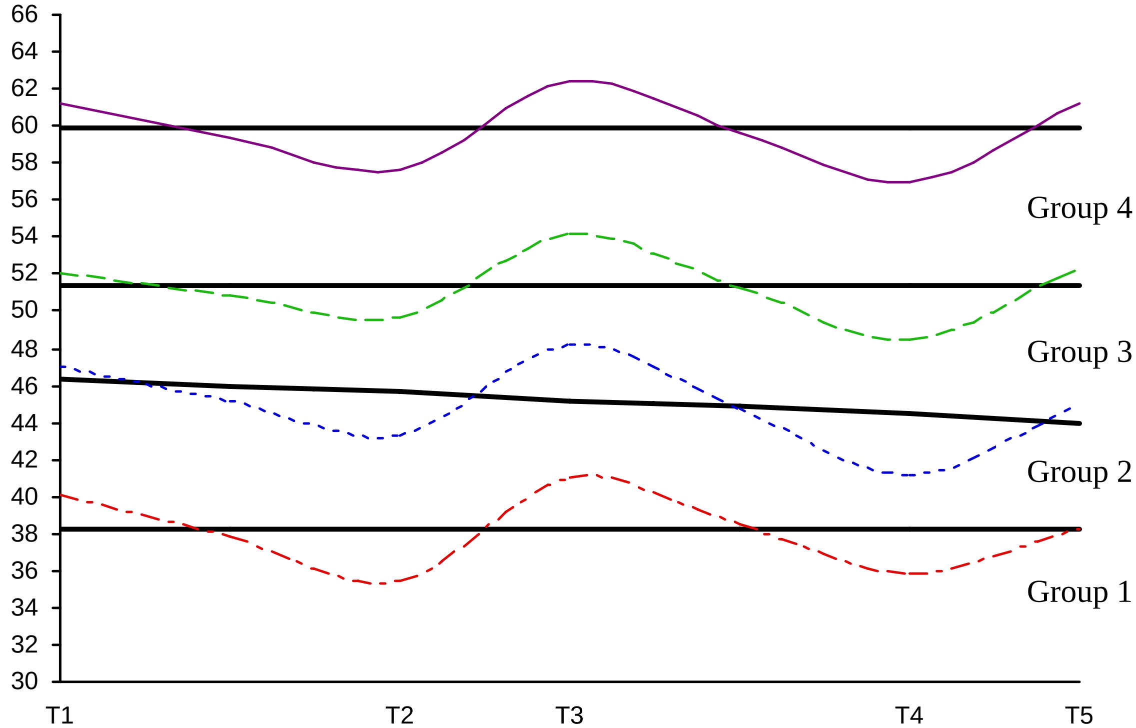
	Group 1	Group 2	Group 3	Group 4
N	18	38	46	16
First 7 year interval	-4.62	-3.76	-2.48	3.56
(T1 to T2)	(3.63)	(4.40)	(4.96)	(3.48)
First pre-post	5.56	4.97	4.50	4.75
(T2 to T3)	(2.38)	(3.23)	(3.07)	(1.73)
Second 7 year	-5.22	-7.11	-5.65	-5.38
interval (T3 to T4)	(3.95)	(4.43)	(4.11)	(2.85)
Second pre-post	2.39	3.82	3.87	4.25
(T4 to T5)	(2.48)	(2.97)	(2.98)	(3.09)
14 year interval	-1.89	-2.07	0.24	0.06
	(5.88)	(7.05)	(4.95)	(2.35)

Table 14

Reasoning change score means for change associated with training: Reasoning training sample

	Group 1	Group 2	Group 3	Group 4
N	18	38	46	16
First training session	0.94	1.21	2.02	1.19
interval (T1 – T3)	(4.58)	(4.62)	(5.01)	(2.76)
Second training session	-2.83	-3.28	-1.78	-1.13
interval (T3 – T5)	(3.79)	(5.17)	(3.88)	(2.55)
14 year interval	-1.89	-2.07	0.24	0.06
	(5.88)	(7.05)	(4.95)	(2.35)

Figure 2. Predicted and mean trajectories for the reason training sample by trajectory group.



Group 2

Group 2 was the only group to display a linear trajectory (Y = 46.88 – 0.59(T)). This group initially had a higher level of ability than group 1 ($p < 0.001$). However, the negative slope suggests that a decline in inductive reasoning ability occurred over time. Group 2 exhibited decline over the first 7-year period ($p < 0.001$), and initial training was effective at remediating this decline ($p < 0.001$). The nonsignificant difference between occasions 1 and 3 is evidence that the training was effective. Over the second 7-year period, there was no evidence of maintenance of the training effects ($p < 0.001$). However, after booster training, there was some remediation of ability ($p < 0.001$). Despite the positive training effects, over the second 7-year period, group 2 declined almost twice as much as over the first 7-year period. As a result of training, group 2 did not exhibit significant change in level over the first training interval (time 1 to time 3). However, there was evidence of significant decline over the booster training interval (time 3 to time 5; $p < 0.001$). Group 2 can be described as the *average ability reasoning training group with the greatest overall (14 year) decline and the greatest decline over the second 7-year period*. Approximately 34% of participants had posterior probabilities that would place them in group 2. Overall, in spite of the linear decline trajectory, there was no evidence of significant decline over the entire 14-year period.

Groups 3 and 4

Zero-order trajectories best fit the data for groups 3 (Y = 51.38) and 4 (Y = 59.83). As indicated by the equations, in comparison to the other groups, both groups 3 and 4 had higher mean levels across all occasions of measurement, with group 4 demonstrating higher levels than group 3 ($p < 0.001$). The zero-order trajectories suggest that over time, these groups did not exhibit an overall increase or decrease in ability level. There was no significant change in ability level from time 1 to 5. Both groups demonstrated decline over the first 7-year period (time 1 to time 2; $p < 0.001$). However, there was significant evidence of training gain at initial training and booster training ($p < 0.01$). Level of reasoning ability did not differ at occasions 1 and 3 (the 7-year period that included initial training) or at occasions 3 and 5 (the 7-year period that included booster training). This suggests that individuals were functioning at comparable levels throughout the entire 14-year period due to the effects of training.

When considering maintenance of training effects, neither group demonstrated maintenance of training gains during the second 7-year period ($p < 0.001$). Group 3 experienced over two times more decline over the second 7-year period compared to the first 7-year period. However, the booster training did result in gains in inductive reasoning ability to levels close to 14 years prior. Overall, neither group exhibited a significant change in ability over the 14-year period. Group 3 can be described as the *average ability reasoning training group*. Group 4 can be described as the *high ability reasoning training group with the least overall decline (14 year)*. Approximately 38% and 14% of the sample was included in groups 3 and 4 respectively.

Change Trajectories for Space Training Group

The BIC indicated that a 5-group model best fit the data for the space training sample (BIC = -1856.47; see Table 15). Linear trajectories best fit four of the five groups for this sample. A zero-order trajectory fit Group 5 (See Figure 3). The BIC improved with the appropriate trajectory shapes (BIC = -1844.47). Groups 1 – 4 differed in level and slope. Overall, the intercept tended to increase, while the steepness of the slope decreased. See Table 16 for descriptive information on the trajectories for each group, and Tables 17 and 18 for change scores associated with these trajectories.

Group 1

A linear trajectory best fit the data for group 1 ($Y = 39.31 – 1.21(T)$). In comparison to other groups, this group exhibited rather steep decline over the 14 year period ($p < 0.001$). Significant decline of similar magnitude occurred over the first and second 7-year periods ($p < 0.001$). This group had the lowest mean inductive reasoning scores across all occasions ($p < 0.001$). There was evidence of a significant retest effect of similar magnitude for both pre-to-posttest measurements ($p < 0.001$). However, despite the evidence of positive retest effects, there was also evidence of significant decline over the two training intervals, time 1 to time 3 ($p < 0.01$), and from time 3 to time 5 ($p < 0.01$). This suggests that group 1 experienced consistent decline throughout the 14-year period. Group 1 can be described as the *low ability space training group with the greatest initial (7 year) and overall (14 year) decline*. Approximately 19% of the sample had posterior probabilities that would place them in Group 1.

Table 15

Nagin Modeling Groups: Space training sample (N=123)

# of Groups	**BIC**
2	-2007.30454
3	-1930.08808
4	-1868.27298
5	-1856.46788
6	-1858.57240
7	-1864.67338
8	-1872.39816

Table 16

Means for the 5-group model: Space training sample

	Group 1	Group 2	Group 3	Group 4	Group 5
N	23	36	30	25	9
% membership	18.71	29.77	24.02	20.29	7.21
Equation	Y = 39.31 – 1.21(T)	Y = 47.61 – 1.31(T)	Y = 52.46 – 0.90(T)	Y = 57.23 – 0.77(T)	Y = 62.56
Occasion 1	39.04(3.70)	46.69(4.12)	51.57(4.52)	59.96(4.14)	62.78(3.60)
Occasion 2	35.35(2.90)	43.86(2.83)	49.70(2.93)	54.08(2.04)	62.11(1.83)
Occasion 3	36.70(3.32)	45.81(3.07)	51.80(2.34)	56.76(2.39)	65.33(2.35)
Occasion 4	33.00(2.88)	39.69(2.83)	46.70(2.47)	52.84(2.69)	60.44(3.78)
Occasion 5	34.17(3.61)	42.03(3.27)	48.54(2.78)	54.07(3.10)	62.11(4.14)

Note: Occasion 1 is 7 years prior to training. Occasion 2 is the first pretest immediately prior to the first training occasion. Occasion 3 is the first posttest immediately following the first training occasion. Occasion 4 is the second pretest immediately prior to the second training occasion. Occasion 5 is the second posttest immediately after the second training occasion.

Table 17

<u>Reasoning change score means across the 14-year interval: Space training sample</u>

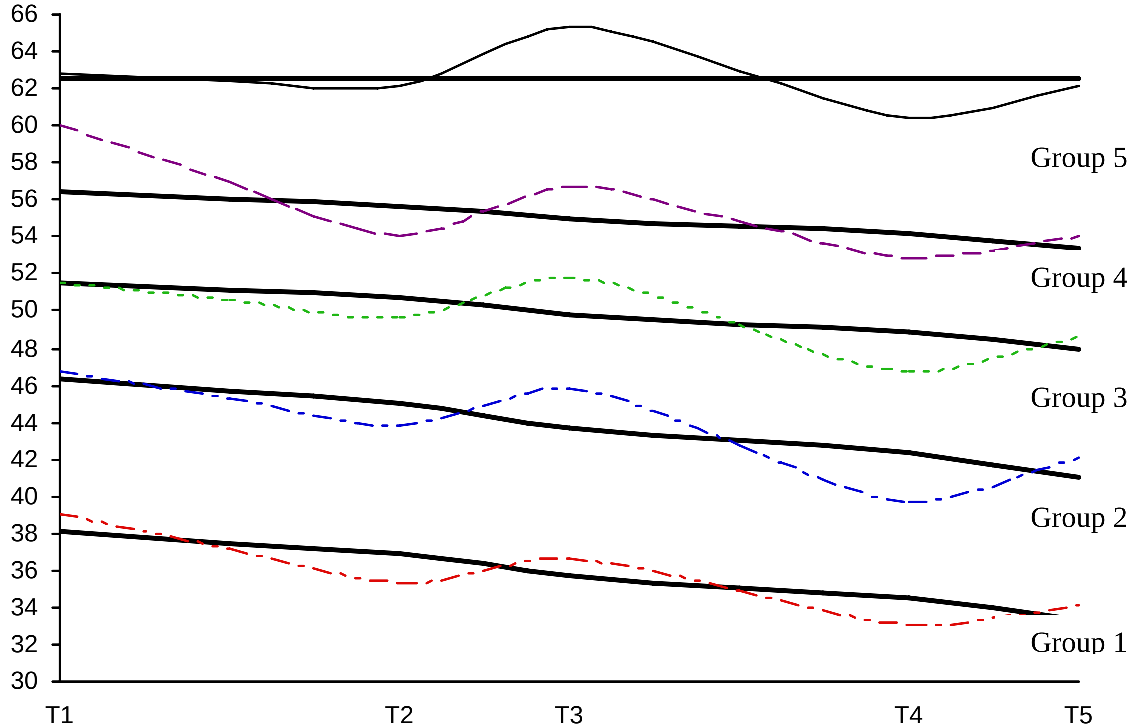
	Group 1	Group 2	Group 3	Group 4	Group 5
N	23	36	30	25	9
First 7 year interval	-3.70	-2.83	-1.87	-2.88	-0.67
(T1 to T2)	(3.82)	(4.25)	(4.88)	(3.99)	(3.50)
First pre-post	1.35	1.94	2.10	2.68	3.22
(T2 to T3)	(2.33)	(2.79)	(3.58)	(2.51)	(3.03)
Second 7 year	-3.70	-6.11	-5.10	-3.92	-4.89
interval (T3 to T4)	(4.11)	(4.08)	(2.83)	(3.03)	(3.37)
Second pre-post	1.17	2.34	1.84	1.23	1.67
(T4 to T5)	(2.29)	(2.40)	(2.37)	(2.99)	(1.87)
14 year interval	-4.87	-4.66	-3.03	-2.89	-0.67
	(4.98)	(5.61)	(5.26)	(5.77)	(2.83)

Table 18

Reasoning change score means change associated with training: Space training group

	Group 1	Group 2	Group 3	Group 4	Group 5
N	23	36	30	25	9
First training session	-2.35	-0.89	0.23	0.20	2.56
interval (T1 – T3)	(3.04)	(4.31)	(4.77)	(4.42)	(3.40)
Second training session	-2.52	-3.77	-3.26	-2.69	-3.22
interval (T3 – T5)	(4.01)	(4.62)	(3.73)	(3.50)	(3.80)
14 year interval	-4.87	-4.66	-3.03	-2.89	-0.67
	(4.98)	(5.61)	(5.26)	(5.77)	(2.83)

Figure 3. Predicted and mean trajectories for the space training sample by trajectory group.



Group 2

A linear trajectory also best fit group 2 ($Y = 47.61 – 1.31(T)$). This trajectory illustrated significant decline over the 14-year period ($p < 0.001$). The rate of decline was slightly steeper for this group in comparison to group 1. As with group 1, there was evidence of significant retest effects of similar magnitude at both training occasions ($p < 0.001$), as well as evidence suggesting significant decline throughout the two 7-year periods ($p < 0.001$). There was approximately twice the amount of decline over the second 7-year period than for the first 7-year period. Furthermore, no evidence of significant decline was found over the first training interval (times 1 to 3), although significant decline occurred over the second training interval (time 3 to 5; $p < 0.001$). The pre-to-post retest effect demonstrated at booster training was not great enough to recover the decline experienced over the second 7-year period. Approximately 30% of participants had posterior probabilities that would place them in this group. Group 2 can be described as *low ability with the greatest decline over the second 7-year period of the 5 space training groups*.

Group 3

The linear trajectory that best fit group 3 ($Y = 52.46 – 0.90(T)$) exhibited significant decline over the 14-year period ($p < 0.01$). However, the rate of decline was less steep than for groups 1 or 2. Group 3 had higher mean scores across occasions compared to groups 1 ($p < 0.001$) and 2 ($p < 0.001$). There was evidence of significant decline over the two 7-year periods ($p < 0.05$), and of pre-to-posttest retest effects ($p < 0.01$). The pre-to-posttest improvements were of similar magnitude, but group 3 experienced over two and a half times greater decline over the second 7-year period in comparison to the first 7-year period. There was also evidence of significant decline over the second training interval (time 3 to time 5; $p < 0.001$), but not over the first training interval (time 1 to 3). Group 3 can be described as the *average ability space training group*. Approximately 24% of the sample had posterior probabilities that would place them in group 3.

Group 4

Again, a linear trajectory best fit group 4 ($Y = 57.23 – 0.77(T)$). As with the four other groups discussed, there was evidence of significant decline throughout both 7-year periods ($p < 0.001$) as well as the entire 14-year period ($p < 0.05$), with evidence of retest effects at both training occasions ($p < 0.05$). Decline over the two 7-year periods was of similar magnitude. The retest effects were twice as great at initial training in comparison to booster training. There was no significant difference in level of reasoning ability from time 1 to time 3 (the 7-year period that included the first training occasion), but there was evidence of significant decline from time 3 to time 5 (the 7-year period that included the booster training occasion; $p < 0.001$). This group did perform significantly higher on reasoning ability at all occasions in comparison to the previous 3 groups ($p < 0.001$). Approximately 20% of participants had posterior probabilities that would place them in this group. Group 4 can be described as the *high ability average group* of the 5 space training groups. In comparison to group 3, group 4 had greater initial decline, while group 3 had greater overall decline and greater decline during the second 7-year period.

Group 5

Members of group 5 remained stable across the 14-year period (Y = 62.56) with no significant decline. Group 5 was the highest functioning group ($p < 0.001$). No significant decline was found over the first 7-year period, but significant decline occurred over the second 7-year period ($p < 0.01$). The decline over the second 7-year period was over 7 times as great as that observed for the first 7-year period. Significant retest effects were found at initial ($p < 0.05$) and booster training ($p < 0.05$). The initial training improvement was twice that of the booster training improvement. Furthermore, the decline from occasions 3 to 5 (the 7-year period that included booster training) was significant ($p < 0.05$), while the change in reasoning ability from occasions 1 to 3 (the 7-year period that included initial training) was not. Group 5 can be described as the *high ability space training group with the least initial and overall decline*. The presence of the zero-order trajectory exemplifies the relative stability over the 14-year period. Approximately 7% of the sample had posterior probabilities that would place them in this group.

Domains of Covariates Associated with Different Change Trajectories for Reasoning Ability

Determination of Covariate Domains by Factor Analysis

A confirmatory factor analysis (CFA) was performed to model the different domains of covariates. The following four latent factors were hypothesized: chronic diseases, health behaviors, cognitive reserve, and cognitive style.

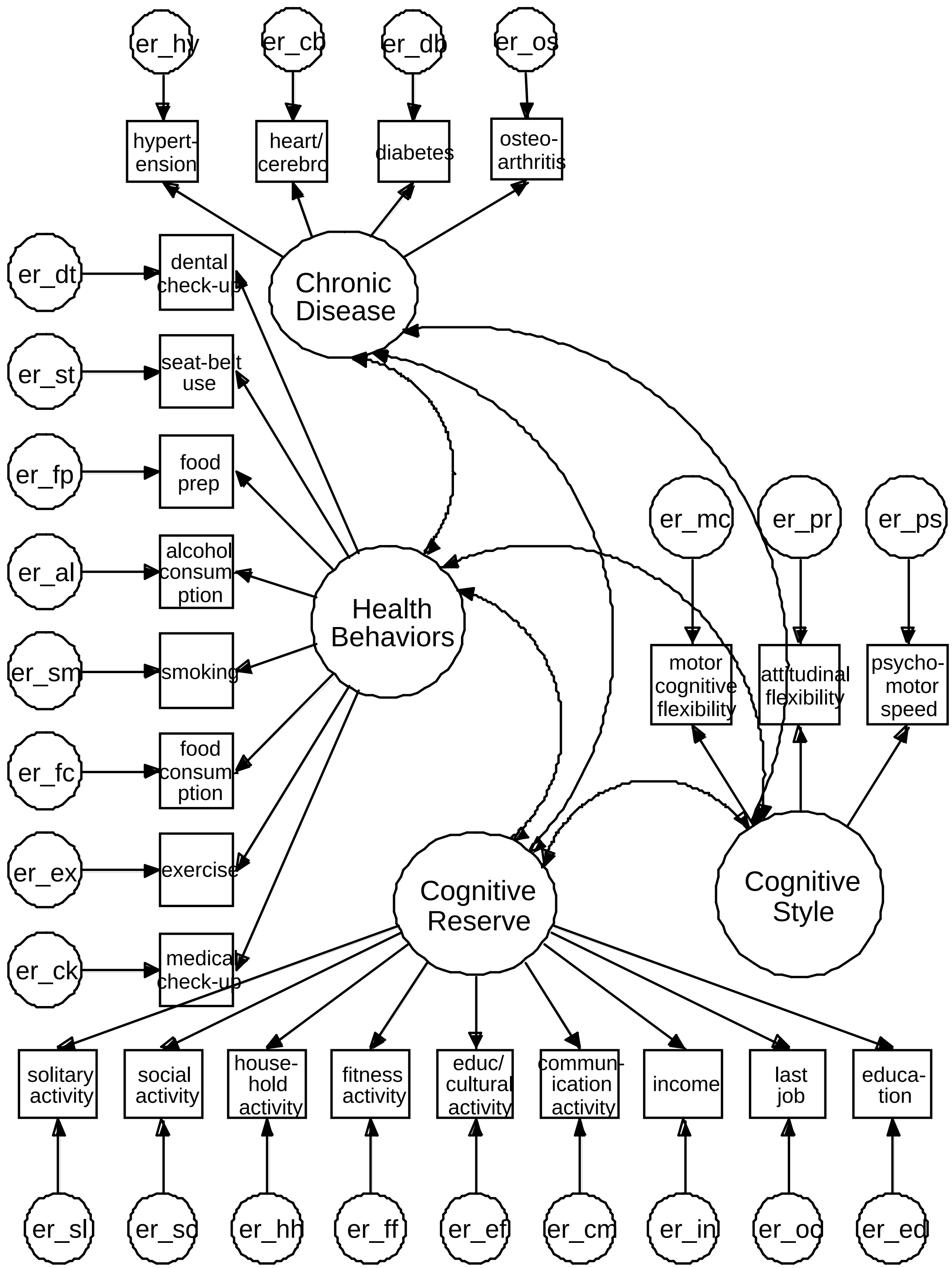
Initial Model

Figure 4 displays the first model examined. For the cognitive reserve factor, six activity factors were included: solitary activities, social activities, educational/cultural activities, household activities, fitness activities, and communication activities. Educational level, income, and status of last occupation before retirement were also included in the cognitive reserve factor. Attitudinal flexibility, psychomotor speed, and motor cognitive flexibility were included in the cognitive style factor. Diabetes, hypertensive disease, cardiac/cerebrovascular disease, and osteoarthritis were included in the chronic disease factor. Finally, eight health behaviors were included in the health behaviors factor: seat belt use, medical check-ups, dental check-ups, food preparation, food consumption, smoking, alcohol use, and exercise. This model allowed correlations between all 4 factors, and allowed only a single pathway for each indicator. This model had a poor fit to the data (X^2(246, N=421) = 549.52 ($p < 0.001$); CFI = 0.60; TLI = 0.51; RMSEA = 0.06).

Model Modifications

To enhance the model fit, alcohol use, smoking, and seat belt use were removed from the health behaviors factor. The communication activity factor, the household activity factor, the solitary activity factor, and the social activity factor were removed from the cognitive reserve factor. In addition, the following factor correlations were set to zero: the correlation between health behaviors and chronic diseases, and the correlation between chronic diseases and cognitive reserve (See Figure 1 in Appendix A). This improved the fit of the model; however, the model was still a poor fit for the data (X^2(115, N=421) = 279.69 ($p < 0.010$); CFI = 0.74; TLI = 0.65; RMSEA = 0.06).

Figure 4. Initial four-factor model.



Further Model Modifications

In further modifications of the model, osteoarthritis was removed, and multiple pathways were added. Food preparation was permitted to load both on the health behaviors and chronic diseases factors. The fitness and educational activity factors were both permitted to load on the cognitive reserve and health behaviors factors (Figure 2 in Appendix A). These changes improved the model to marginally fit the data (X^2(97, N=421) = 170.68 ($p < 0.001$); CFI = 0.88; TLI = 0.83; RMSEA = 0.04). Finally, 3 additional multiple pathways were added: (1) The medical check-ups variable was permitted to load on the health behaviors and chronic disease factors, and (2) income was permitted to load on the cognitive reserve, health behaviors, and (3) cognitive style factors. This improved the fit of the model to between a reasonably good fit (X^2(94, N=421) = 139.48 ($p < 0.01$); CFI = 0.93; TLI = 0.90; RMSEA = 0.03).

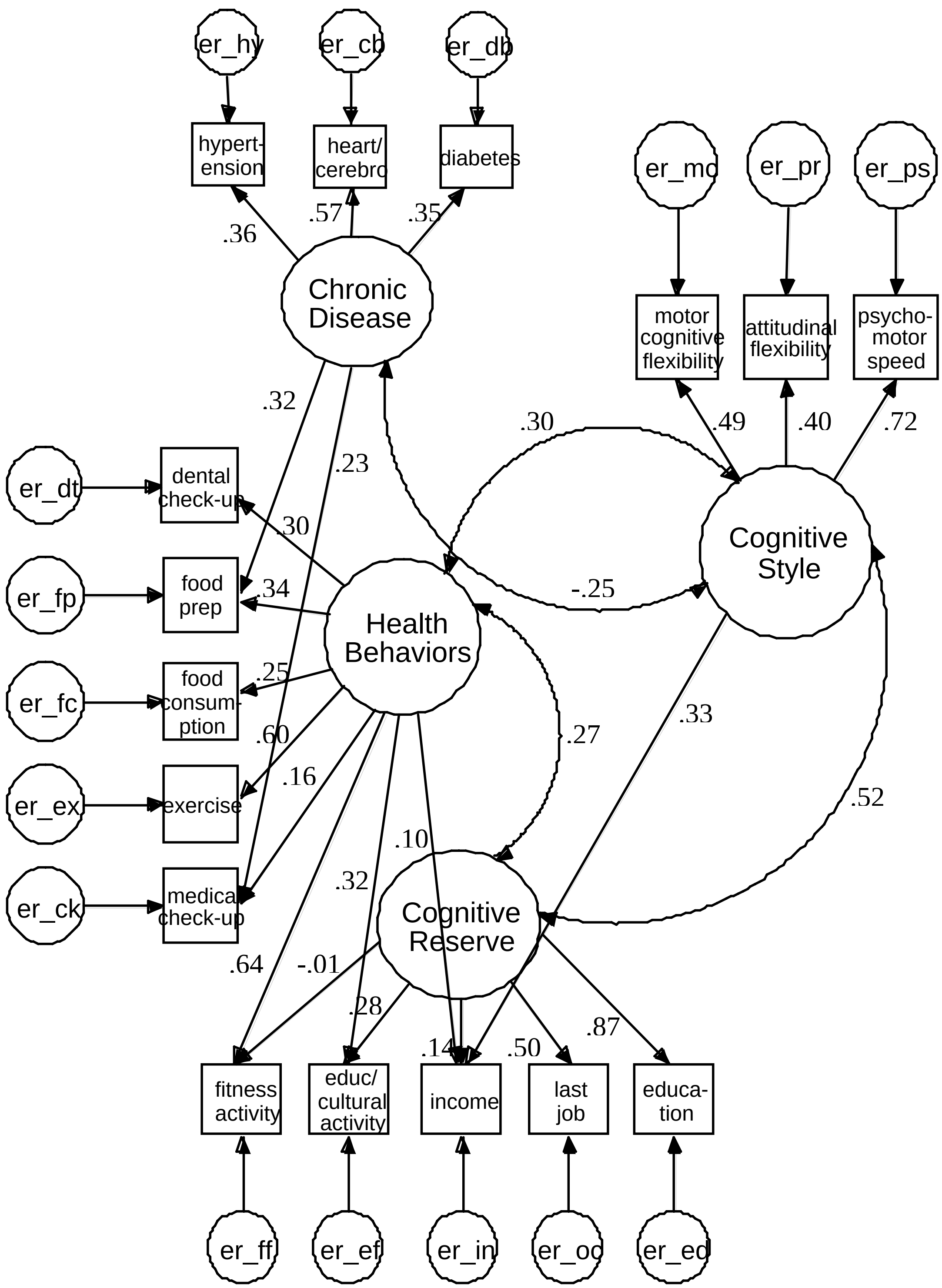
Accepted Model

The final model is illustrated in Figure 5, which also shows the standardized regression weights. The indicators of the cognitive style factor now include attitudinal flexibility, psychomotor speed, motor cognitive flexibility, and income. The chronic disease factor is marked by hypertensive disease, heart/cerebrovascular disease, diabetes, medical check-ups and food. The health behaviors factor includes food consumption, food preparation, medical check-ups, dental check-ups, exercise, fitness activity, educational/cultural activity, and income. Finally, the cognitive reserve factor is comprised of fitness activity, educational/cultural activity, income, status of last occupation before retirement, and education. This is the final factor model defining the covariates to be included in the Nagin mixture models that assess the effect of each factor upon distinguishing group membership in the three samples.

Covariates associated with Different Cognitive Change Trajectories

The factor scores derived from the CFA were incorporated in a second stage of the Nagin models to determine whether and to what degree the covariates distinguished group membership in each of the three samples. Measurement of all the covariates coincided with the last occasion of measurement (Time 5). The one exception was the presence of hypertension, diabetes, and heart/cerebrovascular disease. These variables

Figure 5. Final four-factor model of covariates.



were assessed over the entire 14-year period. For each sample, Group 1, the group with the lowest reasoning scores, served as the comparison group.

Covariates Associated with the Trajectories in the Nontrained Sample

Recall that for the nontrained (control) group, a 5-group model best fit the data. There were two quadratic (the two lowest functioning groups), one cubic, and two linear (the two highest functioning groups) trajectories that characterized the 5 groups. See Table 19 for descriptive information on the 4 covariates by trajectory group.

Cognitive Style. Results of the Nagin modeling indicated that cognitive style was differentially predictive across trajectory groups (see Table 20). Groups 2, 3, 4, and 5 all had higher mean scores on cognitive style than group 1 (low ability with the greatest initial 7 year decline). This indicates that higher levels of inductive reasoning ability are associated with higher levels of cognitive style.

Analysis of Variance (ANOVA) was utilized to test for group differences in level of cognitive style. Results indicated there were significant differences among all pairwise comparisons for the 5 groups ($p < 0.05$) with two exceptions: Groups 3 and 4 did not differ significantly from group 5. In all comparisons, the group with higher levels of reasoning ability also had higher scores on cognitive style. Thus, in terms of level, the three higher functioning groups (3, 4, 5) had similar levels of cognitive style that were higher than those in the lower functioning trajectories (groups 1 and 2).

Multivariate Analysis of Variance (MANOVA) was then employed to determine which indicator variables were most influential. There were no significant group differences in level of income or attitudinal flexibility. For motor cognitive flexibility, the only significant differences in level were between groups 1 and 4 ($p < 0.01$), and groups 1 and 5 ($p < 0.001$). Group 1 scored significantly lower on motor cognitive flexibility than groups 4 and 5. The lowest functioning group (group 1) had much lower scores on motor cognitive flexibility than the two highest functioning groups (4 and 5). All groups significantly differed from one another on psychomotor speed ($p < 0.05$) with two exceptions: Groups 1 and 2 did not significantly differ and groups 4 and 5 did not significantly differ. In all comparisons, the group with higher reasoning scores had higher functioning on psychomotor speed. Thus, the three highest functioning groups (3, 4, 5) had higher scores on psychomotor speed than the two lowest functioning groups (1

Table 19

Mean (standard deviation; range) scores on the covariates for the nontrained sample

	Group				
	1	2	3	4	5
N	19	39	39	35	17
Chronics	55.00	46.26	46.97	47.11	46.71
	(9.02; 38-69)	(10.12; 27-66)	(7.95; 30-62)	(8.99; 27-66)	(6.93; 31-55)
Health Behs	49.79	47.03	48.44	50.26	51.18
	(9.19; 38-68)	(9.02; 28-64)	(11.43; 21-69)	(12.54; 18-69)	(10.77; 34-66)
Cog Reserve	44.16	46.15	49.26	52.00	57.12
	(8.86; 27-59)	(10.33; 24-67)	(10.14; 24-67)	(10.15; 30-70)	(13.31; 39-96)
Cog Style	36.95	44.00	49.69	54.94	54.71
	(9.00; 19-55)	(7.09; 24-56)	(6.53; 36-60)	(6.52; 43-66)	(7.63; 39-65)

Table 20

The impact of chronic diseases, health behaviors, cognitive reserve, and cognitive style on group membership probabilities: Nontrained control sample (BIC = -2145.89; N = 149)

	Group				
	1	2	3	4	5
Constant	-	0.71(2.91)	-4.63(3.33)	-10.63(3.78)	-12.31(4.23)
Chronics	-	-0.07(0.04)	-0.07(0.04)	-0.07(0.05)	-0.09(0.05)
Hlth Behs	-	-0.05(0.05)	-0.09(0.05)	-0.11(0.05) *	-0.11(0.06)
Reserve	-	0.02(0.04)	0.04(0.04)	0.06(0.04)	0.11(0.05)*
Cog Style	-	0.13(0.05)*	0.25(0.06)***	0.37(0.07)***	0.35(0.08)***

NOTE: Values reported are multinomial logit coefficients (standard error). All groups are compared to Group 1.

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

and 2). Additionally, the two highest functioning groups (4 and 5) also had higher psychomotor speed scores than the average functioning group (group 3). The two lowest functioning groups did not differ from each other in level of psychomotor speed, and the two highest functioning groups did not differ from each other in level of psychomotor speed. In summary, for the cognitive style factor, motor cognitive flexibility and psychomotor speed were the most influential indicators associated with the cognitive change trajectories in the nontrained group.

Health Behaviors. Health behaviors had a predictive effect on group membership. Specifically, individuals that engaged in more positive or proactive health behaviors had a greater likelihood of belonging to group 4 (high ability, average group) compared to group 1 (low ability with the greatest initial 7 year decline). It is important to note, that group 4 (N=35; 24% of the sample) displayed a linear decline trajectory, while group 1 (N=19; 14% of the sample) displayed a quadratic decline trajectory. Moreover, recall that in the nontrained sample, group 1 was the only group that did not exhibit significant decline over the entire 14-year period. Thus, it is possible that this group adopted more positive health behaviors with time and/or that group 4 engaged in less positive health behaviors.

Cognitive Reserve. Finally cognitive reserve also had a predictive effect. Individuals with higher levels of cognitive reserve had a greater likelihood of belonging to group 5 (high ability with the least overall decline) compared to group 1 (low ability with the greatest initial 7 year decline). An ANOVA to test for group differences in level of cognitive reserve revealed that the two lowest functioning groups, groups 1 ($p < 0.01$) and 2 ($p < 0.05$), had significantly lower scores than group 5 (the highest functioning group).

MANOVA on the 5 indicators of cognitive reserve revealed that there were significant group differences in status of last occupation and education. Specifically, groups 1 ($p < 0.05$) and 2 ($p < 0.05$) had significantly lower occupational statuses than group 5. Groups 1 ($p < 0.01$) and 2 ($p < 0.05$) also had significantly lower education levels than group 5. In summary, for the cognitive reserve factor, the last occupation and education indicators were the most influential for trajectory group membership in the nontrained sample.

Covariates Associated with the Trajectories in the Reasoning Training Sample

In the reasoning training sample, differences in the salience of the covariates among groups was compared to group 1, the lowest functioning group on reasoning ability. Three of the four groups exhibited zero-order trajectories, while the fourth group demonstrated a linear trajectory. None of the groups exhibited significant decline over the 14-year period, presumably as a result of training on inductive reasoning ability. See Table 21 for descriptive information on the covariates by trajectory group. Results of the Nagin models indicated that both cognitive style and cognitive reserve had a predictive effect on trajectory group (See Table 22).

Individuals with higher scores on cognitive reserve and/or cognitive style had a greater likelihood of being in group 2, 3, or 4 compared to group 1 (low ability with the greatest initial 7-year decline).

Cognitive Reserve. ANOVA revealed that groups 2, 3, and 4 (the highest functioning groups) did not significantly differ in level of cognitive reserve. MANOVA illustrated that of the 5 indicator variables for cognitive reserve, fitness activity, educational/cultural activity, occupational status, income, and education, there were only significant differences in status of last occupation and education. Specifically, groups 3 ($p < 0.001$) and 4 ($p < 0.05$) had significantly higher occupational statuses and education levels ($p < 0.001$) than group 1. In addition, group 3 had a significantly higher occupational status than group 2 ($p < 0.05$). For the reasoning training sample, last occupation and education were the most influential indicators of cognitive reserve associated with group membership.

Cognitive Style. For cognitive style, ANOVA revealed that there were significant mean differences ($p < 0.01$) between all four of the trajectory groups with one exception: groups 3 (average ability) and 4 (high ability with the least overall decline) did not significantly differ in level of cognitive style. Thus, there was no difference in cognitive style between the two highest functioning groups.

A MANOVA of the 4 indicators of cognitive style revealed that there were only significant differences in motor-cognitive flexibility and psychomotor speed. Specifically, all pairwise comparisons were statistically significant ($p < 0.05$) with the exception of the comparison between groups 3 and 4 (the two highest functioning

Table 21

Mean (standard deviation; range) values for the covariates for the reason training sample

	Group			
	1	2	3	4
N	16	34	36	16
Chronics	54.69	51.12	50.33	55.63
	(8.04; 41-69)	(10.83; 32-81)	(9.40; 32-79)	(9.65; 41-75)
Health Behs	50.31	48.32	49.81	53.63
	(9.20; 35-63)	(9.34; 31-69)	(9.68; 29-64)	(10.03; 37-72)
Cog Reserve	40.13	48.91	51.47	52.50
	(5.37; 34-56)	(8.62; 37-64)	(7.61; 36-66)	(6.84; 38-67)
Cog Style	39.44	48.47	56.42	61.69
	(6.47; 29-48)	(8.41; 31-69)	(6.69; 44-72)	(6.04; 51-71)

Table 22

The impact of chronic diseases, health behaviors, cognitive reserve, and cognitive style on group membership probabilities: Reason training sample (BIC = -1546.94; N = 102)

	Group			
	1	2	3	4
Constant	-	-15.21(7.74)	-25.48(8.47)	-35.71(9.26)
Chronics	-	0.00(0.06)	0.02(0.06)	0.08(0.07)
Hlth Behs	-	-0.11(0.06)	-0.14(0.07)*	-0.11(0.08)
Reserve	-	0.25(0.11)*	0.28(0.11)*	0.25(0.12)*
Cog Style	-	0.23(0.09)*	0.40(0.11)***	0.51(0.12)***

NOTE: Values reported are multinomial logit coefficients (standard error). All groups are compared to Group 1.

* $p < .05$

** $p < .01$

*** $p < .001$

groups). In all comparisons, the group with higher levels of inductive reasoning ability also had higher levels of motor cognitive flexibility and psychomotor speed. In summary, for cognitive style, motor-cognitive flexibility and psychomotor speed were the two most influential indicators of cognitive style associated with trajectory group membership for the reasoning training sample.

Health Behaviors. Health Behaviors were also predictive of group membership. Individuals engaging in more positive or less negative health behaviors were more likely to belong to group 1 (low ability with the greatest initial 7 year decline; N=16; 15% of the sample) compared to group 3 (average ability; N=36; 38% of the sample). Both groups 1 and 3 did not experience significant decline over the 14-year period, although group 3 did experience more decline over the second 7-year period than group 1. The health behaviors indicator variables were measured at time 5. It is possible that the lowest functioning group (group 1) adopted more positive health behaviors with time as a result of maintaining their cognitive ability. Alternatively, it is possible that group 3 engaged in less positive health behaviors in conjunction with the decline in reasoning ability experienced throughout the second 7-year period.

Covariates Associated with the Trajectories in the Space Training Sample

In the space training sample, again, all groups were compared to group 1. Four other five trajectory groups were linear. The highest functioning group exhibited a zero-order trajectory.

Cognitive Style. Results of the Nagin modeling indicated that cognitive style had a predictive effect on trajectory group membership (see Tables 23 and 24). Individuals with higher scores on cognitive style had a greater likelihood of being in a group exhibiting higher functioning other than group 1 (low ability with the greatest initial 7-year decline and the greatest overall decline).

ANOVA indicated that all pairwise comparisons of the trajectory groups were significant with two exceptions: Groups 2 and 3 did not significantly differ and groups 4 and 5 did not significantly differ on cognitive style.

A MANOVA of the indicators of cognitive style revealed that group 1 scored significantly lower on motor cognitive flexibility than all other groups ($p < 0.01$). In addition, all pairwise comparisons of trajectory groups were significant ($p < 0.05$) for

Table 23

Mean (standard deviation; range) scores on the covariates for the space training sample

	Group				
	1	2	3	4	5
N	19	30	28	26	8
Chronics	47.42	50.67	52.04	44.12	47.38
	(9.74; 27-61)	(11.94; 22-72)	(11.86; 34-73)	(9.12; 27-59)	(11.75; 32-71)
Health Behs	49.58	47.07	51.00	48.46	53.38
	(10.46; 33-66)	(8.56; 28-58)	(8.87; 35-66)	(9.73; 32-63)	(10.80; 36-69)
Cog Reserve	45.79	45.30	51.14	54.38	59.38
	(12.05; 25-64)	(6.22; 32-55)	(9.84; 33-66)	(9.48; 34-67)	(6.41; 47-67)
Cog Style	37.37	47.00	50.50	56.81	62.50
	(7.18; 25-51)	(7.79; 34-66)	(7.01; 38-66)	(6.85; 48-69)	(4.72; 54-70)

Table 24

The impact of chronic diseases, health behaviors, cognitive reserve, and cognitive style on group membership probabilities: Space training sample (BIC = -1636.72; N = 111)

	Group				
	1	2	3	4	5
Constant	-	-10.06(4.12)	-15.25(4.34)	-19.86(4.97)	-29.87(7.77)
Chronics	-	0.10(0.05)*	0.10(0.05)*	0.02(0.05)	0.03(0.07)
Hlth Behs	-	-0.07(0.05)	-0.06(0.05)	-0.06(0.06)	-0.04(0.08)
Reserve	-	-0.06(0.06)	-0.01(0.06)	0.06(0.07)	0.07(0.09)
Cog Style	-	0.28(0.09)**	0.33(0.09)***	0.42(0.10)***	0.52(0.12)***

NOTE: Values reported are multinomial logit coefficients (standard error). All groups are compared to Group 1.

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

psychomotor speed with the exception of groups 2 (low ability with the greatest decline over the second 7-year period) and 3 (average group) and groups 4 and 5 (the two high ability groups). The group with higher scores on inductive reasoning ability had higher levels of psychomotor speed. Finally, group 1 (low ability with the greatest initial 7 year decline and overall decline) scored significantly lower on attitudinal flexibility than group 4 (high ability, average group; $p < 0.05$). Thus, overall, motor-cognitive flexibility and psychomotor speed were the indicators of cognitive style most highly associated with trajectory group membership in the space training sample.

Chronic Disease. Chronic disease had a predictive effect on membership in trajectory group; individuals with higher scores on chronic disease had a greater likelihood of being in group 2 (low ability with the greatest decline over the second 7-year period) or group 3 (average ability) when compared to group 1 (low ability with the greatest initial 7-year and overall decline). Although all three of these groups exhibited linear trajectories, groups 2 and 3 exhibited more decline over the second 7-year period in comparison to group 1, which may also be indicative of declining health.

Summary: Cognitive change trajectories and covariates

Trajectories. When considering the three samples utilized in this study, the nontrained sample exhibited the most variety in terms of trajectory shapes with evidence of two quadratic, two linear, and one cubic trajectory. In the nontrained sample, all five trajectory groups exhibited significant decline over the two 7-year periods and over the entire 14-year period with the exception of group 1. In addition, all 5 trajectory groups demonstrated retest effects at the initial and booster training occasions. All groups, with the exception of group 1, exhibited more significant decline over the second 7-year period in comparison to the first 7-year period.

Zero-order trajectories best fit 3 of the 4 groups for the reasoning training sample. The groups identified for the reason training sample were distinguished primarily by level differences. This suggests that training contributed to stability or maintenance of inductive reasoning ability over the 14-year period and effects of training did not differ by level. All four groups trained on reasoning ability showed significant decline over each of the two 7-year periods. However, none of the groups exhibited significant decline over the entire 14-year period. All 4 trajectory groups achieved significant improvement at initial training and at booster training.

Finally, for the space training sample, linear decline trajectories best fit 4 of the 5 groups. In general, the rate of decline or the slope was steeper for those with lower initial level. The one zero-order trajectory was indicative of a particularly high functioning group of participants. The four groups that displayed linear decline trajectories exhibited significant decline over both 7-year periods, as well as over the entire 14-year period. All of the groups displayed significant retest effects in conjunction with the two training occasions.

The space training sample did not exhibit zero-order trajectories in comparison to the reason training sample. This may be evidence that simply engaging in mentally stimulating activities is not enough (except in the highest functioning group) to result in maintenance of inductive reasoning ability. Finally, the greatest variability in the trajectories was observed in the nontrained sample. This is not surprising since study participants included in this group were not exposed to any structured cognitive activity, thus leaving more room for variation.

Covariates. Investigation of the covariates of trajectory group membership revealed that cognitive style, and to a lesser extent cognitive reserve, were the most consistent covariates differentiating the trajectories. Across the three samples, individuals exhibiting higher levels of cognitive style and/or cognitive reserve were found in the higher functioning trajectories, or those trajectories that retained higher levels of inductive reasoning ability.

Cognitive Style. For the cognitive style factor, motor cognitive flexibility and psychomotor speed were the two indicators most salient in terms of group differences. Individuals with higher levels of motor cognitive flexibility and/or psychomotor speed tended to be in the higher functioning trajectory groups. This finding was evident across all three samples.

Cognitive Reserve. In addition, when cognitive reserve was significantly associated with trajectory group (in the nontrained and reasoning training samples), status of last occupation and education level were the two indicators that emerged as significantly contributing to trajectory group differences. Higher levels of education and occupational status were associated with membership in the higher functioning trajectory groups. This may be evidence that individuals that are able to maintain their level of ability throughout older adulthood engage in more cognitively stimulating activities and live in more enriching environments that keep their minds active. It is important to note that although the covariates were measured at the final occasion of measurement (time 5), educational level and occupational status were likely to remain the same as reported at time 1. It is possible, therefore, that the relationship between high levels of reasoning ability and high levels of cognitive reserve or style is a reflection of the fact that individuals with higher levels of ability are able to participate in mentally stimulating activities longer, or that they have been exposed to these activities for a longer duration throughout their lives.

Association of Cognitive Change and Clinically Meaningful Outcomes

The association of four clinically meaningful outcomes with change trajectories was investigated in each of the three samples. The outcomes were: health severity, mortality, everyday problem solving, and mental status. Health severity was a single value that represented an estimate of the total annual health expenditures in dollars in 1998. Mortality was a categorical variable that signified whether the participant was dead or alive in 2003. Everyday problem solving was measured in 1998 as the total score on the Everyday Problems Test, which assessed ability to solve problems associated with the instrumental activities of daily living (IADL). Finally, mental status was a categorical variable. Individuals were classified as normal, at-risk of dementia, possible dementia, or probable dementia in 1998 as rated by neuropsychologists.

Clinical Outcomes of Nontrained Group

Health Severity

Analysis of covariance (ANCOVA) was used to investigate whether health care expenditures in 1998 varied as a function of trajectory group. Age, education, replicate, and the chronic disease factor score were used as covariates. The replicate variable indicated whether the participant’s change trajectory spanned from 1977 to 1991 or from 1984 to 1998. Thus, the outcome of health severity was a 7-year outcome for the 1977 to

1991 replicate, and a concurrent outcome for the 1984 to 1998 replicate. Results indicated that there was no significant difference in health care expenditures in 1998 as a function of trajectory group (See Table 25). However, there were significant main effects for the covariates of age ($p < 0.01$), and chronic disease ($p < 0.001$). Younger age and lower chronic disease scores were associated with lower health care costs.

Mortality

Chi-square was employed to investigate whether the trajectory groups differed in proportion of participants deceased versus alive. Mortality was assessed up to 2003. This was a 12 year follow-up for the 1977-1991 replicate and a 5 year follow-up for the 1984-1998 replicate. The chi-square was significant, $X^2(4, N=181) = 12.77$, $p = 0.01$, suggesting a significant mortality effect as a function of trajectory group (see Table 26). Follow-up post-hoc comparisons revealed that there were significant differences between groups 1 and 4 ($p < 0.01$), groups 1 and 5 ($p < 0.01$), groups 2 and 4 ($p < 0.05$), and groups 2 and 5 ($p < 0.05$). Thus, the two lowest functioning groups (1 and 2) significantly differed from the two highest functioning groups (4 and 5).

In comparison with groups 1 and 2 (the lowest functioning groups), group 4 (high ability average group) had significantly more participants still alive. Approximately 88.64% of participants in group 4 were still alive in 2003, compared to only 61.54% of group 1, and 70% of group 2. In comparison with groups 1 and 2 (the two lowest functioning groups), group 5 (high ability with the least overall decline) had significantly more participants still alive. Approximately 95.25% of participants in group 5 were still alive in 2003 compared to only 61.54% in group 1, and 70% in group 2.

Everyday Problem Solving

ANCOVA was used to investigate whether there were differences in everyday problem solving ability in 1998 as a function of trajectory group. Age, education, and replicate were used as covariates. Everyday problem solving ability was a 7-year outcome for the 1977-1991 replicate, while it was a concurrent outcome for the 1984-1998 replicate. There were significant main effects for trajectory group ($p < 0.001$), and the covariates of age ($p < 0.001$) and education ($p < 0.01$). Table 27 presents these results.

Table 25

Analysis of covariance for health severity outcome: Nontrained sample (N=140)

Source	DF	MS	F-Value
Age	1	17012416.42	10.86**
Education	1	209.35	0.00
Chronic diseases	1	29148681.36	18.61***
Replicate	1	2911325.63	1.86
Trajectory group	4	2386908.96	1.52
Error	131	1566575.09	

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

Table 26

Percentage(N) of participants by mortality status and trajectory group: Nontrained sample (N=181)

	Group				
	1	2	3	4	5
Alive	8.84 (N=16)	19.34 (N=35)	17.68 (N=32)	21.55 (N=39)	11.05 (N=20)
Dead	5.52 (N=10)	8.29 (N=15)	4.42 (N=8)	2.76 (N=5)	0.55 (N=1)

Note: The X^2 was significant ($p < 0.01$)

Table 27

Analysis of covariance for the outcome everyday problem solving: Nontrained sample (N=151)

Source	DF	MS	F-Value
Age	1	828.46	24.61***
Education	1	345.42	10.26**
Replicate	1	76.82	2.28
Trajectory group	4	296.68	8.81***
Error	143	33.67	

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

Post hoc analyses (Tukey's HSD for unequal sample sizes) were conducted to interpret the main effect for trajectory group (see Table 28). There were significant differences in level everyday problem solving ability between groups 1 and 3 ($p < 0.001$), groups 1 and 4 ($p < 0.001$), groups 1 and 5 ($p < 0.001$), groups 2 and 3 ($p < 0.01$), groups 2 and 4 ($p < 0.001$), groups 2 and 5 ($p < 0.001$), groups 3 and 4 ($p < 0.05$), and groups 3 and 5 ($p < 0.05$). Groups 2, 3, 4, and 5 all scored significantly higher on problem solving ability than group 1 (low ability with the greatest initial 7-year decline). Groups 3, 4, and 5 all scored significantly higher on problem solving ability than group 2 (low ability with the greatest overall decline). Groups 4 and 5 both scored significantly higher on problem solving ability than group 3. In summary, the higher functioning groups (3, 4, 5) had higher levels of problem solving ability than the two lowest functioning groups (1, 2). Additionally, the two highest functioning groups that exhibited linear trajectories (groups 4, 5), had higher levels of problem solving ability than the three lower functioning groups that demonstrated polynomial trajectories (groups 1, 2, 3). Overall, the post hoc analyses demonstrate that individuals in higher functioning trajectories scored higher on everyday problem solving ability.

Mental Status.

Normal versus "at risk" and possible dementia. Chi-square analyses were employed to investigate trajectory group differences in proportion of participants rated as normal versus impaired. Two different comparisons of mental status groupings were explored: 1) those rated as normal compared to those rated as "at risk" or possibly demented, and 2) those rated as normal or "at risk" compared to those rated as possibly demented. Results indicated that there was a significant effect for mental status rating (normal versus "at risk" or possibly demented) by trajectory group, $X^2(4, N=119) = 13.62$, $p = 0.01$. See Table 29 and Figure 6 for a summary of the results.

A series of 2 X 2 post-hoc chi-square analyses revealed significant differences between groups 1 and 4 ($p < 0.01$), groups 1 and 5 ($p < 0.05$), groups 2 and 4 ($p < 0.01$), and groups 3 and 4 ($p < 0.05$). These differences suggest that individuals in higher functioning trajectories that exhibit less decline are at a decreased risk of being rated "as at risk"/demented in comparison to those in lower functioning trajectories with lower levels of ability. Approximately 82% of group 4 was rated normal in comparison to 37%

Table 28

Summary of post hoc comparisons of group differences in everyday problem solving ability: Nontrained sample

Group	1	2	3	4	5
1					
2					
3	*	*			
4	*	*	*		
5	*	*	*		

Note: * indicates significant difference of at least $p < 0.05$ in level between the two groups.

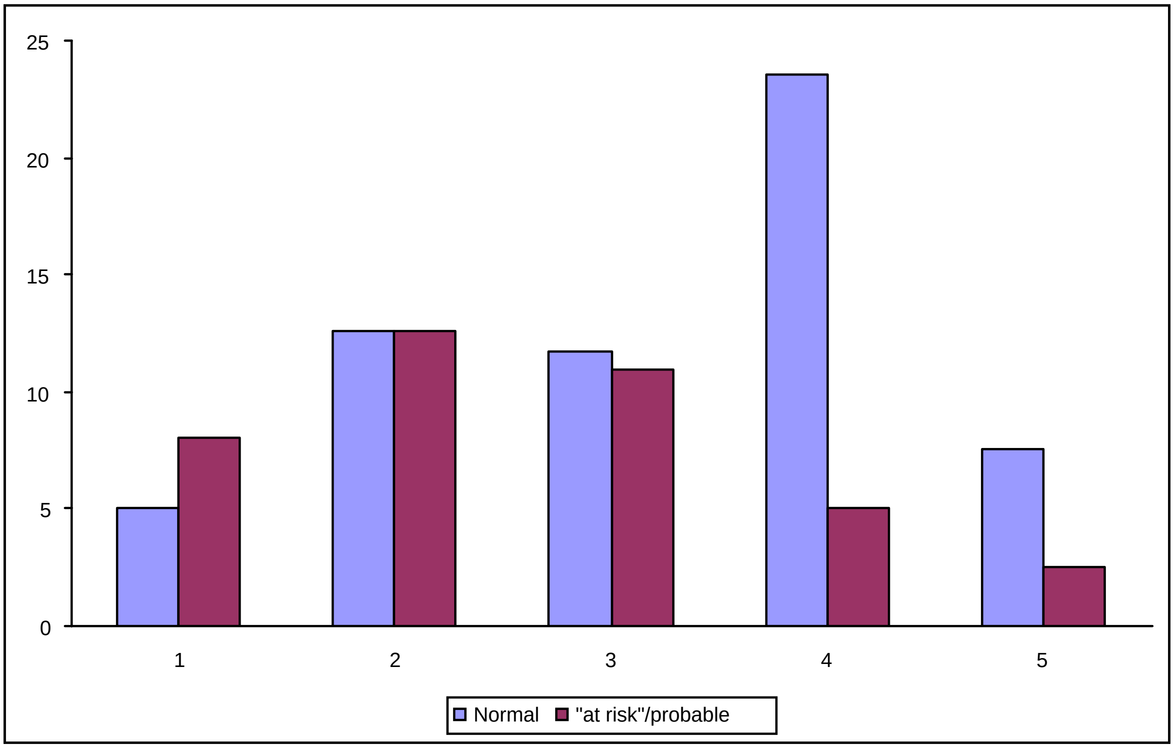
Table 29

Percentage(N) of participants by mental status (normal v "at risk"/possible) and trajectory group: Nontrained sample (N=119)

	Group				
	1	2	3	4	5
Normal	5.04 (N=6)	12.61 (N=15)	11.76 (N=14)	23.53 (N=28)	7.56 (N=9)
"at risk"/Poss	8.40 (N=10)	12.61 (N=15)	10.92 (N=13)	5.04 (N=6)	2.52 (N=3)

Note: The X^2 was significant ($p < 0.01$)

Figure 6. Percentage of total nontrained sample classified as normal versus “at risk”/probable dementia as a function of trajectory group.



of group 1, 50% of group 2, and 52% of group 3. Approximately 75% of group 5 was rated as normal compared to only 37% of group 1. In summary, groups 4 and 5, representing higher functioning trajectories of reasoning ability with the least amount of decline, had significantly fewer participants rated as "at risk"/demented, compared to groups 1 and 2, representing lower functioning on reasoning ability. Twice as many participants in groups 4 and 5 were rated as normal compared to group 1.

Normal/"at risk" versus possible dementia. Results indicated that there was a significant effect for mental status (normal/"at risk" versus possibly demented) as a function of trajectory group, $X^2(4, N=119) = 9.82$, $p = 0.05$. Table 30 illustrates these results. Post-hoc chi-square analyses indicated that there were significant differences between groups 1 (low ability with the greatest initial 7-year decline) and 3 (average ability with relative stability over the first seven year period followed by marked and the greatest decline over the second 7-year period; $p < 0.05$) and groups 1 and 4 (high ability, average group; $p < 0.05$). Approximately 96% of group 3 was rated as normal or "at risk" as compared to only 69% of group 1. Approximately 94% of group 4 was rated as normal or "at risk" compared to only 69% of group 1.

Clinical Outcomes for Reasoning Training Group

Health Severity

Analysis of covariance (ANCOVA) was used to investigate whether health care expenditures varied as a function of trajectory group for the reasoning training sample. As with the nontrained sample, age, education, replicate and the chronic disease factor score were used as covariates. The outcome of health severity was a 7-year outcome for the 1977 to 1991 replicate, and a concurrent outcome for the 1984 to 1998 replicate. There were no significant main effects for the reasoning training group. That is, health expenditures in 1998 did not vary by cognitive change trajectory or by age, education or chronic disease status. See Table 31 for a summary of the results.

Mortality

Chi-square was employed to investigate whether the proportion of deceased participants varied by trajectory group. Mortality was assessed up to 2003. The chi-

Table 30

Percentage(N) of participants by mental status (normal/”at risk” v possible) and trajectory group: Nontrained sample (N=119)

	Group				
	1	2	3	4	5
Normal/”at risk”	9.24 (N=11)	22.69 (N=27)	21.85 (N=26)	26.89 (N=32)	9.24 (N=11)
Poss/prob	4.20 (N=5)	2.52 (N=3)	0.84 (N=1)	1.68 (N=2)	0.84 (N=1)

Note: The X^2 was significant ($p < 0.05$)

Figure 7. Percentage of total nontrained sample classified as normal/“at risk” versus probable dementia as a function of trajectory group.

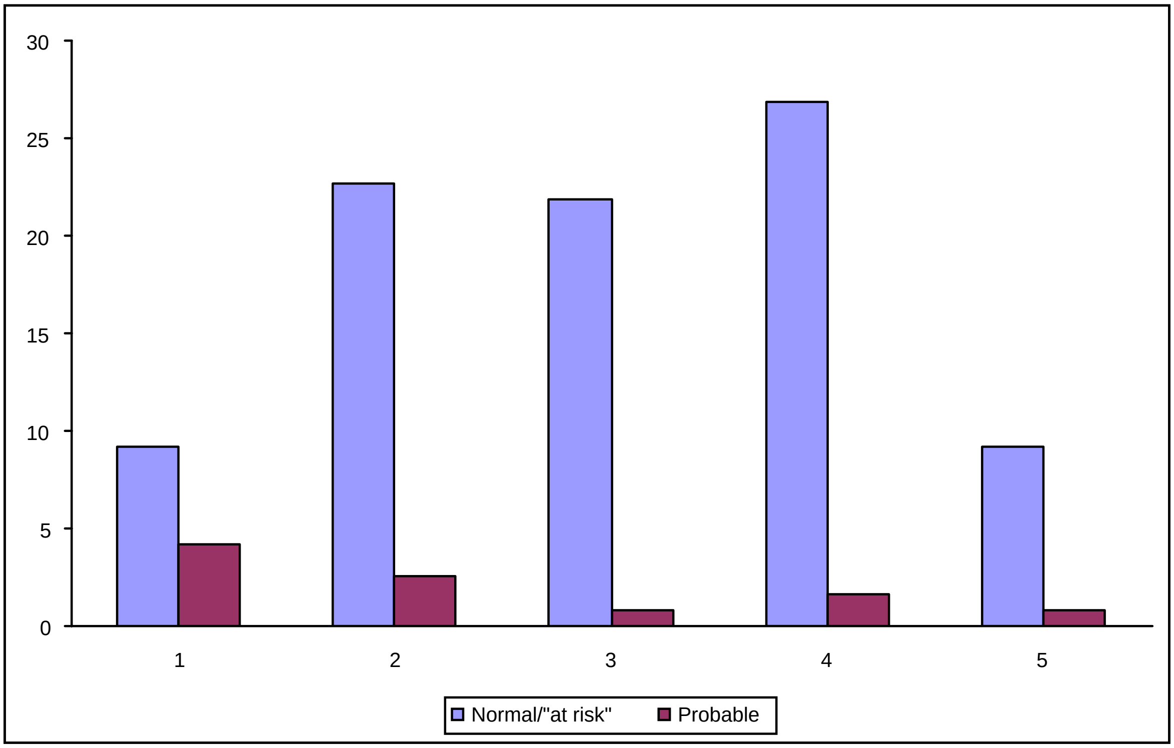


Table 31

Analysis of covariance for health severity outcome: Reason training sample (N=79)

Source	DF	MS	F-Value
Age	1	17756.70	0.01
Education	1	150460.87	0.07
Chronic diseases	1	186.73	0.00
Replicate	1	143761.65	0.07
Trajectory group	3	2061778.65	1.01
Error	71	2041812.40	

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

square was not significant, $X^2(3, N=118) = 1.50$, $p = 0.68$, suggesting that there was no mortality effect as a function of trajectory group for the reasoning training sample (see Table 32).

Everyday Problem Solving

ANCOVA was used to investigate whether there were differences in everyday problem solving ability as a function of trajectory group for the reason training sample. Age, education, and replicate were used as covariates. Everyday problem solving ability was a 7-year outcome for the 1977-1991 replicate, while it was a concurrent outcome for the 1984-1998 replicate. There were significant main effects for trajectory group ($p < 0.001$) and for replicate ($p < 0.01$). See Table 33 for a summary of the results.

Post hoc analyses (Tukey's HSD for unequal sample sizes) were conducted to interpret the main effect for trajectory group (see Table 34). Results of the post-hoc analyses indicated that there were significant differences in everyday problem solving ability between groups 1 and 2 ($p < 0.05$), groups 1 and 3 ($p < 0.001$), and groups 1 and 4 ($p < 0.001$). The higher functioning groups 2, 3, and 4 all scored significantly higher on problem solving ability than group 1, the lowest functioning group. The significant main effect for replicate suggested that individuals in the 1984-1998 replicate had a tendency to score higher on everyday problem solving ability than those in the 1977-1991 replicate. This could simply be a function of selective attrition; problem solving ability was a 7-year outcome for those in the 1977-1991 replicate as compared to a concurrent outcome for those in the 1984-1998 replicate.

Mental Status

Normal versus "at risk" and possible dementia. Chi-square analyses were employed to investigate group differences in proportion of individuals rated as normal versus impaired. The same two mental status groups were employed: 1) those rated as normal compared to those rated as "at risk" or possibly demented, and 2) those rated as normal or "at risk" compared to those rated as possibly demented. Results indicated that there was a significant effect for mental status rating (normal versus "at risk" or possibly demented) by trajectory group, $X^2(3, N=73) = 12.49$, $p = 0.01$ (see Table 35).
A series of 2 x 2 post-hoc chi-square analyses revealed significant differences between groups 1 and 3 ($p < 0.5$), groups 1 and 4 ($p < 0.05$), groups 2 and 3 ($p < 0.01$),

Table 32

Percentage(N) of participants by mortality status and trajectory group: Reason training sample (N=118)

	Group			
	1	2	3	4
Alive	8.47 (N=10)	20.34 (N=24)	23.73 (N=28)	10.17 (N=12)
Dead	6.78 (N=8)	11.86 (N=14)	15.25 (N=18)	3.39 (N=4)

Note: The X^2 was not significant

Table 33

Analysis of covariance for the outcome everyday problem solving: Reason training sample (N=83)

Source	DF	MS	F-Value
Age	1	94.09	2.63
Education	1	13.10	0.37
Replicate	1	396.44	11.08**
Trajectory group	3	438.89	12.26***
Error	76	35.79	

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

Table 34

Summary of post hoc comparisons of group differences in everyday problem solving ability: Reasoning training sample

Group	1	2	3	4
1				
2	*			
3	*			
4	*			

Note: * indicates significant difference in level between the two groups.

Table 35

Percentage(N) of participants by mental status (normal v "at risk"/possible) and trajectory group: Reason training sample (N=73)

	Group			
	1	2	3	4
Normal	6.85 (N=5)	13.70 (N=10)	35.62 (N=26)	12.33 (N=9)
"at risk"/poss	8.22 (N=6)	15.07 (N=11)	6.85 (N=5)	1.37 (N=1)

Note: The X^2 was significant ($p < 0.05$)

and groups 2 and 4 ($p < 0.05$). In summary, the two higher functioning groups that exhibited the least decline in reasoning ability over time (groups 3 and 4) were less likely to be rated as "at risk"/or demented in comparison to the two lower functioning groups that exhibited the most significant decline over time (groups 1 and 2). Approximately 84% of group 3 was rated normal in comparison to 45% of group 1, and 48% of group 2. Approximately 90% of group 4 was rated as normal compared to only 45% of group 1, and 48% of group 2. That is, almost twice as many participants in the highest functioning trajectory group (group 4) were rated as normal compared with the lowest functioning group (group 1).

Normal/"at risk" versus possible dementia. Results indicated that there was not a significant effect for mental status (normal/"at risk" versus possibly demented) as a function of trajectory group, $X^2(3, N=73) = 4.39$, $p = 0.22$ (see Table 36).

Clinical Outcomes for Space Training Group

Health Severity

Analysis of covariance (ANCOVA) was again used to investigate whether health care expenditures in 1998 varied as a function of trajectory group. Age, education, replicate and the chronic disease factor scores were used as covariates. Results indicated that there was only a significant main effect for the covariate chronic disease ($p < 0.01$). Lower chronic disease scores were associated with lower health care expenditure costs. See Table 37 for a summary of the results.

Mortality

Chi-square was employed to investigate whether the trajectory groups differed in proportion of participants deceased versus alive. Mortality was assessed up to 2003. The chi-square was not significant, $X^2(4, N=123) = 8.37$, $p = 0.08$, suggesting that there was not a significant mortality effect as a function of trajectory group for the space training sample (see Table 38).

Everyday Problem Solving

ANCOVA was used to investigate whether there were differences in everyday problem solving ability as a function of trajectory group with age, education, and

Table 36

Percentage(N) of participants by mental status (normal/”at risk” v possible) and trajectory group: Reason training sample (N=73)

	Group			
	1	2	3	4
Normal/”at risk”	12.33 (N=9)	24.66 (N=18)	41.10 (N=30)	13.70 (N=10)
Poss/prob	2.74 (N=2)	4.11 (N=3)	1.37 (N=1)	0.00 (N=0)

Note: The X^2 was not significant

Table 37

Analysis of covariance for health severity outcome: Space training sample (N=85)

Source	DF	MS	F-Value
Age	1	1980222.93	1.48
Education	1	2981563.39	2.23
Chronic diseases	1	11043053.31	8.26**
Replicate	1	1560942.76	1.17
Trajectory group	4	1749418.91	1.31
Error	76	1336356.55	

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

Table 38

Percentage(N) of participants by mortality status and trajectory group: Space training sample (N=123)

	Group				
	1	2	3	4	5
Alive	9.76 (N=12)	14.63 (N=18)	17.07 (N=21)	16.26 (N=20)	5.69 (N=7)
Dead	8.94 (N=11)	14.63 (N=18)	7.32 (N=9)	4.07 (N=5)	1.63 (N=2)

Note: The X^2 was not significant

replicate as covariates. There were significant main effects for trajectory group ($p < 0.001$), and the covariates of replicate ($p < 0.05$) and age ($p < 0.01$). Table 39 illustrates these results.

Post hoc analyses (Tukey's HSD for unequal sample sizes) were conducted to interpret the main effect for trajectory group (see Table 40). Results of the post-hoc analyses indicated that there were significant differences in everyday problem solving ability between groups 1 and 2 ($p < 0.05$), groups 1 and 3 ($p < 0.001$), groups 1 and 4 ($p < 0.001$), groups 1 and 5 ($p < 0.001$), groups 2 and 3 ($p < 0.03$), groups 2 and 4 ($p < 0.001$), groups 2 and 5 ($p < 0.001$), and groups 3 and 4 ($p < 0.05$). The higher functioning groups (groups 2, 3, 4, and 5) all scored significantly higher on problem solving ability than group 1 (the lowest functioning group). Groups 3, 4, and 5 all scored significantly higher on problem solving ability than group 2. Group 4 scored significantly higher on problem solving ability than group 3. Individuals in the higher functioning trajectories (groups 3, 4, and 5) had higher levels of problem solving ability than individuals in the lower functioning trajectories (groups 1 and 2). The significant mains effects for age and replicate suggested that younger individuals and those in replicate 1984-1998 scored higher on everyday problem solving ability. The significant effect for replicate is likely a function of the follow-up period and selective attrition.

Mental Status

Normal versus "at risk" and possible dementia. Chi-square analyses were employed to investigate group differences in mental status ratings. Results indicated that there was no significant effect for mental status rating (normal versus "at risk" or possibly demented) by trajectory group, $X^2(4, N=76) = 7.34$, $p = 0.12$ (see Table 41).

Normal/"at risk" versus possible dementia. Results indicated that there was no significant effect for mental status (normal/"at risk" versus possibly demented) as a function of trajectory group for the space training sample, $X^2(4, N=76) = 5.43$, $p = 0.25$. See Table 42 for a summary of the results.

Table 39

Analysis of covariance for the outcome everyday problem solving: Space training sample (N=88)

Source	DF	MS	F-Value
Age	1	215.29	8.32**
Education	1	3.04	0.12
Replicate	1	132.27	5.11*
Trajectory group	4	336.93	13.03***
Error	80	25.86	

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

Table 40

Summary of post hoc comparisons of group differences in everyday problem solving ability: Space training sample

Group	1	2	3	4	5
1					
2	*				
3	*	*			
4	*	*	*		
5	*	*			

Note: * indicates significant difference in level of at least $p < 0.05$ between the two groups.

Table 41

Percentage(N) of participants by mental status (normal v "at risk"/possible) and trajectory group: Space training sample (N=76)

	Group				
	1	2	3	4	5
Normal	3.95 (N=3)	17.11 (N=13)	19.74 (N=15)	15.79 (N=12)	7.89 (N=6)
"at risk"/Poss	9.21 (N=7)	9.21 (N=7)	10.53 (N=8)	5.26 (N=4)	1.32 (N=1)

Note: The X^2 was not significant

Table 42

Percentage(N) of participants by mental status (normal/"at risk" v possible) and trajectory group: Space training sample (N=76)

	Group				
	1	2	3	4	5
Normal/"at risk"	7.89 (N=6)	22.37 (N=17)	27.63 (N=21)	18.42 (N=14)	7.89 (N=6)
Poss/Prob	5.26 (N=4)	3.95 (N=3)	2.63 (N=2)	2.63 (N=2)	1.32 (N=1)

Note: The X^2 was not significant

Summary: Clinical outcomes for the trajectory groups

Health Severity. For the health severity outcome, the results indicated that presence of chronic diseases is the most salient variable in determining later health care costs. This is not surprising because individuals with more health problems or a greater number of chronic diseases will likely need to have more visits to their primary care providers. Trajectory group had little impact on health severity. However, trajectory group membership was more influential for the outcomes of mortality, problem solving, and mental status.

Mortality. Trajectory group was only a predictor of mortality status for the nontrained group. With respect to mortality status, younger individuals, and those functioning at a higher level (groups 4 and 5) exhibited greater longevity than older individuals or those with lower levels of ability (groups 1 and 2).

Everyday Problem Solving. Trajectory group was a significant predictor of everyday problem solving ability for all three samples. For problem solving ability, those individuals belonging to trajectories exhibiting less decline over the 14-year period demonstrated higher levels of problem solving ability. With the exception of those trained on reasoning ability, younger age was also significantly associated with higher problem solving ability.

Mental Status. Trajectory group was a significant predictor of mental status for the nontrained and reasoning trained samples. For the normal versus impaired comparison, the lower functioning groups (groups 1 and 2) had fewer participants in the normal category than the two higher functioning groups. The normal/"at risk" versus possibly impaired comparison was only significant for the nontrained sample, with the lowest functioning groups having significantly fewer normal and "at risk" classifications than the higher functioning groups (groups 3 and 4). Thus, in summary, individuals who maintain their inductive reasoning ability were more likely to fare better in terms of long term outcomes such as problem solving ability, mental status, and mortality.

Clinical Outcomes as a Function of Training Status

To investigate whether training status (trained/nontrained) affected clinically meaningful outcomes, ANOVA and logistic regression were employed to test for group differences. ANOVAs were used for the continuous outcomes of everyday problem solving and health severity. Two separate ANOVAs were conducted, one with everyday problem solving as the dependent variable, and one with health severity as the dependent variable. Training status served as the primary grouping variable in both ANOVAs. Age and education were included as covariates. To account for cognitive ability level, the inductive reasoning pretest score was also included as a covariate. Finally pre-to-posttest change in both reasoning and spatial ability as well as replicate were included as covariates.

Hierarchical logistic regression was used to determine whether training status impacted consensus ratings and mortality. Separate hierarchical logistic regressions were conducted, one with consensus ratings as the dependent variable, and one with mortality as the dependent variable. For both dependent variables, Step 1 included only training status. Step 2 added in the demographic predictors of age and education. Step 3 added the inductive reasoning pretest score as an indicator of cognitive ability and the pre-to-posttest change on reasoning and space abilities. The final step included replicate.

Health Severity

Analysis of covariance (ANCOVA) was used to investigate whether health care expenditures varied as a function of training group. Age, education, the chronic disease factor score, replicate, and the pre-to-posttest raw change scores for spatial orientation and inductive reasoning ability were used as covariates. This analysis was conducted for two different time periods: once as a 7 year outcome for both replicates, and a second time as a 14 year outcome for the 1984 training replicate and a 7 year outcome for the 1991 training replicate. The second analysis used 1998 health severity data for all participants.

7-year outcome. Results indicated that there was not a significant difference in health care expenditures 7-years post-training as a function of training status (see Table 43). However, there were significant main effects for the covariates age ($p < 0.001$), replicate ($p < 0.05$) and chronic disease ($p < 0.001$). Younger age and lower chronic

Table 43

Analysis of covariance for the 7-year health severity outcome: Train versus nontrained (N=520)

Source	DF	MS	F-Value
Age	1	42212097.30	30.68***
Education	1	2718267.53	1.98
Chronic diseases	1	63511803.81	46.16***
Reasoning gain	1	12825.31	0.01
Space gain	1	1096395.45	0.80
Replicate	1	13472658.05	9.79**
Training status	1	3719232.86	2.70
Error	512	1375891.14	

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

disease scores were associated with lower health care expenditure costs. The 1998 replicate tended to have higher health care expenditure costs. This finding is likely due to inflation of health care costs from 1991 (the 7 year follow-up for the 1984 replicate) to 1998 (the 7 year follow-up for the 1991 replicate).

1998 data. Results indicated that there was a significant difference in health care expenditures in 1998 as a function of training status ($p < 0.05$). Nontrained individuals had higher health care costs than trained individuals. There were also significant main effects for the covariates of age ($p < 0.001$) and chronic disease ($p < 0.001$). Younger age and lower chronic disease scores were associated with fewer health care expenditure costs. There was no significant main effect for replicate. This finding was likely due to the fact that the health severity score utilized in this analysis employed 1998 data for all individuals, regardless of replicate. See Table 44 for a summary of these results.

Mortality

Hierarchical logistic regression was employed to investigate whether the training groups differed on mortality status. This analysis was conducted for two time periods: once as a 7-year outcome for both replicates, and a second time as a 19-year outcome for the 1984 replicate and a 12-year outcome for the 1991 replicate. The second analysis assessed mortality status up to 2003 for all participants. For all analyses, age, education, reasoning pretest, pre to posttest gain on reasoning and space, and replicate were included as covariates in various steps of the analysis.

7-year outcome. Training status (trained versus nontrained) did not reach statistical significance in any of the four steps. In the second step, age at baseline was a significant predictor of mortality status ($p < 0.05$). Younger individuals were more likely to be living 7 years post-training than older individuals. Age retained significance in the third ($p < 0.05$), and fourth steps ($p < 0.05$). None of the other variables reached significance. See Table 45.

2003 data. Training status was not significant in the first step, or any steps in this analysis (Table 46). Both age ($p < 0.001$) and education ($p < 0.01$) emerged as significant predictors of mortality status in the second step. Younger age and higher levels of education were associated with an increased likelihood of living 12 to 19 years

Table 44

Analysis of covariance for the 1998 health severity outcome: Train versus nontrained (N=435)

Source	DF	MS	F-Value
Age	1	23439778.35	14.91***
Education	1	1746766.42	1.11
Chronic diseases	1	47359306.51	30.13***
Reasoning gain	1	1337730.45	0.85
Space gain	1	3153253.74	2.01
Replicate	1	56524.92	0.04
Training status	1	6194581.17	3.94*
Error	427	1571881.74	

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

Table 45

Logistic regression predicting 7-year mortality status: Trained versus nontrained (N=1203)

	Step 1			Step 2			Step 3			Step 4		
	β	SE	OR	β	SE	OR	β	SE	OR	β	SE	OR
Train	-0.12	0.15	0.88	-0.05	0.16	0.95	-0.12	0.17	0.89	-0.11	0.17	0.89
AgeT1				-0.13*	0.01	0.88	-0.12*	0.01	0.89	-0.12*	0.01	0.89
EducT1				-0.02	0.03	0.98	-0.03	0.03	0.97	-0.04	0.03	0.96
Reason							0.020	0.01	1.02	0.02	0.01	1.02
Gain R							0.02	0.04	1.02	0.03	0.04	1.03
Gain S							0.01	0.03	1.00	0.03	0.03	1.03
Replicate										0.05	0.02	1.05

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

Table 46

Logistic regression predicting mortality status up to 2003: Trained versus nontrained (N=1203)

	Step 1			Step 2			Step 3			Step 4		
	β	SE	OR	β	SE	OR	β	SE	OR	β	SE	OR
Train	-0.16	0.12	0.85	-0.13	0.14	0.87	-0.25	0.15	0.78	-0.17	0.15	0.84
AgeT1				-0.16***	0.01	0.85	-0.13***	0.01	0.87	-0.14***	0.01	0.87
EducT1				0.06**	0.02	1.06	0.01	0.02	1.01	-0.01	0.03	0.99
Reason							0.04***	0.01	1.04	0.04***	0.01	1.04
Gain R							0.00	0.04	1.00	0.03	0.04	1.03
Gain S							-0.11***	0.03	0.89	-0.02	0.03	0.98
Replicate										0.21***	0.02	1.22

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

post-training. In the third step, age retained significance ($p < 0.001$), while reasoning pretest score ($p < 0.001$) and gain on spatial orientation ability ($p < 0.001$) emerged as predictors. In the fourth step, age was still significant ($p < 0.001$) as was the reasoning pretest score ($p < 0.001$), and replicate also emerged as a significant predictor of mortality status ($p < 0.001$). This suggests that younger individuals, those in the 1991 replicate, and those with higher reasoning pretest scores were more likely to be alive in 2003. The significant effect of replicate is not surprising because this outcome was 19 years post-training for the 1984 replicate, and only 12 years post-training for the 1991 replicate.

Everyday Problem Solving

ANCOVA was used to investigate whether there were differences in problem solving ability as a function of training status. Age, education, reasoning pretest score, pre-to-posttest gain in reasoning and space, and replicate were used as covariates. Problem solving ability was a 14-year outcome for the 1984 replicate, while it was a 7-year outcome for the 1991 replicate. There were significant main effects for replicate ($p < 0.05$), age ($p < 0.01$), education ($p < 0.01$), and reasoning pretest ($p < 0.001$). This suggests that younger age, higher levels of education, higher reasoning pretest score, and being in the1991 replicate were all associated with higher scores on problem solving. Again, the significance of replicate could be a function of the length of time from training to the outcome: 7 years for the 1991 replicate and 14 years for the 1984 replicate. See Table 47.

Mental Status

Normal versus "at risk" and Possible dementia. Logistic regression was employed to investigate training status differences in mental status ratings. Two different mental status groupings were explored: 1) those rated as normal compared to those rated as "at risk" or possibly demented, and 2) those rated as normal or "at risk" compared to those rated as possibly demented. For the 1984 replicate this was a 14-year outcome, while for the 1991 replicate, it was a 7-year outcome. Age, education, reasoning pretest, pre-to-posttest change in reason and space ability, and replicate were covariates in various steps of the analysis. Training status did not reach statistical significance in any of the four steps. Age emerged as a significant predictor in the second step ($p < 0.01$),

Table 47

Analysis of covariance for the everyday problem solving outcome: Train v nontrained (N=461)

Source	DF	MS	F-Value
Age	1	267.22	7.53**
Education	1	384.12	10.82**
Reasoning pretest	1	4797.59	135.18***
Reason gain	1	135.94	3.83
Space gain	1	31.56	0.89
Replicate	1	209.77	5.91*
Training status	1	111.51	3.14
Error	453	35.49	

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

but this was not retained throughout the remaining steps. Reasoning pretest score emerged as a significant predictor in step 3 ($p < 0.001$), and remained significant in the final step ($p < 0.001$). Replicate was also a significant predictor of mental status in the final step ($p < 0.01$). These results indicated that individuals with higher reasoning pretest scores, and those in the 1991 replicate were more likely to be rated as normal as compared to "at risk" or possibly demented. See Table 48.

Normal/"at risk" versus possible dementia. Results of the hierarchical logistic regression analyses indicated that training status was not a significant predictor of mental status. Age ($p < 0.05$) and education ($p < 0.05$) emerged as significant predictors in the second step. Education remained predictive of mental status in the third ($p < 0.01$) and fourth steps ($p < 0.01$). In the third step, training group ($p < 0.05$) and reasoning pretest score ($p < 0.01$) significantly predicted mental status. In the final step, reasoning pretest remained a significant predictor ($p < 0.001$), while replicate ($p < 0.01$) was significantly associated with mental status. Individuals with higher reasoning pretest scores, lower education, and those in the 1991 replicate were more likely to be rated as normal or "at risk". See Table 49. The low education finding could be due to the selection of the sample. Only approximately 5% of the sample had less than 12 years of education, and all of these individuals fell in the normal/"at risk" grouping.

Summary: Clinically meaningful outcomes for trained/nontrained

The results of these analyses suggest that training status (trained versus nontrained) is not an influential predictor of the long term outcomes investigated. Age and ability level appear to be more influential. Younger and higher functioning individuals (assessed by reasoning pretest scores) tend to fare better in terms of health severity, problem solving, mental status, and mortality. Prior findings indicate that trajectory group rather than just categorical training status shows stronger association with clinical outcomes.

Table 48

Logistic regression predicting mental status (normal versus "at risk"/probable): Trained versus nontrained (N=373)

	Step 1			Step 2			Step 3			Step 4		
	β	SE	OR	β	SE	OR	β	SE	OR	β	SE	OR
Train	0.00	0.22	1.01	0.12	0.23	1.13	-0.14	0.26	0.87	-0.06	0.26	0.94
Age				-0.06**	0.02	0.94	-0.04	0.02	0.96	0.00	0.03	1.00
Educ				0.02	0.04	1.02	-0.03	0.04	0.97	-0.04	0.04	0.96
Reason							0.07***	0.02	1.07	0.08***	0.02	1.08
Gain R							0.05	0.05	1.05	0.08	0.06	1.08
Gain S							0.03	0.05	1.03	0.06	0.05	1.06
Replicate										0.13**	0.04	1.14

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

Table 49

Logistic regression predicting mental status (normal/"at risk" versus probable): Trained versus nontrained (N=373)

	Step 1			Step 2			Step 3			Step 4		
	β	SE	OR	β	SE	OR	β	SE	OR	β	SE	OR
Train	0.00	0.22	1.01	-0.39	0.36	0.68	-0.81*	0.39	0.45	-0.68	0.40	0.51
Age				-0.06*	0.03	0.94	-0.03	0.03	0.97	0.03	0.04	1.03
Educ				-0.14*	0.06	0.87	-0.20**	0.07	0.82	-0.23**	0.07	0.80
Reason							0.09**	0.03	1.09	0.10***	0.03	1.11
Gain R							0.09	0.08	1.10	0.12	0.08	1.12
Gain S							0.02	0.07	1.02	0.05	0.07	1.06
Replicate										0.19**	0.06	1.21

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

Clinically Meaningful Outcomes and Training Gain

To investigate whether training group (space/reason) and initial training gain (pre-to-posttest change on ability trained) had an impact on the clinically meaningful outcomes, ANOVA and logistic regression were employed.

Hierarchical logistic regression was used to determine whether training group and training gain influenced consensus ratings and mortality. As in the prior question, separate hierarchical logistic regressions were run, one with consensus ratings as the dependent variable, and one with mortality as the dependent variable. The progression of hierarchical logistic regressions was similar to the steps in the previous question except gain was included in the first step along with training group in the current analyses. ANOVA was employed for the health severity and problem solving outcomes with the same covariates utilized as in the previous analyses.

Health Severity

Analysis of covariance (ANCOVA) was used to investigate whether health care expenditures varied as a function of training group and training gain. Age, education, the chronic disease factor scores, replicate, and the pre-to-posttest raw change scores on ability trained were used as covariates. This analysis was conducted for two time periods: once as a 7-year outcome for both replicates, and a second time as a 14-year outcome for the 1984 replicate and a 7-year outcome for the 1991 replicate. The second analysis used 1998 health severity data for all participants.

7-year outcome. As illustrated in Table 50, the results indicated that there was no significant difference in health care expenditures 7 years post-training as a function of training group. However, there were significant main effects for the covariates age ($p < 0.001$), replicate ($p < 0.05$) and chronic disease ($p < 0.001$). Younger age and lower chronic disease scores were associated with lower health care expenditure costs. The 1998 replicate tended to have higher health care expenditure costs. This finding is likely due to inflation of health care costs from 1991 (the 7-year follow-up for the 1984 replicate) to 1998 (the 7-year follow-up for the 1991 replicate).

Table 50

Analysis of covariance for the 7-year health severity outcome: Space versus reason train (N=236)

Source	DF	MS	F-Value
Age	1	17679835.02	12.58***
Education	1	76518.63	0.05
Chronic diseases	1	21140158.81	15.04***
Training gain	1	329703.73	0.23
Replicate	1	7934843.45	5.65*
Training group	1	461409.06	0.33
Error	229	1405458.74	

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

1998 data. Results indicated that there was no significant difference in health care expenditures as a function of training group. Chronic disease score was the only significant covariate ($p < 0.05$), suggesting that those with higher scores on the chronic disease factor score were likely to have higher health care costs in 1998. See Table 51 for an illustration of these results.

Mortality

Hierarchical logistic regression was employed to investigate whether the training groups differed on mortality status. This analysis was conducted for two time periods: 1) once as a 7-year outcome for both replicates, and 2) a second time as a 19-year outcome for the 1984 replicate and a 12-year outcome for the 1991 replicate. The second analysis assessed mortality status up to 2003 for all participants. For all analyses, age, education, reasoning pretest, pre to posttest gain on ability trained, and replicate were included as covariates in various steps of the analysis.

7-year outcome. Training group was not significant in any steps of this analysis. Age emerged as a significant predictor in the second step and was the only variable to retain significance through the final step ($p< 0.001$). This suggests that younger individuals were less likely to have died 7-years later. See Table 52 for a summary of these results.

2003 data. Neither training group nor gain emerged as significant predictors in the first step. Age was a significant predictor in the second ($p < 0.001$), third ($p < 0.001$), and final steps ($p < 0.001$). Reasoning pretest score significantly predicted mortality status in the third step ($p < 0.05$). Finally, replicate was significant in the final step ($p < 0.001$). This suggests that younger individuals, and those in the 1991 replicate were more likely to be alive in 2003 (see Table 53).

Everyday Problem Solving

ANCOVA was used to investigate whether there were differences in problem solving ability as a function of training group. Age, education, reasoning pretest score, pre-to-posttest gain on ability trained, and replicate were used as covariates. Everyday problem solving ability was a 14-year outcome for the 1984 replicate, while it was a 7-year outcome for the 1991 replicate.

Table 51

Analysis of covariance for the 1998 health severity outcome: Space versus reason train (N=166)

Source	DF	MS	F-Value
Age	1	2438886.69	1.45
Education	1	383205.27	0.23
Chronic diseases	1	7391181.95	4.40*
Training gain	1	2157148.29	1.28
Replicate	1	227083.42	0.14
Training group	1	1229660.98	0.73
Error	159	1679059.01	

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

Table 52

Logistic regression predicting 7-year mortality status: Space versus reason train (N=407)

	Step 1			Step 2			Step 3			Step 4		
	β	SE	OR	β	SE	OR	β	SE	OR	β	SE	OR
Train	-0.11	0.24	0.89	-0.07	0.26	0.93	-0.06	0.26	0.94	-0.06	0.26	0.94
Gain	0.07	0.04	1.07	0.04	0.04	1.04	0.04	0.040	1.04	0.04	0.04	1.04
AgeT1				-0.14***	0.02	0.87	-0.13***	0.02	0.88	-0.13***	0.02	0.88
EducT1				0.00	0.04	1.00	-0.01	0.05	0.99	-0.01	0.05	0.99
Reason							0.02	0.02	1.02	0.02	0.02	1.02
Replicate										0.02	0.04	1.02

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

Table 53

Logistic regression predicting mortality status up to 2003: Space versus reason train (N=407)

	Step 1			Step 2			Step 3			Step 4		
	β	SE	OR	β	SE	OR	β	SE	OR	β	SE	OR
Train	-0.03	0.20	0.97	-0.02	0.22	0.98	0.01	0.22	1.01	0.02	0.23	1.02
Gain	0.06	0.03	1.06	0.04	0.03	1.04	0.05	0.03	1.05	0.05	0.04	1.06
AgeT1				-0.14***	0.02	0.87	-0.12***	0.02	0.88	-0.14***	0.02	0.87
EducT1				0.01	0.04	1.01	-0.03	0.04	0.98	-0.04	0.04	0.96
Reason							0.03*	0.02	1.04	0.03	0.02	1.03
Replicate										0.18***	0.03	1.19

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

There were significant main effects for replicate ($p < 0.05$), reasoning pretest ($p < 0.001$), and training group ($p < 0.001$). Individuals trained on inductive reasoning ability tended to have higher scores on problem solving. In addition, higher reasoning pretest scores were associated with higher scores on problem solving. Finally, individuals in the 1991 replicate also tended to have higher scores on problem solving ability. This could simply be a function of length of time post-training. See Table 54.

Mental Status

Normal versus "at risk" and possible dementia. Hierarchical logistic regression was employed to investigate training group differences in mental status ratings. The same two mental status groupings were explored. Age, education, reasoning pretest, pre-to-posttest change on ability trained, and replicate were included as covariates at the specified steps of the analysis. None of the predictor variables or covariates reached statistical significance in the first or second steps. In the third step, reasoning pretest score was a significant predictor of mental status ($p < 0.001$). This effect was maintained in the final step ($p < 0.001$), along with significant effects for education ($p < 0.05$) and replicate ($p < 0.05$). Individuals with higher reasoning pretest scores, lower education, and those in the 1991 replicate were more likely to be rated as normal (see Table 55). The association of low education with greater likelihood to be rated as normal could be due to the small number of individuals with low education in the sample.

Normal/"at risk" versus possible dementia. None of the predictor variables or covariates were significant in the first or second steps. Education ($p < 0.05$) and reasoning pretest score ($p < 0.05$) were significant in the third and fourth steps. Finally, replicate ($p < 0.05$) was also significant in the final step. These results indicated that individuals with higher reasoning pretest scores, lower education, and those in the 1991 replicate were more likely to be rated as normal or "at risk" as opposed to possibly demented (see Table 56). Approximately 7% of the sample had less than 12 years of education. All of these individuals were in the normal/"at risk" classification. Thus, it is possible that these individuals are responsible for the low education finding.

Table 54

Analysis of covariance for the everyday problem solving outcome: Space versus reason train (N=173)

Source	DF	MS	F-Value
Age	1	24.37	0.73
Education	1	0.08	0.00
Reasoning pretest	1	2624.23	78.52***
Training gain	1	6.95	0.21
Replicate	1	134.51	4.02*
Training group	1	439.54	13.15***
Error	166	33.42	

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

Table 55

Logistic regression predicting mental status (normal versus "at risk"/probable): Space versus reason train (N=153)

	Step 1			Step 2			Step 3			Step 4		
	β	SE	OR	β	SE	OR	β	SE	OR	β	SE	OR
Train	0.11	0.35	1.12	0.08	0.35	1.08	0.26	0.38	1.30	0.29	0.39	1.33
Gain	0.05	0.05	1.05	0.05	0.05	1.05	0.08	0.06	1.09	0.11	0.06	1.12
Age				-0.06	0.03	0.95	-0.02	0.04	0.98	0.03	0.05	1.04
Educ				-0.02	0.06	0.98	-0.14	0.07	0.87	-0.17*	0.07	0.85
Reason							0.12***	0.03	1.13	0.13***	0.03	1.14
Replicate										0.15*	0.06	1.16

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

Table 56

Logistic regression predicting mental status (normal/"at risk" versus probable): Space versus reason train (N=153)

	Step 1			Step 2			Step 3			Step 4		
	β	SE	OR	β	SE	OR	β	SE	OR	β	SE	OR
Train	0.52	0.51	1.69	0.47	0.52	1.59	0.64	0.56	1.89	0.68	0.57	1.98
Gain	0.04	0.07	1.04	0.03	0.07	1.03	0.05	0.08	1.05	0.07	0.08	1.08
Age				-0.04	0.05	0.96	0.00	0.05	1.00	0.09	0.07	1.09
Educ				-0.10	0.08	0.90	-0.21*	0.10	0.81	-0.25*	0.11	0.78
Reason							0.10*	0.04	1.11	0.12**	0.05	1.13
Replicate										0.20*	0.10	1.22

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

Summary: Clinically meaningful outcomes as a function of training group and gain

There was limited support for differential outcomes as a function of training group or gain. The one exception is problem solving. Individuals trained on inductive reasoning ability scored higher on problem solving than their peers trained on spatial orientation. Overall, age and/or chronic diseases were most predictive of health severity, while age alone was highly predictive of mortality. Finally, for mental status, prior reasoning ability level and education were salient predictors.

CHAPTER 6
Discussion

This discussion section will highlight the major findings of this study and provide commentary, explanation, and implications of these findings. The trajectory groups for each of the three samples will be discussed, as well as the covariates that impacted group membership. Variation in long-term outcomes will be considered as a function of trajectory group, training status, and training group and training gain. Strengths, limitations and suggestions for future research will be addressed. Finally, a summary of the results of the current study, as well as implications of this research will be considered.

Overview of Findings

The purpose of this study was to examine differential patterns of cognitive change in inductive reasoning ability in three samples. The patterns of cognitive change were investigated in nontrained, reasoning trained, and space trained individuals. These samples were investigated separately because determining whether the trajectory groups differed as a function of organized cognitive activity in the form of training programs was of interest. Inductive reasoning was the ability of interest because it has been found to have associations with problem solving in daily life. This ability was also of interest because it was one of the abilities trained in the Seattle Longitudinal Study. The impact of person level variables such as cognitive reserve, cognitive style, health behaviors, and chronics diseases on trajectory group membership was examined in each of the three samples. Finally, the impact of trajectory group membership, training status, training group and training gain on long-term clinically meaningful outcomes was explored. Specifically three major questions were addressed in the study. 1) What sub-groups representing distinctive patterns of cognitive change in inductive reasoning ability can be identified in three samples (nontrained, reasoning trained, space trained)? 2) What individual level variables are associated with the various cognitive change trajectories for inductive reasoning in each of the three samples? 3) Are cognitive change trajectories, training status, and training group and training gain associated with clinically meaningful outcomes?

There were three major findings in this study. First, overall the results indicated that there was significant variability in reasoning ability over the 14-year period for each of the three samples. Five different groups of trajectories with differing shapes were identified in the nontrained sample. Two quadratic, one cubic, and two linear trajectories best fit the data. The differences among the five groups were in level, slope, and overall rate of change in inductive reasoning ability. For the reasoning training sample, four different trajectories were apparent. Three of the four groups exhibited zero-order trajectories while the other group fit a linear trajectory. Level differences primarily distinguished these four groups. Finally, for the space training samnple, five trajectories best fit the data with four linear and one zero-order trajectory. Differences in the trajectories were present in level and slope. Thus, the presence of multiple trajectory groups across the three samples lends support to the claim that there is much interindividual variability in cognitive change in older adulthood (Christensen et al., 1999; MacDonald, Hultsch, & Dixon, 2003). Furthermore, these findings also suggest that cognitive interventions can impact the rate of change. This is apparent because the trajectories in the reasoning training sample were primarily zero-order suggesting no significant change over time. In addition, the space training sample primarily exhibited linear decline trajectories. This was not the case for the control sample. A comparison of the trajectories across the three samples will be provided later in this section.

The second major finding revolves around the association of trajectory group membership with the four covariates, chronic disease, health behaviors, cognitive reserve, and cognitive style. Consideration of the covariates revealed that cognitive style had a significant impact on trajectory group membership across the three samples. Specifically, individuals with higher levels of cognitive style had posterior probabilities that would place them in higher functioning trajectory groups. Cognitive reserve was also influential for the nontrained and reasoning training samples. Individuals with higher levels of cognitive reserve in both samples were likely to belong to higher functioning trajectory groups. These findings suggest that individuals with higher levels of cognitive ability tend to engage in more mentally stimulating activities in old age, similar to the concept of cognitive reserve. In addition there is support for the idea that individuals who are more flexible and willing and capable of adapting to new situations tend to have higher levels of cognitive ability in older adulthood. Activity and flexibility appear to be important variables associated with cognitive ability and rate of cognitive change in older adulthood.

Finally, the third major finding focuses on the four long term outcomes investigated, mortality, everyday problem solving, mental status and health severity. Investigation of the long-term outcomes revealed that trajectory group membership was predictive of mortality, everyday problem solving, and mental status. This suggests that level and rate of change in cognitive ability has an impact on functioning with regard to important clinical outcomes in late life. Training status (trained /nontrained) was not a significant predictor for any of the long-term outcomes investigated. However, training group (reasoning/space) was predictive of everyday problem solving ability, with those individuals trained on reasoning ability scoring higher. Hence, cognitive training programs may be beneficial in promoting the maintenance of cognitive ability associated with problem solving in daily life. Finally, neither training group (reason/space train) nor training gain was a significant predictor of health status, mortality or mental status.

Trajectories of Cognitive Change in Inductive Reasoning Ability, Covariates, and Clinical Outcomes for Three Samples

The key findings have briefly been discussed in the above section. The remainder of this discussion section will consider these findings in greater depth and will discuss the similarities and differences among the three samples. Nagin mixture modeling was employed to identify the number of distinct trajectories present in each of the three samples, and to investigate the impact of these covariates on trajectory group membership. Long-term outcomes were investigated for the trajectory groups in the 3 different samples, and also as a function of training status (trained/nontrained), and training group (reason/space) and training gain. The major findings for each of these samples are reported in the following section.

Nontrained Sample

The nontrained sample exhibited the most variability in trajectory shape out of the three samples. This coincides with prior research stating that differential patterns of normative decline exist and there is much interindividual variability in cognitive decline (Christensen et al., 1999; MacDonald, Hultsch, & Dixon, 2003). The nontrained sample was not exposed to any structured and organized cognitive activity as a part of the Seattle Longitudinal Study. Therefore, the groups of trajectories present in this sample may be a reflection of the groups present in the larger population of older adults who are relatively high functioning and not experiencing non-normative cognitive decline.

All 5 of the nontrained groups experienced declines in inductive reasoning ability over time. By the second occasion of measurement, all individuals were at least 60 years of age. Thus, the decline in ability level is consistent with prior research stating that there is normative age-related decline beginning in the mid-60's and thereafter (Finkel et al., 2003; Hickman et al., 2000; Schaie, 1996; Singer et al., 2003). Furthermore, all groups with the exception of group 1 experienced at least twice as much decline over the second 7-year period in comparison to the first. This could be partially due to increased age.

Trajectory group membership was found to be differentially associated with the covariates and the outcomes. In particular, there were two patterns of association present in the nontrained sample: (1) differences in association with covariates and outcomes as a function of level of cognitive ability, (2) differences in association with covariates and outcomes as a function of trajectory shape (quadratic versus linear).

The differences present across trajectory group as a function of level, regardless of shape, were only for the cognitive style covariate. Specifically, higher scores on cognitive style were associated with increased probability of belonging to any group (2, 3, 4, 5) other than group 1. All of these groups had higher scores on cognitive style than group 1. This suggests that cognitive style is related to level of cognitive ability because despite the various trajectory shapes, all groups consistently functioned at a higher level compared to Group 1. In addition, all groups significantly differed in level of cognitive style except the three highest functioning groups (3, 4, 5). Groups 3 and 4 were not significantly different than group 5. This supports prior research that inductive reasoning ability is strongly associated with cognitive style (Schaie, 1984; 1996; 2004). Furthermore, Schaie (1984; 1996; 2004) found the associations between cognitive style and inductive reasoning ability to decrease slightly with age. Thus, the associations may be even stronger or more influential if cognitive style had been measured at time 1 opposed to time 5.

Investigation of the specific indicators of cognitive style revealed that income and attitudinal flexibility did not significantly differ amongst the groups while motor-cognitive flexibility and psychomotor speed did. Prior research has stated that inductive reasoning ability has strongest relations with psychomotor speed and motor-cognitive flexibility (Schaie 1984; 1996; 2004). Specifically for motor-cognitive flexibility, groups 4 and 5 (the two highest functioning groups exhibiting linear trajectories) scored significantly higher than group 1. For psychomotor speed, all groups differed significantly from one another except for the two lowest functioning groups (groups 1 and 2 with the quadratic trajectories) and the two highest functioning groups (groups 4 and 5 with the linear trajectories). The finding that individuals with higher psychomotor speed and motor-cognitive flexibility also tend to be in the higher functioning trajectory groups is not surprising. This suggests that higher functioning individuals more readily respond to familiar stimuli (psychomotor speed) and adapt to changes in stimuli (motor-cognitive flexibility). Thus, these individuals are able to adapt to changes in the world around them, which is extremely important for adapting to the biological, physical, cognitive, and social changes associated with the aging process.

There were also trajectory group differences in covariates and outcomes as a function of trajectory shape, specifically between the linear (high functioning) and quadratic (low functioning) trajectories. Differences were present in the health behavior and cognitive reserve covariates, and in the mortality, everyday problem solving, and mental status outcomes.

Health behaviors were only associated with group membership for groups 1 and 4. Specifically higher scores or more positive health behaviors were associated with decreased likelihood of belonging to group 4 in comparison to group 1. Prior research has shown that engaging in more positive health behaviors such as healthier food consumption, regular exercise, and medical check-ups is associated with higher cognitive ability (Belloc & Breslow, 1972; Blumenthal & Gullette, 2002; Correa Leite et al., 2001; Emery & Blumenthal, 1991; La Rue et al., 1997; Ortega et al., 1997). Group 1 exhibited a quadratic trajectory while group 4 exhibited a linear trajectory. Group 1 was the lowest functioning group that exhibited that greatest initial decline, however, they did not significantly decline over the entire 14-year period. Group 4 was the higher functioning average group. Compared to group 1, group 4 did experience more significant decline over the second 7-year period, and decline over the entire 14-year period was significant. Thus, although group 4 had higher ability overall at time 5, because group 1 experienced less decline over the second 7-year period, this could partially explain why group 1 engaged in more positive health behaviors. Recall, the health behaviors were measured at time 5. It is possible that group 1 began to engage in more positive health behaviors over time due to their initial low cognitive status. Alternatively, irrespective of baseline ability level, group 4 experienced more cognitive decline over the 7 years prior to the measurement of health behaviors than group 1. It is clear that more significant cognitive decline is more detrimental than constant lower cognitive functioning. Thus, the decline in ability may be more indicative of lack of engagement in proactive health behaviors than level alone.

Cognitive reserve was associated with a greater likelihood of belonging to group 5, the highest functioning group with the least overall decline, in comparison to group 1, the lowest functioning group with the most initial decline. The significant differences were apparent for the occupational status and education indicators of cognitive reserve. Individuals with posterior probabilities placing them in group 5 (high ability with the least overall decline) were more likely to have higher educational levels and occupational statuses than individuals in group 1 (low ability with the most initial decline). This is consistent with prior literature on cognitive status. Tuokko and colleagues (2003) found that individuals with higher levels of education, occupation, and premorbid IQ were less likely to be cognitively impaired. Research has also found that individuals with higher levels of education and occupational status tend to have delayed manifestation of symptoms of impairment due to higher levels of cognitive reserve (Snowdon et al., 1996; Stern et al., 1999; Tuokko et al., 2003). This finding suggests that maintenance of or even increased participation in cognitive stimulating activity throughout older adulthood should be promoted to prolong an independent lifestyle.

The association between trajectory group and mortality was only present in the nontrained sample (not in the reasoning trained or space trained samples). Specifically individuals in the two highest functioning groups (4 and 5) had significantly more participants still alive at the follow-up than the two lowest functioning groups (1 and 2). The follow-up period was 5 years for the 1984-1998 replicate and 12 years for the 1977-1991 replicate. This finding is consistent with some prior literature on cognitive ability and mortality. Smits and colleagues (1999) found that level of cognitive performance was predictive of mortality. The results for the nontrained group suggest that individuals with higher levels of cognitive ability are at a decreased risk of mortality compared to their lower functioning peers. Furthermore, the two lowest functioning groups (1 and 2) exhibited quadratic trajectories, while the two highest functioning groups (4 and 5) exhibited linear trajectories. Individuals exhibiting linear trajectories had less decline throughout the 14-year period than those with quadratic trajectories. They exhibited a constant rate of decline, while those with quadratic trajectories exhibited an accelerated rate of decline. This could be evidence that linear trajectories exemplify normative age-related decline more than quadratic trajectories, which may be an early indicator of terminal drop. Thus, individuals exhibiting quadratic trajectories may be at risk for greater cognitive decline, and an increased risk of mortality. However, it is also important to consider the possibility that the differences in sheer ability level may also be partially responsible for the morality effects.

Trajectory group was also associated with everyday problem solving ability in the nontrained sample. The two highest functioning groups (4 and 5; linear trajectories) outperformed groups 1, 2, and 3. Thus, the highest functioning groups exhibiting linear decline trajectories performed better on everyday problem solving ability than the three lower functioning groups that displayed quadratic and/or cubic trajectories. These findings provide evidence that individuals with higher levels of functioning and less dramatic rates of decline on basic cognitive abilities such as inductive reasoning also perform better on problem solving tasks associated with daily life. This supports prior research that has found associations between cognitive ability and everyday performance (Willis, Jay, Diehl, & Marsiske, 1992; Willis & Marsiske, 1991; Willis & Schaie, 1986).

Finally, trajectory group membership was also associated with mental status for the nontrained sample. It is important to consider the distinction between the two groupings. For the first comparison, normal individuals were compared to individuals rated as "at risk" or possibly demented. In the second comparison, normal or "at risk" individuals were considered a group and were compared to those rated as possibly demented. Thus, based on the findings from these analyses, it appears that groups 1, 2, and 3 (the lowest functioning groups) had proportionally more individuals rated as monitor or impaired than groups 4 and 5 (the higher functioning groups). This is apparent by observing that groups 2 and 3 had significantly more impaired individuals compared to groups 4 and 5 in the first mental status grouping opposed to the second. This provides more evidence for the suggestion that the quadratic and cubic trajectories displayed by the lower functioning groups may be indicative of the early stages of cognitive impairment or mild cognitive impairment. Those groups with the higher order polynomial trajectories (groups 1, 2, 3) had lower levels of cognitive ability throughout the 14-year period and exhibited more decline over the entire 14-year period than the higher functioning groups (groups 4 and 5). In other words, the linear trajectories of the higher functioning groups exemplified constant decline over time while the quadratic and cubic trajectories of the lower functioning groups typified acceleration in the rate of decline over time, which may be indicative of cognitive impairment. The findings do support prior literature on cognitive ability level and impairment. Individuals with lower baseline ability (such as group 1) tend to progress and exhibit the symptomology of impairment more rapidly than individuals with higher levels of ability (such as groups 4 and 5; Raykov et al., 2002; Rubin et al., 1998; Teri et al., 1995).

Reasoning Training Sample

The reasoning training sample exhibited stability over the 14-year period. Three out of the four groups were characterized by zero-order trajectories indicating no overall change. All four groups demonstrated a lack of significant decline over the 14-year period and significant gain at each training session. This suggests that despite prior ability level, training on inductive reasoning ability is effective and ultimately contributes to the maintenance of an independent lifestyle in late life. The lack of overall decline over the 14-year period as a result of cognitive training supports prior research on the efficacy of cognitive training programs (Ball et al., 2002; Baltes, Sowarka, & Kliegl, 1989; Calero & Garcia-Berben, 1997; Schaie & Willis, 1986; Willis & Nesselroade, 1990). Also, the overall stability achieved for all four trajectory groups, regardless of prior ability, provides even more evidence that cognitive training is effective for a wide range of older adults who have begun to experience normative age-related decline, adding support to prior research (Baltes et al., 1989; Calero & Garcia-Berben, 1997; Gunther, Schafer, Holzner, & Kemmler, 2003).

There were two patterns both relating to level differences present among the association between covariates and outcomes and trajectory group membership in the reasoning training sample. The first pattern reflects differences in association as a function of ability level. The second pattern of differences primarily exists between the high and low level trajectories.

The association of cognitive style, cognitive reserve, and everyday problem solving with trajectory group membership varied incrementally as a function of level. The association between cognitive style and group membership revealed that higher scores on cognitive style were associated with belonging to a higher functioning group (2, 3, 4) than group 1. Higher scores on cognitive style were associated with higher scores on inductive reasoning ability. This is consistent with the prior work by Schaie (1984; 1996; 2004). Investigation of the indicators of cognitive style revealed significant group differences for motor-cognitive flexibility and psychomotor speed. In particular, all groups significantly differed from one another on both of these variables except for groups 3 and 4, the two highest functioning groups. Individuals in the higher functioning reasoning ability groups had higher scores on psychomotor speed and motor-cognitive flexibility. This is also in accordance with the findings of Schaie (1984; 1996; 2004) that found motor-cognitive flexibility and psychomotor speed had the strongest associations with inductive reasoning ability. Again, this suggests that the higher functioning individuals were able to more readily respond and adapt to the environment. Cognitive style was measured at time 5. Schaie (1984; 1996; 2004) has found that the associations between cognitive style and reasoning ability tend to slightly decrease with age. Thus, it is not completely erroneous to suggest that those with higher levels of cognitive style tend to exhibit cognitive trajectories with less dramatic decline.

Higher scores on cognitive reserve were associated with membership in a higher functioning group (2, 3, 4) than group 1. Thus, higher scores on cognitive reserve were associated with higher levels of inductive reasoning ability. This is consistent with prior literature on engagement in intellectually stimulating activities. Individuals that participate in more cognitive stimulating activities both throughout their lives and in older adulthood typically have higher levels of reserve capacity and higher levels of cognitive ability (Hultsch et al., 1993; Hultsch et al., 1999; Schooler, 1987; Wilson, Bennett, et al., 2002; Wilson, Mendes de Leon, Barnes, Schneider, Bienias, Evans, & Bennett, 2002). Engagement is not only beneficial for reserve capacity but also serves as a protective factor for cognitive decline and maintenance of remaining cognitively active (Wilson, Bennett et al., 2002; Wilson, Mendes de Leon et al., 2002).

Investigation of the indicators of cognitive reserve revealed that individuals in the two highest functioning groups (3, 4) with the least overall decline had significantly higher educational attainment and occupational statuses in comparison to group 1, the lowest functioning group with the most initial decline. In addition, for occupational status, on average group 3 had significantly higher occupational attainment than group 2. As stated for the nontrained group, prior research has suggested that individuals with higher levels of educational and occupational attainment typically experienced delayed manifestation of the symptomology of cognitive impairment due to higher levels of cognitive reserve (Snowdon et al., 1996; Stern et al., 1999; Tuokko et al., 2003). The differences between the group distinctions in the nontrained and reasoning training groups also suggest that cognitive training on inductive reasoning ability serves as a sufficiently stimulating and engaging cognitive activity for individuals of varying educational and occupational levels.

For the nontrained group there were only significant differences in cognitive reserve between the highest (group 5) and lowest (group 1) functioning groups. In the reasoning training group however, the three higher functioning groups (groups 2, 3, 4) all were significantly different from group 1 (the lowest functioning group). Although the differences for both the nontrained and reasoning training groups resulted primarily from education level and occupational status, this does not suggest that the other indicator variables (income, educational activity, fitness activity) were meaningless. Although education and occupation were measured at time 5, the values of these variables were likely the same at time 1. Most of the individuals in this study retired between the first and second occasions of measurement because they were at least 56 years of age at time

1. Higher education and occupation may be associated with participation in cognitively stimulating activities or increased intellectual engagement.

For the outcome of everyday problem solving ability, the three higher functioning groups (2, 3, 4) all performed significantly better on everyday problem solving ability than the lowest functioning group (group 1). Although none of the groups experienced significant decline over the 14-year period, demonstrating overall cognitive stability, group 1 consistently had the lowest scores on inductive reasoning ability across the five occasions. The significant association of trajectory group with everyday problem solving ability for the reasoning training sample suggests that level of inductive reasoning ability is predictive of everyday problem solving. Moreover, higher levels of inductive reasoning ability are associated with higher levels of everyday problem solving ability.

The second pattern of differences primarily distinguishing the high and low ability trajectory groups was present for the health behaviors covariate, and the outcome of mental status. The health behaviors covariate was significantly associated with group membership for groups 1 and 3. Specifically, individuals engaging in more positive health behaviors were less likely to be in group 3. Group 3 did experience more decline over the second 7-year period than group 1. Thus, because health behaviors were measured in accordance with the last measurement occasion, it could be possible that in comparison to group 3, group 1 engaged in more positive health behaviors over time. In fact, some of the items on the HBQ required individuals to consider their behavior over the 7 years prior. Therefore, the more dramatic decline over the second 7-year period exhibited by group 3 would corroborate prior literature (Belloc & Breslow, 1972; Blumenthal & Gullette, 2002; Correa Leite et al., 2001; Emery & Blumenthal, 1991; La Rue et al., 1997; Ortega et al., 1997) that has found a relationship between proactive health behaviors and cognitive ability.

For mental status, trajectory group was only significantly associated with the normal versus impaired comparison, not the normal/"at risk" versus possible dementia comparison. The results indicated that the two highest functioning groups (3 and 4) had significantly fewer impaired individuals (approximately 10 to 15%) than the two lower functioning groups (1 and 2; approximately 50%). Though not significant, the lower functioning groups exhibited the most overall decline. Since these groups had lower scores on inductive reasoning ability across occasions compared to groups 3 and 4, this does support prior research that found lower functioning individuals exhibit the symptoms of cognitive impairment more rapidly (Raykov et al., 2002; Rubin et al., 1998; Teri et al., 1995). Furthermore, this also supports and extends prior research on cognitive training for individuals with varying levels of cognitive status. Both Yesavage (1982) and Raykov and colleagues (2002) found that the magnitude of training gain varied as a function of cognitive status. The current study suggests that individuals with varying levels of cognitive impairment are able to benefit from training.

Trajectory group membership was not associated with health severity or mortality for the reasoning training sample. It is important to note that there were no significant predictors of health status in the reasoning training sample, while chronic disease was a significant covariate for both the nontrained and space training samples. Because all of the reasoning training individuals across trajectory groups benefited from the training program, the reasoning training sample did not experience significant change in cognitive ability over the 14-year period. This finding is encouraging, and suggests that participating in activities that promote maintenance of cognitive ability may decrease the risk of mortality, at least for a period of time, and possibly even promote better health.

Space Training Sample

Five trajectory groups best fit the space training sample, with four linear decline trajectories and one zero-order trajectory. The highest functioning group demonstrated the zero-order trajectory. This may suggest that for high functioning individuals, global practice may help maintain reasoning ability. The space training sample did not experience the same magnitude of benefit as the reasoning training sample. However, this was not anticipated because the outcome of interest was inductive reasoning ability, not spatial orientation. Thus, for the purposes of this study, participants in the space training sample simply served as a group that experienced organized cognitively stimulating activity that was not directly related to the ability of interest.

When comparing the trajectories of the space training sample to the nontrained sample, it appears that participants in the space training sample did experience some cognitive benefit as a result of the training. Only linear decline trajectories were present for the space training sample, suggesting that there was a lack of evidence of precipitous decline compared to the nontrained sample. Only the highest functioning nontrained groups exhibited linear trajectories. Thus, although the mechanism of benefit is not entirely clear, it appears that participating in some structured cognitive activity (opposed to none) does provide some cognitive benefit for inductive reasoning ability. However, participating in targeted cognitive activity is even more beneficial, as is evident from the trajectories of the reasoning training sample.

As with the reasoning training sample, the same two patterns of differentiation focusing on level between association of covariates and outcomes and trajectory group were present. The first was predominantly an incremental difference in ability level. The second pattern distinguished between the high and low functioning groups.

Differences among all trajectory groups were present for the cognitive style covariate. As with the nontrained and reasoning trained samples, for the space trained sample, higher levels of cognitive style were significantly associated with membership in any of the higher functioning groups (2, 3, 4, 5) compared to group 1 (the lowest functioning group with the greatest initial and overall decline). This supports and extends the prior work of Schaie (1984; 1996; 2004). All groups significantly differed from one another except for groups 2 and 3 (both with average levels of ability and substantial decline over the second 7-year period) and groups 4 and 5, the two highest functioning groups with the least overall decline.

Investigation of the indicators of cognitive style revealed that there were significant differences for motor-cognitive flexibility, psychomotor speed, and attitudinal flexibility. Only groups 1 and 4 significantly differed in attitudinal flexibility, with group 4 scoring higher. For motor cognitive flexibility, all groups scored better than group 1, and higher scores on motor-cognitive flexibility were associated with higher levels of reasoning ability. Finally, for psychomotor speed, all groups significantly differed from one another except for groups 2 and 3, and groups 4 and 5. Those individuals with higher levels of inductive reasoning ability also had higher levels of psychomotor speed and motor-cognitive flexibility, which suggests that they were more readily able to respond and adapt to stimuli. The finding that attitudinal flexibility was influential in this sample suggests that the individuals in group 4 had more self-reported tolerance to unpredictability, ambiguity, and sudden changes than the individuals in group 1.

The second pattern of differences, distinguishing the high and low functioning groups, was present for the chronic disease covariate, and the outcome of everyday problem solving. Chronic disease scores were associated with group membership for groups 1, 2, and 3. Specifically, individuals with higher scores on chronic disease were more likely to be in groups 2 and 3 compared to group 1. Prior research has suggested that individuals with chronic diseases are likely to have lower levels of cognitive ability than their peers without chronic disease. For example, individuals with diabetes tend to have lower levels of cognitive ability at baseline (Arvanitakis et al., 2004; Elias et al., 1997; Fontbonne et al., 2001; Ryan, 2001). A negative relationship between hypertension and cognitive function has also been documented (Elias et al., 1995; Hertzog et al., 1978; Raz et al., 2003; Waldstein et al., 1996). In addition, research has found that individuals suffering from heart/cerebrovascular disease have lower levels of cognitive function (Fahlander et al., 2000; Verhaeghen et al., 2003). Groups 2 and 3 did exhibit more substantial decline over the second 7-year period in comparison to group 1. Additionally, group 2 had slightly more hypertensive participants over the second 7-year period than group 1, while group 3 had more hypertensive individuals and those with heart/cerebrovascular disease over the second 7-year period than group 1. This suggests that groups 2 and 3 were declining in health, possibly due to increased presence of chronic diseases, which in turn contributed to more substantial cognitive decline.

The significant association of trajectory group with everyday problem solving ability revealed that all groups performed better than the lowest functioning group. The three highest functioning groups (3, 4, 5) also performed better than group 2. This reiterates that level of reasoning ability is associated with everyday problem solving ability. The lower functioning groups (1 and 2) scored lower on inductive reasoning ability across occasions, and also exhibited more overall decline throughout the 14-year period than the higher functioning groups (3, 4, 5). Thus, individuals with higher levels of cognitive ability perform better on measures of everyday problem solving ability.

Though not statistically significant ($p = 0.08$), approximately 50% of participants for the two lowest functioning groups (1 and 2) had died by the follow-up, compared to only approximately 20% of participants in the two highest functioning groups (4 and 5). This supports research that has found cognitive ability to be a predictor of mortality

(Smits et al., 1999). In addition, for the first comparison of mental status (normal versus impaired), although not significant ($p = 0.12$), only 30% of the lowest functioning group (1) was rated as normal, while over 75% of the two highest functioning groups (4 and 5) were rated as normal. Even though these findings did not reach statistical significance, they are still in accordance with the results of the nontrained and reasoning trained samples, and still support prior literature that individuals with lower baseline levels of ability exhibit the symptomology of impairment more rapidly.

Summary: 3 Samples of trajectory groups

After reviewing the major findings of the three samples, it is now possible to compare and contrast the findings amongst these samples. The nontrained sample demonstrated the most variability in trajectory type. The trajectories ranged from consistent decline over time (linear), to periods of accelerated decline (quadratic), and even relative stability followed by more dramatic accelerated decline (cubic). The nontrained individuals did not receive any structured cognitively stimulating activity. Thus, the trajectories present may be a reflection of the larger population of high functioning older adults. The space training sample, on the other hand, did engage in structured cognitively stimulating activity, though not directly related to the outcome of interest (inductive reasoning ability). However, the trajectories present in the space training sample lend evidence to support that engaging in global cognitive activity can, to a certain degree, be beneficial for the maintenance of inductive reasoning ability. The magnitude of benefit is not known however, the suggestion could be made that global benefit is possible. Only linear decline trajectories exhibiting constant decline were present and there was no evidence of accelerated decline in the space training sample as there was in the nontrained sample. Finally, the zero-order trajectories displayed by the reasoning training sample provide sufficient evidence that training on inductive reasoning is beneficial for the maintenance of inductive reasoning ability. All individuals in the sample, regardless of prior ability level, demonstrated comparable levels of reasoning ability across the 14-year period. Thus, the differences in the trajectory groups found in the three samples provide support for the impact of different levels of cognitive activity.

Although the trajectories exhibited in the three samples differed considerably, there were similarities present among trajectory group membership and the covariates.

Cognitive style was significantly associated with trajectory group membership for all groups in all three samples. More so, specifically, motor-cognitive flexibility and psychomotor speed were the most influential indicators. It was not surprising that these indicators were the most influential. Previous research has found psychomotor speed and motor-cognitive flexibility to have high associations with inductive reasoning ability (Schaie 1984; 1996; 2004). Furthermore, psychomotor speed involves the speed at which an individual responds to familiar stimuli and motor-cognitive flexibility is an individual's ability to respond to stimuli or adapt to changes in stimuli, both of which are important to inductive reasoning ability. Inductive reasoning ability includes identifying patterns or rules and applying them to solve a problem. Inductive reasoning ability also involves the ability to recognize novel concepts or relationships and the ability to solve logical problems. Thus, given the definitions of psychomotor speed, motor-cognitive flexibility, and inductive reasoning ability, it is not surprising that cognitive style was so highly associated with trajectory group membership.

Since cognitive style was associated with all trajectory groups in the three samples, with those in higher functioning trajectories scoring higher on cognitive style, this suggests that cognitive style is associated with level of reasoning ability. Because cognitive style was measured at time 5, this would imply that higher levels of inductive reasoning are associated with higher levels of cognitive style. However, as mentioned previously, the association between inductive reasoning and cognitive style tends to decrease with age (Schaie, 1984; 1996; 2004). Thus, it is possible that individuals higher on cognitive style tend to maintain higher levels of inductive reasoning ability throughout older adulthood.

Cognitive reserve was also associated with trajectory group membership in the nontrained and reasoning trained samples. Cognitive reserve was associated with all groups in the reasoning trained sample, thus suggesting that cognitive reserve was related to level of reasoning ability. The association in the nontrained sample reiterates this claim because the only significant differences were between the highest and lowest functioning groups. Education and occupation were the most influential indicators. Specifically, those with higher levels of education and occupation had higher levels of reasoning ability. Although measured at time 5, education and occupation were likely stable since time 1. Thus, it would not be too presumptuous to suggest that the findings of this study support that those with higher educational and occupational attainment tend to have higher levels of reserve capacity, and therefore maintain their cognitive ability longer.

Although health behaviors and chronic disease showed some association with trajectory group membership, these associations were less pronounced. This could be due to the high functioning nature of the sample. Because the sample was relatively healthy and had regular access to a health maintenance organization, restriction of range on the chronic disease and health behaviors factors is a very plausible hypothesis.

Finally, in terms of clinically meaningful outcomes, everyday problem solving was most consistently associated with trajectory group membership in all three samples. In all samples, higher scores on everyday problem solving were associated with membership in higher functioning trajectories. Thus, level of reasoning ability was associated with everyday problem solving.

Mental status was only associated with trajectory group membership in the nontrained and reasoning training samples. In both samples the lower functioning trajectory groups were more likely to be rated as “at risk” or possibly demented than the higher functioning groups. Although this was nonsignificant in the space training sample, a similar pattern of findings was present. This null finding in the space training sample could be due to the distribution of participants in the trajectory groups.

Mortality was only significant in the nontrained sample. Again, lower functioning individuals were more likely to be deceased at follow-up than their higher functioning peers. Because these same patterns were not present in the other two samples (reasoning trained and space trained), further discussion of the nontrained trajectories is warranted. Specifically, the two higher functioning trajectory groups displayed linear trajectories with constant cognitive decline over time. The two lowest functioning trajectory groups displayed quadratic trajectories with accelerated decline, particularly over the first 7-year period. Thus, trajectory shape may be a meaningful predictor of impending mortality for older adults who have not received or participated in any organized cognitive activity.

Clinical Outcomes as a Function of Training Status

The analyses on trajectory group membership yielded meaningful information about the impact of rate of cognitive change on inductive reasoning ability as a function of training status (nontrained, reason train, space train) on these clinical outcomes. To determine whether the differences in the clinically meaningful outcomes were present at a more global level, analysis of variance and logistic regression were employed utilizing training status and training group as grouping variables.

Health Severity

Of the four outcomes assessed, training status (trained/nontrained) was only a significant predictor of health severity in 1998. Specifically, the nontrained individuals had significantly higher health care expenditure costs than that of the trained sample. This was not replicated for the 7-year follow-up. Investigation of the 1998 health severity data included individuals from the 1984 replicate that remained in the study 14-years post training (as opposed to only 7 years post-training for the 1991 replicate). Furthermore, replicate was not a significant covariate in this analysis. These findings suggest that the trained individuals that returned for the 1998 wave were particularly high functioning. This is evident simply from their participation in the training program. Participation in training required them to be in the study 14 years pre-training and they also remained in the study at least 14 years post-training. Pre-training participation was not required of the nontrained sample. Thus, the trained participants were likely healthier and higher functioning. Overall, for health severity, age and presence of chronic diseases appeared to be significant predictors. This is in accordance with prior research that individuals with more health conditions typically utilize more health services (Clark et al., 1995; Perkins et al., 2004; Von Korff et al., 1992).

Mortality

For mortality, age was a significant predictor. However, for the long-term mortality assessment (up to 2003), replicate and reasoning pretest score were also significant. The impact of replicate is not surprising because for the 1991 replicate mortality in 2003 was only a 12 year follow-up, while it was a 19 year follow-up for the 1984 replicate. On the other hand, the importance of reasoning pretest score is consistent with prior literature on ability level and mortality. Individuals with higher levels of cognitive ability tend to be at a decreased risk for mortality in comparison to their lower functioning peers. The findings of this study support prior research that older age (Hassing et al., 2002; Small et al., 2003) and lower cognitive ability (Smits et al., 1999; Wilson et al., 2003) are predictive of mortality.

Everyday Problem Solving

Age, education, replicate, and reasoning pretest score were more influential predictors of everyday problem solving than training status. Again, the replicate finding is not surprising because everyday problem solving was a 14-year outcome for the 1984 replicate and a 7-year outcome for the 1991 replicate. The significance of reasoning pretest score supports prior literature that has found cognitive ability to be predictive of everyday problem solving ability (Willis et al., 1992; Willis & Marsiske, 1991; Willis & Schaie, 1986). The nonsignificant training status finding may simply be indicative of the highly educated and high functioning nature of the sample. Alternatively, including the reasoning and space training groups together as one group may mask the impact of training. Reasoning or space ability may be more pertinent for everyday problem solving ability. Thus, by combining these two samples into one group (the trained group), the training effects may be suppressed.

Mental Status

Finally, for both groupings of mental status, replicate and reasoning pretest score tended to be the most influential predictors. Replicate is not out of the ordinary because mental status was a 14-year follow-up for the 1984 replicate and only a 7-year follow-up for the 1991 replicate. Thus, it is reasonable that the 1991 replicate had fewer instances of impairment. The predictive quality of level of cognitive ability is consistent with prior research (Raykov et al., 2002; Rubin et al., 1998; Teri et al., 1995). The nonsignificant training status finding could just be a reflection of the high functioning nature of the sample. Alternatively, it could be evidence that once the symptoms of impairment manifest, the cognitive training programs employed in this study are not able to remedy or mask the non-normative decline. Although the findings from this study do suggest that training can be effective for individuals with varying levels of impairment, the magnitude of the impact is still unknown.

Clinical Outcomes as a Functioning of Training Group and Gain

While considering the four outcomes, only everyday problem solving ability was significantly associated with training group. Training group was a significant predictor of everyday problem solving. Individuals trained on inductive reasoning ability performed better than those individuals trained on spatial orientation ability. The prior investigation of training status (trained/nontrained) found no significant effect for training status on everyday problem solving ability. However, the results of this analysis suggest that inductive reasoning ability may be more salient for everyday problem solving than spatial orientation ability. Thus, inductive reasoning ability may be a more critical skill, at least in older adulthood, for the maintenance of everyday problem solving ability. This supports prior research that has found everyday problem solving ability to be multifaceted, composed of several basic mental abilities (Allaire & Marsiske, 1992; 2002; Willis, et al., 1992).

None of the outcomes were predicted by training gain. As in the previous analysis on training status, chronic disease and age were the most influential predictors of health severity, which is consistent with prior literature (Clark et al., 1995; Perkins et al., 2004; Von Korff et al., 1992). Only age, however, was consistently predictive of mortality status. The lack of significance for reasoning pretest and gain could be a reflection of the positive impact of cognitive training programs. Encouraging people to participate in cognitively stimulating activity could serve as a protective mechanism for cognitive decline such that only age remains an influential factor for mortality. This suggestion would be supportive of prior research that has found participation in mentally simulating activities to have a positive impact on the maintenance of cognitive ability (Hultsch et al., 1993; Hultsch et al., 1999; Wilson, Bennett, et al., 2002; Wilson, Mendes de Leon, et al., 2002).

Finally, for mental status, reasoning pretest score, replicate, and education were the most influential predictors. Training group was not influential. This suggests that once the symptoms of impairment are manifest, training on reasoning or space ability does not differentially impact the rate of progression. Neither training program appears to be superior in delaying impairment. Prior ability level (reasoning pretest), however, does appear to be salient. This supports prior literature that found lower baseline levels of ability to be associated with rapid progression (Raykov et al., 2002; Rubin et al., 1998; Teri et al., 1995). The nonsignificant finding of gain appears to be somewhat contradictory to prior research (Davis et al., 2001; Oswald et al., 1996; Raykov et al., 2002; Yesavage, 1982; Yesavage et al., 1992). However, this could be due to the inclusion of training on two different abilities and gain was a function of gain on the ability trained. Investigating each training group separately and assessing the impact of training gain may provide a more complete picture of the relationship between training gain and cognitive status.

Summary

The results of the ANOVA provide support that consideration of rate of cognitive change of trajectory group membership in addition to training status is important. The impact of training status on the long term outcomes was much more evident when considering the trajectory groups. This provides evidence that observing cognitive ability prior to cognitive intervention is important because it can provide information about expectations for long-term outcomes.

Strengths, Limitations, and Suggestions for Future Studies

The results of this study contributed many novel findings to the literature on rate of cognitive change. First however, it is important to mention the strength of the study design. The Seattle Longitudinal Study is a longitudinal study that provides assessments on participants in 7-year intervals. Due to the design of the SLS, utilizing modeling techniques to investigate change over time was possible.

Strengths

There were several strengths or contributions of the current study. Utilizing a newer modeling procedure, Nagin Mixture Modeling, provided information on the types of cognitive change trajectories of inductive reasoning ability present in three samples. In addition, because the groups of trajectories present differed in the three samples, this demonstrated the impact of structured cognitive stimulation on inductive reasoning ability. The results of this study also provided support for the benefits of cognitive flexibly and cognitive activity in older adulthood. Furthermore, this study provided insight on clinically meaningful outcomes, mainly that these outcomes vary by cognitive trajectory group. Even more evident was the importance of considering trajectory group membership in addition to training status.

Limitations

Although this study contributed many significant findings to the literature, it is important to consider what factors may limit the generalizability of the results to the larger older adult population. First, there are aspects of the sample composition that limit generalizability. The sample of older adults included in the Seattle Longitudinal Study is not a completely random sample. All participants resided in the greater Seattle, Washington area and were recruited through their membership in Group Health Cooperative of Puget Sound, a health maintenance organization (HMO). This sample was not only part of a HMO, implying regular health check-ups and health coverage, but also a population that represents the upper tier in education and income. As was suggested by the HMO membership, this sample was relatively healthy (physically and functionally). The portion of the sample included in this study still resided independently in the community. Furthermore, these adults were highly educated and active, thus suggesting that the majority were mentally intact. Another factor that may limit the generalizability of these results is the ethnic composition of the sample; the sample was predominantly Caucasian, making generalizations to other ethnic groups in the population difficult.

The high functioning nature of the current sample, along with the longitudinal design of the SLS necessitates mention of selective positive attrition. All samples included in the current study required participation in the SLS for at least 7 years, but the majority of the sample participated for a minimum of 21 years. Thus, it is well known that individuals that return for follow-up testing are higher functioning, both cognitively and physically, than their non-returning peers. Therefore, because the current study required participation in at least 2 waves of the SLS, selective positive attrition impacts the generalizability of these results to the larger population of older adults. However, although there are limitations associated with selective positive attrition, as mentioned previously, this type of investigation would not have been possible if longitudinal data were not available. Thus, longitudinal designs serve as both a strength and a weakness.

Future Research

Despite these limitations, the findings from the present study have generated several ideas for future research. The current study found multiple groups of trajectories over a 14-year period within each of the three samples. Investigating both what these individuals' trajectories looked like in midlife and longer follow-up in later life may be especially helpful to determine the normative and non-normative trajectories of cognitive change present in the population. In particular, it would be interesting to explore the cognitive change exhibited by the nonlinear trajectory groups and the lowest functioning groups in midlife because these individuals seem to be at a disadvantage both cognitively (everyday problem solving ability and mental status) and functionally (mortality) in comparison to the higher functioning trajectory groups. Further follow-up would also allow the long-term impact of training and training gains to be explored.

Investigating the clinically meaningful outcomes at a longer follow-up occasion would also be meaningful. Although training status, training group, and training gain did not appear to be influential predictors of these outcomes, a greater impact might be present if the follow-up period was extended. Similarly, examining the impact of trajectory group membership on these outcomes measured at a later occasion would provide evidence about which trajectory groups or profiles are at risk of functional decline that would limit independence. This could be informative for preventative purposes such as implementing training programs or other interventions earlier in older adulthood.

The covariates investigated in the current study were measured in conjunction with the final occasion of measurement (time 5). Examining these variables prior to the occasions of measurement to be included in the trajectory, or at the same time as the first occasion, would provide predictive information. Including health behaviors, cognitive style, and cognitive reserve as predictor variables would allow the researcher to determine if any of these domains could be targeted earlier in life, such as midlife, to prevent cognitive decline or to promote cognitive stability in later life. Additionally, these variables could be measured at each occasion of measurement and be included in the model as time varying covariates. This would allow the researcher to determine if certain groups of cognitive trajectories tend to display similar patterns in other domains, such as chronic disease, cognitive activity or reserve, health behaviors, and cognitive style.

Finally, investigating what type of cognitive training (intensity, frequency, and duration) is necessary to help low functioning individuals maintain or remediate cognitive ability is necessary. For example, does the type of training or the focus of the training need to be modified or tailored for lower functioning individuals? Alternatively, maybe lower functioning individuals simply need more training sessions, longer training sessions, or more frequent training sessions. These are important questions that need to be addressed. The current study demonstrated that individuals with varying levels of cognitive ability are able to benefit from training, however, those in the lowest functioning group appear to be at the greatest risk of cognitive impairment, even after participation in a targeted cognitive training program. Furthermore, additional research needs to be done on transferring the act of participating in cognitively stimulating activities (as is done during the cognitive training programs) to active practice in daily life. This could be possible through booster training sessions, but better yet could include activities in daily life that utilize the mental abilities focused on during training. Encouraging older adults to make a permanent change in their lives to incorporate cognitively stimulating activities on a more regular basis may help with maintenance of the training effects and also contribute to prolonged independence.

Summary and Implications

The results of this study have implications for understanding the rate of cognitive change in older adulthood and the impact of cognitive change on clinically meaningful outcomes in later life. The presence of multiple trajectory groups in each of the three samples demonstrates that there is much interindividual variability in rate of change in inductive reasoning ability in older adulthood. There is not one trajectory of normative cognitive change.

The lower functioning groups in the nontrained sample exhibited nonlinear trajectories. Thus, it is possible that nonlinear trajectories with low baseline scores may be indicative of non-normative cognitive decline. Nonlinear trajectories were not present for either the space or reasoning training samples. In fact, the trajectories present in both the reasoning training and space training samples differed from each other (zero-order compared to linear trajectories) in addition to differing from those in the nontrained sample (trajectories of varying shapes). First and foremost this suggests that cognitive interventions can impact the rate of cognitive change. Second, this implies that participating in structured cognitively stimulating activity can impact cognitive ability. Although the space training sample was not trained on inductive reasoning ability, only linear decline trajectories were present in this sample, suggesting that the activity engaged in was beneficial in some way. Thus, this provides evidence that participating in any cognitively stimulating activity may provide some protection against cognitive decline. Furthermore, because the space training sample did not exhibit the zero-order trajectories exhibited by the reasoning training sample, this is evidence that engaging in cognitively stimulating activity directly related to the ability of interest will produce even more protective benefits against cognitive decline than global cognitive activity.

The benefits of targeted cognitive training were especially evident in the results of the third question where those trained on inductive reasoning ability performed significantly better on problem solving ability than those trained on spatial orientation ability. Training on an ability closely related to functioning in daily life is more beneficial than participating in cognitively stimulating activities more distally related to the ability of interest. It is important however, to keep in mind that the results of this study do support that participation in even distally related cognitively stimulating activities seems to be better for maintenance of cognitive ability than engaging in little or no cognitively stimulating activity.

The results of this study also suggested that cognitive style and cognitive reserve are associated with level of ability in older adulthood. Individuals with higher levels of reserve capacity (evinced mostly through occupational status and education level) and those that respond and adapt to changing situations more readily were typically functioning at a higher level of inductive reasoning ability. These findings complement the implications stated above. In order to prolong independence in late life, it is important to promote remaining cognitively active in older adulthood. Participating in activities, hobbies, and situations that provide cognitive stimulation are important for helping older adults maintain cognitive competence.

Finally, in regard to the clinically meaningful outcomes investigated, the current study provides evidence that inductive reasoning ability is related to everyday problem solving ability and mortality. Mortality was only significantly associated with the trajectory groups present in the nontrained sample. This again reiterates that participation in cognitively stimulating activities (such as those engaged in by the training participants) is important not only for prolonging life, but also for prolonging independence. The nontrained individuals with the nonlinear trajectories had the highest mortality rates. This implies that nonlinear trajectories may be suggestive of impending mortality. Investigation of the other samples most often yielded a significant impact of baseline reasoning ability. Due to the discrepant prior research on the impact of fluid ability on impending mortality, these findings provide evidence that more research on the relationship between cognitive change in inductive reasoning ability and mortality is needed.

Problem solving ability was consistently associated with inductive reasoning ability in the current study (both in the analyses for the trajectory groups, and the various training groups). This constant finding is extremely important because although everyday problem solving ability is comprised of multiple basic cognitive abilities, the results of the current study demonstrate that inductive reasoning ability is an extremely important component or facet of everyday problem solving. Future research aimed at promoting and prolonging the independent lifestyle of older adults should be sure to consider the impact of inductive reasoning ability on activities of daily life, and make efforts to maintain older adults' level of inductive reasoning ability.

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Appendix A
Confirmatory Factor Analysis Models

Figure 1. CFA: Reduced Model #1

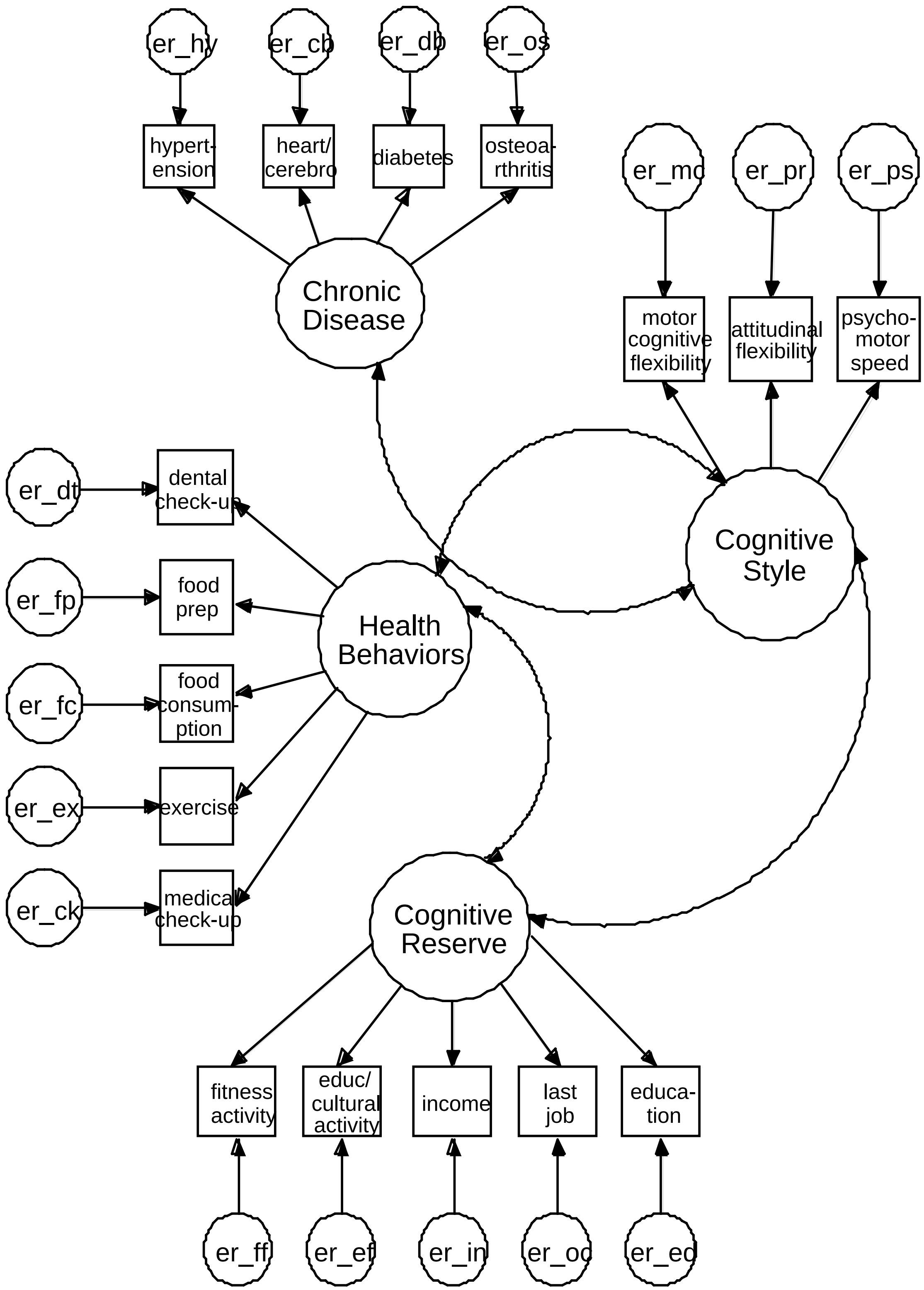
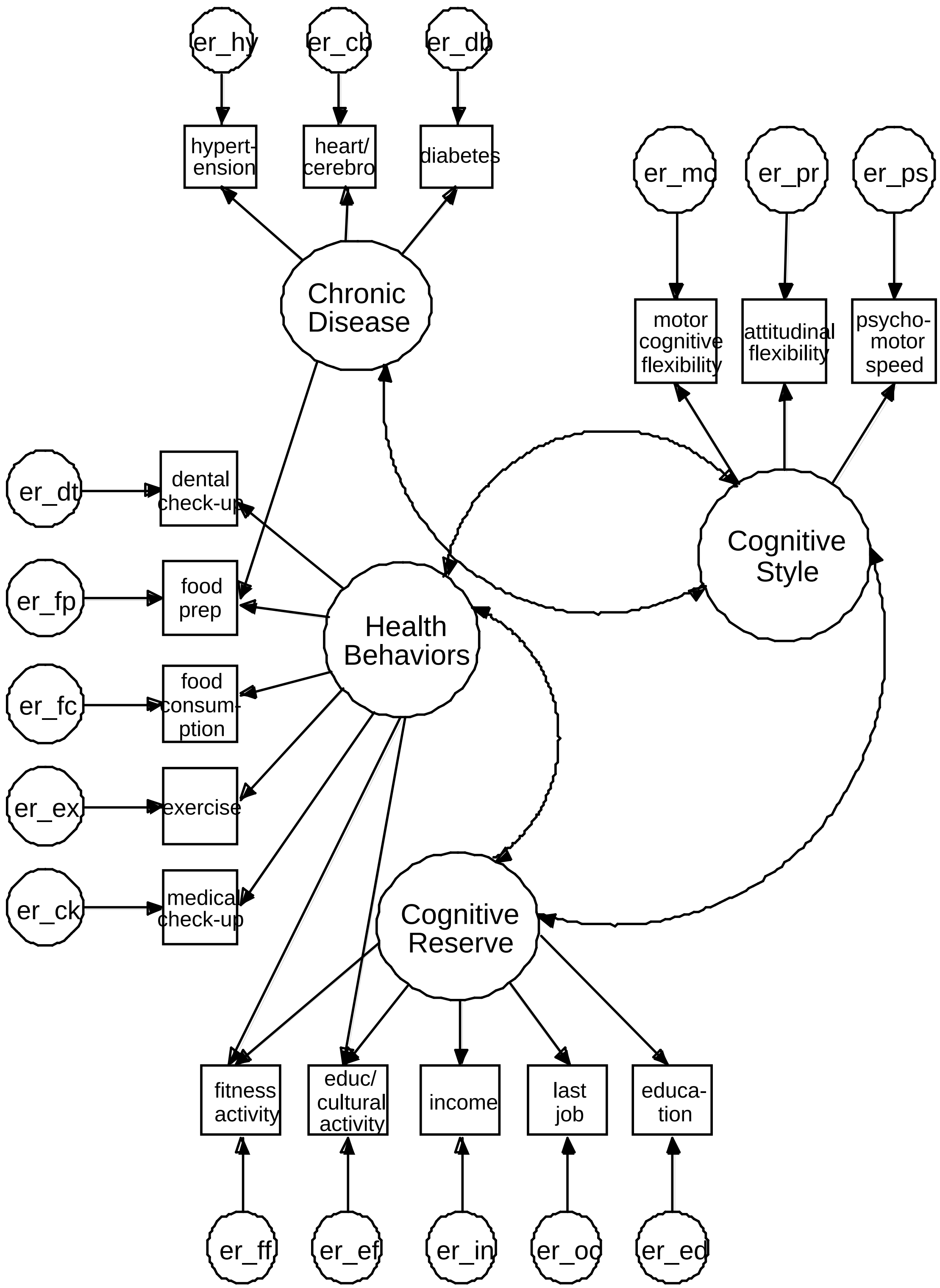


Figure 2. CFA: Reduced Model #2



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PUBLICATIONS

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Boron, J.B., Turiano, N.A., Willis, S.L., & Schaie, K.W. Effects of cognitive training on speed and accuracy of inductive reasoning ability: Remediation of ability seven years prior to training.

Boron, J.B., Willis, S.L., & Schaie, K.W. Relation of training gain to subsequent dementia ratings in the Seattle Longitudinal Study.

SELECTED CONFERENCE PRESENTATIONS

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