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Memory Training and Strategy Use in Older Adults: Results from the ACTIVE Study

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Abstract

Little is known about the long-term effects of memory training in later life on strategy use. Data from the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study (n = 1,401) were used to describe strategy use in a community-dwelling sample of older adults. Strategy clustering scores on verbal list learning tasks of episodic memory were used to test the impact of memory training on strategy use and study longitudinal associations between strategy clustering, memory performance, and everyday functioning. Results suggested that younger, female, white, healthier, and more educated participants show higher strategy clustering scores initially but no characteristics were consistently associated with different trajectories in strategy clustering across all strategy clustering measures together. Memory training had significant immediate effects on all measures of strategy use that were maintained through five years of follow-up. With respect to longitudinal mediation, pre-post training changes in most strategy clustering scores mediate changes in objective memory performance and everyday functioning, implying that strategies can be modified and are closely related to both memory ability and the ability to function independently. This study provides evidence that older adults can be trained to use cognitive strategies, the effects are durable, and strategies are associated with memory and everyday functioning.

Keywords

memory training; strategy use; everyday functioning; older adults

Cognitive strategies are techniques by which individuals may perform on a task at higher levels than otherwise expected, thereby accomplishing significant goals (Lemaire & Reder, 1999). Strategies compensate for age-related declines in processing speed and other cognitive domains by instead taking advantage of abilities that do not decline with age, thereby shifting cognitive performance demands away from those cognitive mechanisms that do decline with age (Hertzog, Kramer, Wilson, & Lindenberger, 2008; Salthouse, 1991). In terms of memory, strategies are conscious and unconscious attempts to organize information from the environment and direct retrieval processes (Hertzog, McGuire, & Lineweaver, 1998; Moscovitch, 1992; Woods, Scott, Conover, Marcotte, Heaton, et al., 2005). For example, one might use an organizational strategy or visual imagery, or a combination of both, to remember a shopping list or pay a bill.

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The Importance of Strategies

Strategies are a useful subject of study in cognitive aging research for two reasons. First, some forms of memory such as semantic memory do not decline with age (Zacks & Hasher, 2006), so certain strategies like semantic organization may be easier for older adults to use than other, more difficult ones like the method of loci (Brooks, Friedman, & Yesavage, 1993; Hazlett, Buchsbaum, Mohs, Spiegel-Cohen, Wei, et al., 1998; Van der Linden, Philippot, & Heinen, 1997). Older adults often achieve excellence in areas of everyday functioning that place demands on cognitive mechanisms that have declined by adopting strategies that minimize the role of such cognitive mechanisms (Hertzog et al., 2008). For example, one might develop a daily routine that integrates contextual supports or external memory aids to overcome processing limitations (Bäckman, 1989; Craik & Byrd, 1982; Park et al., 1999). Cognitive aging research can benefit from studying what types of strategies are bested internalized, selected, and executed by older adults. A second reason to study memory strategies is that they offer information about cognitive processes that underlie memory performance (Schmitt, Murphy, & Sanders, 1981). Strategies require executive control and reflect underlying mechanisms of cognitive abilities (Hertzog et al., 2008). Consequently, changes in strategies as a consequence of memory training can be used to evaluate how well the training conveyed its intended lessons and informs intervention efforts.

In the present study, strategy use will be studied in the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) trial (Ball, Berch, Helmers, Jobe et al., 2002; Jobe, Smith, Ball, Tennstedt et al., 2001; Unverzagt, Smith, Rebok, Marsiske, Morris, et al., 2009; Willis, Tennstedt, Marsiske, Ball et al., 2006). Strategy use will be measured using observed serial, semantic, and subjective clustering scores calculated from word-list learning recall tasks that represent indicators for mnemonic strategies used on word-list learning tasks. Although the ACTIVE memory intervention did not show direct training-related improvement in everyday functioning using performance-based measures of memory (Willis et al., 2006), we hypothesize that strategies mediate that association. Measuring specific strategies rather than indicators for broad types of strategies described by the clustering scores was not feasible in ACTIVE because participants were neither told to use certain strategies nor asked how they remembered information. *Serial clustering* provides a measure of how much a respondent recalls consecutive items from a word list in the same order as items were presented (Delis, Kramer, Kaplan, & Ober, 1987; Stricker, Brown, Wixted, & Delis, 2002). On an unrelated list of words, high levels of serial clustering indicate that reliable associations were formed between words, possibly through repetition, imagery, or some other strategy. Given a list of semantically related words from different categories not presented together in their semantic categories, however, more serial clustering reflects an inability to utilize semantic relationships that exist among items (Harnadek & Bourke, 1994). *Semantic clustering* reflects the extent to which contiguously recalled words come from the same semantic category (Bruce & Echemendia, 2003; Gershberg & Shimamura, 1995; Stricker et al., 2002). Higher scores indicate increased use of a categorization strategy. Individuals who use more categorical clustering remember more than adults who exhibit lower levels of such clustering (Bower, 1970; Zarit, Gallagher, & Kramer, 1981), which is described by the levels of processing effect (Craik & Lockhart 1972; Craik & Tulving 1975; Tulving & Schacter, 1990). *Subjective clustering*, sometimes called pair frequency, is a measure of the degree to which individuals cluster the same words together between sequential trials on a test (Sternberg & Tulving, 1977; Tulving, 1962). Higher subjective clustering on a task containing related words or unrelated words might be attributed to consistent use of semantic categorization or serial clustering over the trials, respectively. It could also indicate the use of idiosyncratic strategies, such as alphabetizing or utilizing phonetic characteristics.

Strategy clustering scores from word-list learning tasks have real-world analogs. Strategic approaches that organize elements of daily life into higher levels of organization are analogous to semantic organization. An older adult might order a day's chores in order of importance, or spatially by where they might be accomplished around town. Similarly, a grocery list can be organized by locations in the market to navigate the market more efficiently. Because a serial clustering strategy reflects a lack of appreciation of contextual clues in the context of higher levels of order, a real-world analog is to approach daily tasks without organization, which leads to forgetting, errors, and slower performance (Fisher & DeLuca, 1997). An analog to subjective clustering is to develop approaches that are used consistently to facilitate recall even if such approaches are idiosyncratic or unique. For example, an older adult without pharmaceutical training might ritually sort his or her weekly medications by pill color or size to ensure necessary drugs are taken at the correct times and in correct amounts.

Memory Strategies in Cognitive Aging Research

Inferences about strategic processes are usually made by comparing cognitive performance between an intervention and a control group. Such inferences are indirect and problematic because superior performance on a task can be reached through a variety of strategies, some of which are more mentally effortful than others but still effective (Belmont & Butterfield, 1977; Schmitt et al., 1981). Further, subgroups of individuals might exist within an intervention group who use certain strategies more than others. Langbaum, Rebok, Bandeen-Roche, and Carlson (2009) found distinct patterns of responsiveness to ACTIVE memory training and concluded that this is attributable to the use of different strategies.

Strategies used on word-list learning tests might be ascertained in one of three general ways. The most straightforward approach is to ask individuals to describe their approach to remembering information after completing a cognitive task. This can be done explicitly with multiple choice questionnaires (e.g., Dunlosky & Hertzog, 1998; Saczynski, Rebok, Whitfield, & Plude, 2007) or implicitly with open-ended questions (e.g., Hertzog et al., 1998). Forgetting and lack of insight might compromise the reliability of such retrospective reporting (Dunlosky & Hertzog, 2001), though the use of complex strategies, or in situations with ill-defined problem statements or goals, may leave an investigator with no other choice than to solicit self-reports. A second way to identify strategies is to instruct participants to use a certain strategy during an evaluation and assume that protocols are followed (e.g., Mason & Smith, 1977).

When individuals are neither asked what strategies they used nor told to use a certain technique, as was the case in the ACTIVE study, a third option is to study patterns of recall performance using strategy clustering scores on word-list learning memory tasks. Clustering scores described above are objectively calculated post-hoc based on the order of words recalled with respect to other words recalled, as well as with respect to the order of the originally presented words. Such clustering measures make word-list learning tasks uniquely suited to provide information about underlying strategic memory processes (Woods et al., 2005). Clustering scores enable researchers to determine the degree to which, for example, an individual uses a serial encoding strategy or adopts contextual cues such as semantic similarities or imagery to chunk words for more effective encoding and subsequent retrieval. An advantage of clustering scores is that because strategies can be learned unconsciously and applied before one is explicitly aware of using them, clustering scores do not depend on conscious awareness of strategy use (Colcombe, Kramer, Erickson, & Scalf, 2005; Salthouse, 1984; Siegler & Stern, 1998).

Memory Training and Strategy Use

Memory training interventions such as ACTIVE are an important resource for studying the role of strategies in memory and everyday functioning. Modern memory training interventions teach memory strategies with the ultimate goal being to attenuate the rate of age-related cognitive decline and consequently enhance a target population's ability to live independently in a community (Hertzog et al., 2008; Rebok, Carlson, & Langbaum, 2007; Unverzagt et al., 2009; Salthouse, 2006). Strategies compensate for cognitive deficits that develop with age if they can be selected appropriately and executed in relevant contexts (Bäckman & Dixon, 1987; Cavanaugh, Grady, & Perlmutter, 1983; Sinnott, 1986). Because more strategy use is associated with better memory performance, and some strategies are more effective than others (Craik & Lockhart 1972; Craik & Tulving 1975; Webber & Marshall, 1978), interventions to improve memory ability in cognitively normal older adults usually focus on teaching various internal mnemonic or external memory strategies for use in relevant situations (Acevedo & Lowenstein, 2007; Belleville, 2008; Jobe et al., 2001). Prior intervention research has shown older adults can be trained to learn and apply new memory strategies (e.g., Ball et al., 2002; Carretti,, Borella, & De Beni, 2007; Cavallini, Pagnin, & Vecchi, 2003; Floyd & Scogin, 1997; Verhaeghen, Marcoen, & Goossens, 1992). Research also suggests that strategy execution for complex or attentionally demanding strategies declines with age, and that this disparity increases with increasing strategy complexity (Allen et al., 1992; Arnaud et al., 2008; Dunlosky & Hertzog, 1998; Dunlosky, Hertzog, & Powell-Moman, 2005; Geary & Wiley, 1991; Geary, French, & Wiley, 1993; Kausler, 1994; Siegler & Lemaire, 1997; St. Clair-Thompson, 2007).

Despite their utility, strategy use is understudied in memory training research. Memory training generally yields moderate effect sizes using performance on standard memory tests. The average standardized pre-post training gain for memory training, regardless of what strategies are trained, is 0.73 (Verhaeghen et al., 1992). The ACTIVE study reported a standardized effect size of 0.23 for the memory intervention comparing gain in the memory and control groups five years after training (Willis et al., 2006). Available evidence suggests, however, that measures of strategy use provide stronger training effect sizes (Hohaus, 2007; Rapp, Brenes, & Marsh, 2002; Troyer, Murphy, Anderson, Moscovitch, & Craik, 2007). Troyer and colleagues (2007) studied strategy use after a mnemonic memory training intervention in individuals with mild cognitive impairment. Self-reported strategy use and knowledge were collected using two questionnaires, the Memory Toolbox (Troyer, 2001) and the strategy subscale of the Multifactorial Metamemory Questionnaire (Troyer & Rich, 2002). Pre-training to post-training effect sizes for these measures were respectively four and five times that of another objectively measured word-list learning test outcome. This ratio increased three months after training. This contrast suggests that memory training affects cognitive operations in ways not captured by performance measures. Such mechanisms could lead to changes in more distal outcomes, such as everyday functioning, even if memory performance is unaffected.

Despite the promise of these findings, the long-term effects of memory training on strategy use are understudied. We are aware of no studies that have explicitly studied demographic predictors of memory strategies in a training context. The present study addresses this research gap. In addition toTroyer et al. (2007), we identified 11 other studies of memory training for older adults that reported data on strategic behaviors or strategic knowledge before and after memory training. Four studies (Bagwell & West, 2008; Scogin, Prohaska, & Weeks, 1998; West, Bagwell, & Dark-Freudeman, 2007; Woolverton, Scogin, Shackelford, Black, & Duke, 2001) used the Strategies of Memory Questionnaire (Camp, Markely, & Kramer, 1983). The mnemonics usage subscale of the Memory Functioning Questionnaire (Gilewski, Zelinski, & Schaie, 1990) and the Multifactorial Memory Questionnaire (Troyer

& Rich, 2002) were used in other studies to measure strategic behaviors. The average pre-post training effect size, which reflects the standardized difference in pre-post training change between trained and control groups is 1.86. This effect size indicates 97% of trained individuals in these studies show more improvement than most control participants on strategy use behaviors (Andrewes et al., 1994; Bagwell et al., 2008; Caprio-Prevette & Fry, 1996; Craik et al., 2007; Hohaus, 2007; Rapp, Brenes, & Marsh, 2002; Scogin et al., 1998; Troyer, Murphy, Anderson, Moscovitch, & Craik, 2007; West et al., 2007; Woolverton et al., 2001). By contrast, the analogous mean effect size of performance-based memory outcomes reported from these same studies is 0.34 (detailed results available upon request).

We are aware of only one intervention study that used clustering scores from word-list learning tasks to measure strategy use (Craik, Winocur, Palmer, Binns, Edwards, et al., 2007). From a 14-session training intervention with sessions on goal management, mnemonic strategies, and a psychosocial component,Craik et al. (2007) reported semantic clustering score improvements over time on the Hopkins Verbal Learning Test (HVLT; Brandt & Benedict, 2001). The effect size after one year was approximately three times that of the HVLT sum of recall score when compared to baseline scores in a within-subjects design. This is informative because it suggests strategy clustering scores captured some training effects undetected by the sum of words recalled. Such training effects may still impact distal outcomes such as everyday functioning through mechanisms or levels not captured by the memory performance measure.

One explanation for the higher training effect sizes for measures of strategies has to do with measuring an intervention’s scope. Because ACTIVE memory training taught internal mnemonic strategies, measuring strategies may more accurately characterize the full scope of the training because measures of memory performance may not capture changes in executive functioning, time management, and other training-related changes (Hertzog et al., 2008). It is informative to understand an intervention’s scope because interventions that affect broader cognitive abilities are more likely to affect life tasks and everyday activities than interventions that target particular abilities that do not transfer to other domains (Hertzog et al., 2008). If memory strategies are better measures of scope because they more completely characterize the intervention's impact, then strategies may be more strongly associated with everyday functioning than are conventional memory performance outcomes (Goldsmith & Koriat, 2008). The total number of words recalled on a verbal episodic memory task may not be a complete reflection of a memory training's scope because such scores reflect the amount and quality of information retained and accessible in memory. These scores assume that the primary goals of memory are to reproduce information with high levels of accuracy and completeness (Castel, 2008; Goldsmith & Koriat, 2008). Outside of laboratory situations, however, other goals exist that may conflict with demands for accuracy and completeness. For example, rarely in real-life settings is one asked to indiscriminately recall or recognize many unrelated pieces of information. Although performance scores represent an intervention's cognitive product, they are still not adequate correlates of everyday function because they do not capture the full range of cognitive ability that a process measure like strategy use encompasses. Remembering is not always a mindless, reflexive act because people use techniques or strategies to prioritize what gets reported (Moscovitch, 1992).

Overview of Major Research Goals

The present study has three goals. First, cross-sectional and longitudinal demographic correlates of strategy use measured using strategy clustering scores are described in a large sample of community-dwelling older adults on tests of verbal memory. Second, we report the long-term impact of memory training on strategy use. We expected training to result in increased strategy use, except in the case of HVLT serial clustering because the HVLT involves semantically related words and so HVLT serial clustering implies a lack of appreciation for contextual cues. Third, we report longitudinal associations between strategy clustering, memory performance, and everyday functioning, under the assumption that clustering scores are mediators of cognition that are related to memory and everyday functioning. We hypothesized that training gains in strategy use indicators explain longitudinal change in memory performance and everyday functioning, and that individual differences in memory training gains are explained by individual differences in training gains in strategy use. This long-term evaluation of strategy use takes advantage of five years of longitudinal data on a large population of community-dwelling older adults in the ACTIVE study.

Methods

Data Source

ACTIVE is a multi-site, controlled, randomized trial in which 2,802 community-dwelling adults age 65 and over were randomly assigned to receive one of three types of cognitive training interventions: reasoning, speed of information processing, or memory training. A no-contact control group constituted a fourth group. The present study uses baseline, immediate post-test, and annual follow-up evaluations at one, two, three, and five years for 1,401 participants randomized to either the memory training group (n = 703) or the no-contact control group (n = 698). Memory training involved teaching and practicing several mnemonic strategies through ten training sessions, each lasting 60 to 75 minutes, administered over the course of six weeks. The intervention targeted organization, association, visualization, and method of loci strategies.

Variables

Memory performance—All evaluations included the HVLT, Auditory Verbal Learning Test (AVLT), and the Rivermead Behavioral Memory Test (RBMT) to assess verbal memory (Brandt, 1991; Brandt & Benedict, 2001; Schmidt, 2004; Wilson, Cockburn, & Baddeley, 1985). Administration of the HVLT consisted of three trials during which the same list of 12 words, consisting of three semantic groups with four words each, was read aloud from an audio tape to participants in the same order during each trial. In a modification of the task's clinical administration, participants were asked to write down as many words as they could recall after each trial. The AVLT uses a 15-word list composed of unrelated words. For five trials, participants listened to the same word list read from an audiotape and asked to write down as many words as they could recall after each trial. An interference trial with a different 15-word list followed, and finally a short-delay recall trial was administered in which participants were asked to recall words from the original list. In the RBMT, participants were read a story and asked afterwards to recall details from it. Different parallel versions of each test, designed to be equivalent, were administered at each study wave.

The sum of recalled words from the HVLT (three trials) and AVLT (first five trials) as well as paragraph recall from the RBMT provided a summary measure of memory performance. Test-retest reliability for these tests is generally very good (HVLT test-retest reliability: 0.74; AVLT test-retest reliability: 0.84; RBMT test-retest reliability: 0.85; Brandt & Benedict, 2001; Schmidt, 2004; Wilson et al., 1985). Scores for each test were first standardized to their baseline mean and standard deviation using Blom transformation procedures and then averaged to create a composite memory measure for analysis (Blom, 1958). Because alternate but non-equivalent versions of these measures were administered across study time points, the composite memory measure was further adjusted using an equipercentile equating procedure to account for differences in test difficulty. This procedure ensures that scores over time have comparable means and standard deviations, facilitating valid within-person comparisons over time (Kolen & Brennan, 1995).

Strategy clustering scores—Three types of continuously distributed clustering indices, subjective, serial, and semantic, are reported here. Serial and subjective clustering scores are calculated for both the HVLT and AVLT. Stricker and colleagues (2002) provide a detailed explanation, history, and instructions for calculating each of these chance-adjusted, list-based clustering scores. All three can be calculated from the HVLT. Because the AVLT contains non-semantically related items, a semantic clustering score cannot be derived. Due to differences in test difficulty indicated by a comparison of quantile-quantile plots of clustering scores at each assessment time, clustering scores were equipercentile equated in a procedure similar to the memory composite score (Kolen & Brennan, 1995).

Everyday functioning—A composite functioning outcome was constructed using measures of cognitive and physical function including the Minimum Dataset - Home Care (MDS-HC), Observed Tasks of Daily Living (OTDL), Everyday Problems Test (EPT), and the Timed Instrumental Activities of Daily Living (TIADL) test. The MDS-HC asks about self-reported performance in the past 7 days on a variety of physical instrumental activities of daily living (IADL) functions (Teresi, Lawton, Holmes, & Ory, 1997). The OTDL is a performance-based test of everyday functioning that involves assorted tasks including medication management, telephone use, and checkbook balancing (Diehl, Marsiske, Horgas, Rosenberg, Saczynski, et al., 2005). The EPT uses reading comprehension tasks to assess cognitive IADLs through 15 sets of intellectual tasks using everyday printed materials that older adults encounter in daily life, such as reading medication labels and telephone bills (Willis & Marsiske, 1993). The TIADL task measures the time required to complete a series of IADL tasks (Owsley, Sloane, McGwin, & Ball, 2002).

A composite index of functioning was created from these tests to reduce the type 1 error rate from multiple tests and make inferences about the construct of everyday functioning rather than about particular tests. A principal components analysis of baseline scores revealed that one factor explains 53% of the total variance from the EPT, OTDL, MDS-HC, and TIADL. Results from a confirmatory factor analysis were consistent with the hypothesis that these tasks represent a unidimensional construct of everyday functioning (CFI: 0.97; RMSEA: 0.047; SRMR: 0.03). Scores for each test were standardized to their baseline mean and standard deviation using Blom transformation procedures, and then averaged to create a composite measure of everyday functioning (Blom, 1958).

Other Variables—Other covariates accounted for in models were participant age, coded continuously in years; years of education, coded continuously; self-rated health status; sex, coded dichotomously; and ethnicity coded dichotomously into white and nonwhite. These demographic variables were selected a priori. Age and education were centered at their sample means. Self-rated health status was measured on a scale of 1-5 but dichotomized into 1 (*Excellent, Very Good*) and 0 (*Good, Fair, Poor*). Those who rated their health as “good” were included with the latter group because they were more similar to those who rated their health as *Fair* or *Poor* in terms of composite functioning and strategy clustering scores.

Analysis Plan

Descriptive analyses were carried out to characterize the study population. The test-retest reliability of each clustering score was quantified using intraclass correlation coefficients (ICC; Shrout & Fleiss, 1979). Parallel process latent growth curve models were then used to explore changes in strategy clustering over time and estimate associations between strategy use, demographic characteristics, and trajectories of memory performance and everyday functioning (McArdle & Bell, 2000; Muthén, 1997; Muthén & Curran, 1997; Stull, 2008). Latent factors, formed by random intercepts (e.g., initial or baseline status) and random slopes (e.g., trajectories or longitudinal changes), represent person-specific growth processes for observed continuous variables measured repeatedly over time. A parallel process latent growth curve model is called such because several growth processes (a strategy clustering score, objective memory, an everyday functioning) are included in the latent growth measurement model.

One parallel process latent growth curve model was estimated for each of the five strategy clustering scores among control and memory-trained participants in a two-group structural equation modeling (SEM) approach. Models also included growth trajectories for memory performance and everyday functioning. The general model setup is shown graphically in Figure 1 and strategy-relevant portions are provided notationally here:

$$\text{Level 1 (time):} T_{ijm}=\eta_{0mi}+\eta_{1mi}\text{time}_j+\eta_{2mi}\text{time}_j \cdot I(j \le 2)+\varepsilon_{im}$$

$$\text{Level 2 (individual):} \quad \eta_{0mi}=\beta_{0m}+\Sigma^5{}_{p=1}\Sigma^5{}_{m=1}\beta_{0mp}X_{ip}+\zeta_{0im}$$
$$\eta_{1mi}=\beta_{1m}+\Sigma^5{}_{p=1}\Sigma^5{}_{m=1}\beta_{1mp}X_{ip}+\zeta_{1im}$$

In these equations, T represents the individual-level outcome for strategy clustering score m (HVLT semantic clustering, HVLT subjective clustering, HVLT serial clustering, AVLT subjective clustering, and AVLT serial clustering) for the i'th individual at the j'th time. Growth parameters η for each strategy clustering score outcome include vectors for an initial status (η_0) factor and a linear slope (η_1) (Muthén & Curran, 1997). To accommodate nonlinear growth in strategy use in the memory-trained group (Figure 2), a latent piecewise growth model was fit by fixing factor loadings for a second slope (η_2) to 0 at baseline and 1 for subsequent assessment waves. This parameter captures the pre-post training effect on a strategy clustering score between baseline and immediate post-test. Level 1 (ε) and level 2 (ζ) residual errors are represented for the growth processes, and were constrained to be equal across time points within each growth process. Demographic covariates p were regressed on growth parameters for the intercepts and trajectories for strategy clustering scores, parameters for which are represented by β.

Two-group parallel process latent growth curve models allowed us to characterize demographic characteristics associated with initial statuses and changes in strategy clustering in each intervention group (Aim 1). To quantify the amount of between-subjects variance in initial status of each strategy clustering measure explained by adding demographic covariates, a coefficient of determination (R^2) was calculated by taking the ratio of explained variance to the total variance in the control group (Cnaan, Laird, & Slasor, 1997; Lane & Zelinski, 2003).

To test for differences by training status in initial levels and changes in strategy clustering scores (Aim 2), means, variances, and covariances among latent growth factors for strategy clustering scores were allowed to vary between the intervention groups in each model. Growth parameter means were constrained to be equal in a series of more restrictive steps. Nested models were compared with the Satorra-Bentler scaled χ^2 difference test because models were estimated with a robust maximum likelihood estimator (Satorra, 2000; Satorra & Bentler, 1994). To test whether training-related baseline levels or changes in strategy clustering scores differ across demographic characteristics (Aim 2), Wald tests were constructed for the differences between regression coefficients (β) in the memory-trained and control groups in the two-group parallel process latent growth curve models described in equations above and Figure 1. A significant difference by training status in the relationship between the growth parameter and a demographic characteristic suggests effect modification by training status.

To further study effects of memory training on *levels* of strategy clustering scores at each assessment wave (Aim 2), standardized training effect sizes were calculated by regressing strategy clustering scores on indicators for training status, time, interactions between training status and time, and demographic covariates using generalized estimating equation (GEE) methods that specified an exchangeable correlation matrix and an identity link (Liang & Zeger, 1986). Training by time interactions are covariate-adjusted effect sizes for standardized differences between memory-trained and control groups at each assessment wave.

To test the third hypothesis that training-related improvements in memory strategies mediate training-related changes in memory performance and everyday functioning, parallel process latent growth models included growth processes for objective memory and everyday functioning composites. Because models were estimated in a two-group SEM framework in which groups (training status) were the predictors in mediation paths, longitudinal mediation was assessed by taking the difference in trajectory slopes representing pre-post training gains (η_2) of strategy clustering mediating growth processes between the memory and control groups (A paths). A mean difference in slopes between intervention groups in a two-group SEM is the same as a regression coefficient of a slope on an indicator for training status in a single-group SEM. Trajectories for the memory and functioning growth processes were simultaneously regressed on the pre-post training slope for each strategy mediator (B paths). Differences between memory and control groups in mean trajectories for memory and functioning were calculated in a manner similar to the A paths (C paths). The mediated effect was assessed for each strategy clustering mediator using the product test, which takes the product of coefficients for paths A and B that compose the indirect effect for each mediator (MacKinnon et al., 2002; MacKinnon et al., 2008).

Analyses were conducted using the MPLUS (version 5.21) software package (Muthén & Muthén, 1998–2008). Parameter estimates adjust for missing data using a robust full information maximum likelihood (FIML) estimator, which assumes data are missing at random conditioning on variables in models (Donders, van der Heijden, Stijnen, & Moons, 2006; Little & Rubin, 1987). Overall model goodness of fit was assessed with standard model fit indices. The root mean square error of approximation (RMSEA; Steiger, 1989), comparative fit index (CFI; Hu & Bender, 1999), and the standardized root mean square residual (SRMR; Browne & Cudeck, 1993) are reported. An RMSEA around or below 0.05, CFI greater than 0.90, and SRMR smaller than 0.08 are indicators of excellent model fit (Hu & Bender, 1999). In addition to standard model fit indices, residual diagnostic procedures set forth in Wang, Brown, and Bandeen-Roche (2005) were used to assess whether the presented parallel process models adequately reflect observed trajectories and to explore model misspecification.

Results and Discussion

ACTIVE memory training and control groups were similar at baseline in terms of age, sex, ethnicity, self-rated health, education, Mini-Mental State Exam (MMSE) score (Folstein, Folstein, & McHugh, 1975), everyday functioning, and baseline strategy clustering measures (Table 1). ICC’s reveal each clustering score was fairly reliable across five years except for HVLT serial clustering. All clustering scores were associated with higher recall sum scores, which would be expected if they are measures of strategy and strategies help one accomplish goals. The proportion of data missing over time was not significantly associated with any cognitive variables, training status, or demographic characteristics except for older age.

Initial and Longitudinal Correlates of Strategy Use: Results and Discussion

Parallel process latent growth curve models shown in Figure 1 were estimated. Absolute model fits were excellent (Table 2). Residual diagnostics revealed that trajectories of expected and observed trajectories corresponded closely with each other, and time trend plots of residuals revealed no gross departures from acceptable fit. Residual variances of each indicator were constrained to be equal for each growth process, and were significantly different from zero (Table 2).

Coefficients estimates in Table 2 represent differences in a strategy clustering growth parameter for a unit difference in the demographic characteristic in the control group, after accounting for repeated measures over time and other covariates. Initially, younger, female, white, healthier, and more educated participants were significantly more likely to use more semantic and subjective clustering on the HVLT and more serial and subjective clustering on the AVLT. Only sex, ethnicity, and education were associated with initial levels of HVLT serial clustering (Table 2). Coefficients of determination revealed that demographic characteristics together explained between 32% and 34% of the between-subjects variance in each HVLT and AVLT clustering score intercept, with the exception of HVLT serial clustering, for which only 5% of the variation was explained by these variables. With respect to predictors of longitudinal change in strategy clustering over time, no demographic variables were associated with different trajectories across all strategy clustering measures together (Table 2). Younger participants used more HVLT subjective, AVLT subjective, and AVLT serial clustering over time but did not exhibit different trajectories for other clustering scores. Demographic predictors of the pre-post training slopes and the post-training to fifth year slopes were similar in strength.

These descriptive results of predictors of strategies are informative. Although certain groups defined by demographic characteristics, namely the older, male, non-white, unhealthier, and less educated, show less strategy use at baseline, no characteristics are at risk for accelerated declines in strategy use. Demographic predictors of initial status, therefore, might be used to target cognitive interventions in high-risk populations. The lack of significant relationships between changes in the use of strategies over time and demographic characteristics, however, suggests one's potential for using strategies is not limited by age, sex, ethnicity, self-rated health status, or education.

Memory Training and Strategy Use: Results and Discussion

Mean trajectories of strategy clustering scores by training group are shown in Figure 2. Standardized effect sizes, adjusted for demographic covariates, were calculated at each follow-up evaluation for each outcome (Table 3). With the exception of HVLT serial clustering, significant and large time-specific effect sizes speak to the magnitude and sustainability of the ACTIVE memory training intervention's effect on strategy use. For comparison, effect sizes for the HVLT sum of recall score ranged over time from 0.20 at the immediate post-test evaluation to 0.16 five years after training. For the AVLT, effect sizes for the sum score were between 0.10 and 0.13 at the immediate post-test and fifth year visits, respectively.

The parallel process latent growth models, results from which are provided in Table 2, in which latent growth parameter means were allowed to vary across intervention group were compared with a series of constrained models. Satorra-Bentler scaled χ^2 difference tests revealed significantly worse relative model fits for all strategy clustering score models in which mean pre-post training trajectories were constrained to be equal across groups (HVLT semantic: Satorra-Bentler scaled $\chi^2_{df=1}$=157.4, p<0.001; HVLT subjective: Satorra-Bentler scaled $\chi^2_{df=1}$=13.8, p<0.001; HVLT serial: Satorra-Bentler scaled $\chi^2_{df=1}$=4.6, p=0.03; AVLT subjective: Satorra-Bentler scaled $\chi^2_{df=1}$=24.4, p<0.001; AVLT serial: Satorra-Bentler scaled $\chi^2_{df=1}$=21.8, p<0.001). In contrast, neither baseline levels (all p>0.36) nor average growth trajectories between immediate post-test and the fifth annual waves (all p>0.46) differed by training status in any strategy clustering score model. With respect to whether any demographic groups benefited more than others from training, participants with higher education and lower self-rated health in the memory training group performed better on HVLT serial clustering over time after training but there was no other evidence of effect modification (results not shown).

Analyses of strategy clustering scores reveal immediate boosts following memory training in levels of semantic and subjective strategies used on the HVLT and in levels of serial clustering strategies on the AVLT. This improvement is maintained through five years of follow-up. The general lack of significant interaction terms between training status and demographic characteristics speaks to the generalizability of the ACTIVE memory training intervention across populations of older adults who differ by these demographic characteristics. Age did not significantly modify the longitudinal association between training and any measure of strategy use, suggesting the training intervention's benefit was not limited to any age range in this study despite modest age-related declines over time in the use of strategies (Table 2). Although this finding appears to conflict with findings byVerhaeghen et al. (1992) that older age is associated with lower training gains, our sample represents a more restrictive age range of older adults than samples from that meta-analysis and our cognitive measures are strategic processes.

Strategy Use, Memory, and Everyday Functioning: Results and Discussion

Table 4 shows estimates from the mediation portions of the parallel process latent growth mediation models. Memory training is associated with pre-post improvements in all strategy clustering scores except HVLT serial clustering (Table 4, A paths). Higher trajectories of memory performance and everyday functioning are associated with higher trajectories for all clustering scores except for HVLT semantic clustering (Table 4, B paths). Associations with the memory composite are consistently larger than with everyday functioning. Direct associations between intervention status and trajectories of memory (C paths) are significant except for everyday functioning in the HVLT serial clustering model. Growth in all strategy clustering scores except HVLT serial clustering mediates training-related changes in memory and everyday functioning (Table 4, mediated paths).

Results suggest that changes in strategy clustering are strongly associated with improved memory performance over time and, to a lesser degree, everyday functioning. Changes in memory strategy use mediate training-related improvement in memory and functioning except in the case of HVLT serial clustering. In arguing for the need for more longitudinal data in intervention research, Salthouse (2006) speculated that cognitive training might initially boost performance to unsustainable levels over time that would then result in steeper declines in cognitive variables generally, and that this is not evidence for lasting training benefits. With the exception of HVLT semantic clustering, we did not find evidence for such a steeper decline with respect to strategy clustering scores. Our results are consistent with inferences from Figure 2 that although training effect sizes were all relatively high for clustering scores (Table 3), these gains were maintained after five years.

The ultimate goal of any cognitive training program for older adults is to enhance cognition such that lasting improvements are seen for everyday functioning. That changes in strategy use are associated with changes in everyday functioning is remarkable because research suggests cognition accounts for a limited portion of everyday functioning. Performance-based memory measures predict approximately 1.9% of the variability in levels of everyday functioning (Royall et al., 2007), although the HVLT trial recall sum score explains nearly half the variability in more complex IADL tasks such as everyday problem-solving (Gross et al., in press; McCue, Rogers, & Goldstein, 1990). The present findings must be replicated, but are consistent with the hypothesis that memory strategy use assists with cognitive components of everyday functioning.

General Discussion

This study reported cross-sectional and longitudinal associations between demographic characteristics and strategy use among older adults, explored long-term impacts of memory training on strategy use, and investigated longitudinal associations between memory strategy clustering scores, memory performance, and everyday functioning. We found that younger, female, white, healthier, and more educated participants are more likely to select more effective types of strategies appropriate to the HVLT and AVLT, but that few demographic characteristics are associated with changes in the use of strategies over time. These findings have implications for intervention targeting efforts. Further, training gains in memory strategies mediate training-related changes in memory performance and the even further downstream construct of everyday functioning.

Memory training improves levels of strategy use, and appears to have benefitted most demographic groups equally. Standardized effect sizes for training were as high as 0.73 for HVLT semantic clustering at immediate post-test, which is over three times that for HVLT word-list recall performance. This is consistent with our review of prior training studies that report larger effect sizes for strategic behaviors than objective memory measures (Bagwell & West, 2008; Becker et al., 2008; Craik et al., 2007; Hohaus, 2007; McDougall et al., 2009; Rapp et al., 2002; Scogin et al., 1998; Troyer et al., 2007; West et al., 2007; Woolverton et al., 2001). The memory training's enduring effects lay in an upward boost in strategy use that was maintained over time but not an increased or shallower decline in strategy use.

Increases in strategy clustering measures are associated with improved trajectories for memory performance and everyday functioning. This finding is informative because it suggests trajectories of memory performance and even more distal everyday functioning are malleable to changes in strategy use. How older adults *approach* tasks and not just their task performance impacts their everyday functioning in the community. It should be stressed that these associations are not definitive evidence of causal associations because individuals were not randomized to different levels of strategy use and the detected associations could be correlational in nature. This merits further study.

Three important observations should be kept in mind when interpreting results from post-hoc measures of strategy use. First, a clustering score is a clue that reflects a type of encoding strategy; it is not a specific strategy like categorization or the method of loci. Strategy clustering should be thought of as indicators of related underlying cognitive mechanisms; from them one cannot know with certainty what specific strategies an individual used. High levels of subjective clustering, for instance, might mean that one either alphabetized items, generated logical or nonsense sentences, created stories or sentences out of words, or made a mental picture to somehow associate the words to facilitate recall. For example, “sword” and “spatula” are two words from the HVLT Form 2 used in ACTIVE at the immediate post-test and fifth annual visits. Recalling these words together across trials of a test will increase one's subjective clustering score, but this does not reveal whether a participant organized words alphabetically or mentally grouped objects with sharp edges. This limitation is also a strength, as previous research on strategies suggests that multiple strategy use on tasks is a rule more than an exception (Arnaud et al., 2008; Duverne & Lemaire, 2005; Fiske, 1993; Saczynski et al., 2004; Siegler, 1987). Because of multiple strategy use, it is more meaningful to study families of strategies than individual strategies. A second major limitation of using post-hoc strategy clustering scores to make inferences about strategy use is that the order in which an individual writes down words may not be the order in which he or she encoded them. One must assume that the order of recall measured after retrieval reflects encoding processes. This is a reasonable assumption because modern theories of memory and learning posit that strategies like categorization and the method of loci take place during encoding and not at retrieval (Butters & Cermak, 1980; Squire, 1987).

A third limitation that arises from using any strategy measure from laboratory exercises such as word list-learning tasks, concerns generalizability. Although conventional cognitive tests are controlled environments in which accuracy, completeness, and speed are the only reasonable goals (therefore making it easier to quantify memory ability), goals are not as straightforward in real life when one has more control over them because decisions in naturalistic settings are embedded into contexts (Castel, 2008; Goldsmith & Koriat, 2008). In everyday life, goals may depend on more than quantity or accuracy. The shortest route from home to work may not be scenic, or convenient grocery stores may not lie along the route. In terms of memory, it is more advantageous at times to forget certain faces and names, or to shop for groceries without a list. Unfortunately, goal identification is what makes decision-making and strategy use in real life complicated and nearly impossible to simulate in controlled environments. Strategy measurement using clustering scores can still offer insights, however, into strategies that older adults use, since even many complex behaviors can be explained by simpler strategies (Greeno, 1976; Simon, 1979).

Several questions arise from this study that may inform future research directions. First, our findings should be replicated in other samples and populations. We are aware of no studies of memory training among older adults that have explicitly studied demographic predictors of memory strategies. Second, effects of other types of cognitive training other than memory, such as processing speed and reasoning, on strategy clustering scores should be assessed to study potential transfer effects. Strategies should also be studied in training programs that feature multi-factorial approaches to increase the scope of training targets by integrating memory training with pharmacotherapy, physical exercise, or even social components (Fabre, Chamari, Mucci, Masse-Biron, & Prefaut, 2002; Hertzog et al., 2008; Rebok et al., 2007; Small et al., 2006). Finally, relations between strategy measures and other clinically relevant distal outcomes, such as mental health outcomes, could provide useful diagnostic tools that may make important contributions to public health.

In conclusion, the present study explored strategies older adults use to approach cognitive tasks. Results are consistent with the notion that strategic mechanisms are more relevant to real-world phenomena than are conventional memory performance outcomes (Goldsmith & Koriat, 2008). This study provides new evidence that memory training can equip older adults with strategies, and that such strategies are used in appropriate situations based on characteristics of information to be remembered. The training effects are durable as far out as five years, and strategies are positively associated with memory performance and everyday functioning.

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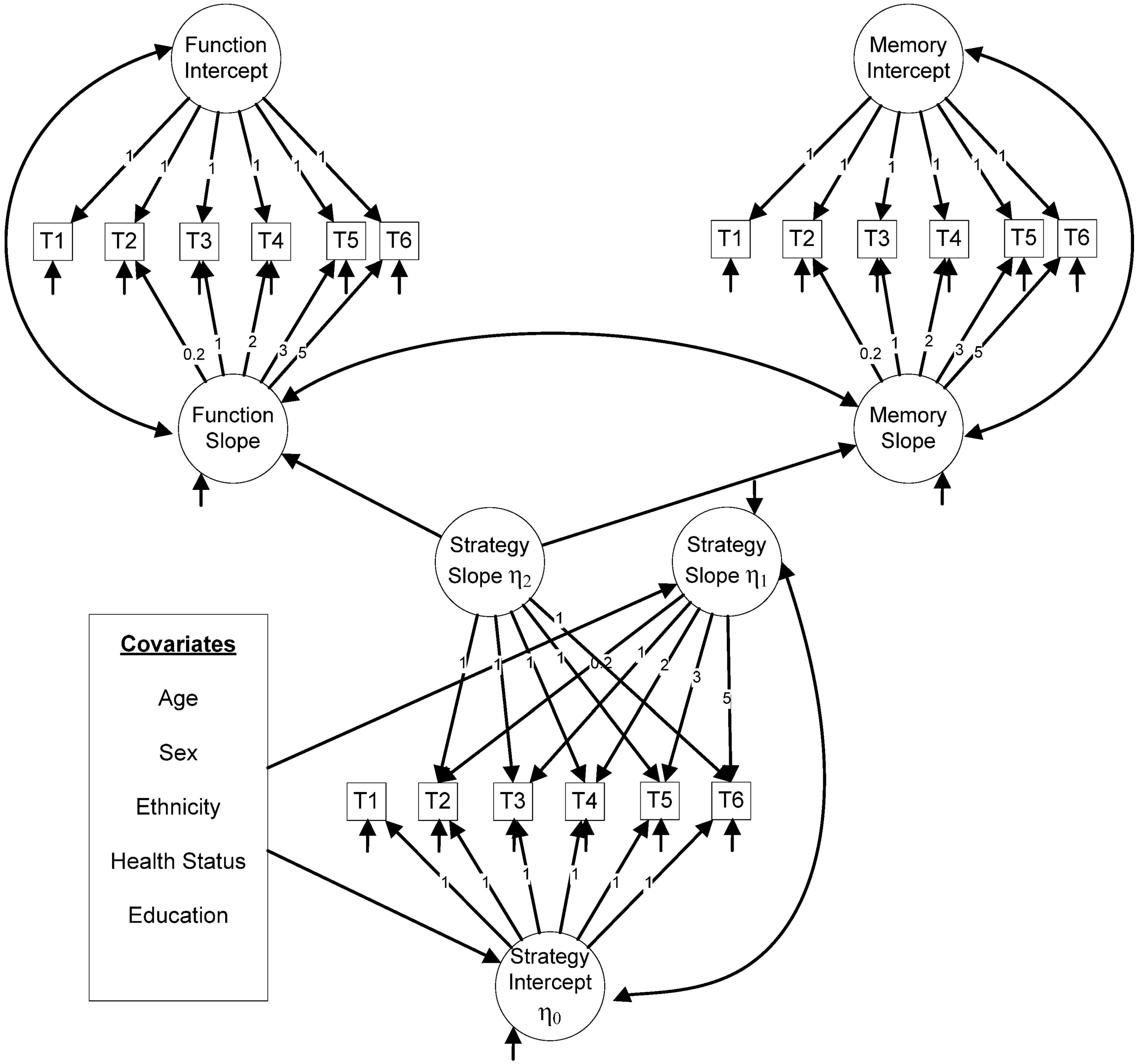

Figure 1. Parallel Process Latent Growth Curve Model of Strategy Clustering Scores

Group-specific parallel process latent growth model of strategy clustering growth processes (HVLT semantic, subjective, and serial clustering; AVLT subjective and serial clustering) across six measurement occasions in the ACTIVE study. The model is described notationally in equations in the Methods section. Latent variable intercepts and slopes for each strategy clustering score were regressed on covariates, which included age, sex, ethnicity, self-rated health, and education. Residual error variances are shown by smaller arrows going towards the observed (boxed) and latent (circled) dependent variables. Numbers on arrows going from latent growth parameters to observed time points indicate factor loadings. T: Assessment wave (1=Baseline; 2=Immediate Post-test; 3=Year1; 4=Year2; 5=Year3; 6=year5).

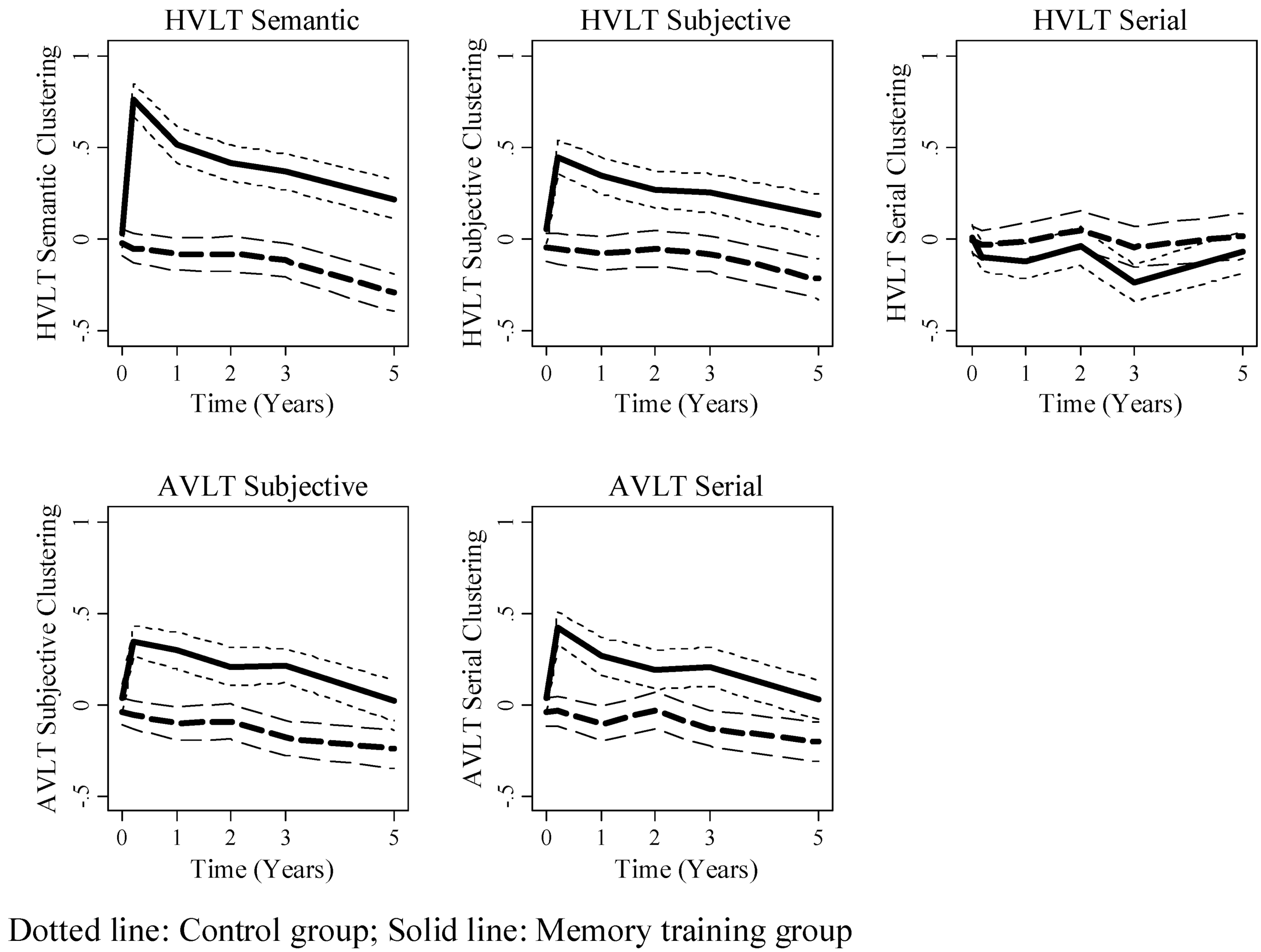

Figure 2. Mean Trajectories of Strategy Clustering Scores: Results from ACTIVE (N=1,401)
Mean trajectories of strategy clustering scores for the ACTIVE memory training and control groups are shown by solid lines and dotted lines, respectively. 95% confidence bands are shown for each group.

Table 1

Baseline Participant Characteristics and Test Scores: Results from ACTIVE

	ACTIVE Cohort			
	Memory Group (N=703)	**Control Group (N=698)**	**Range**	**p for Difference**
Age, *mean (SD)*	73.53 (6.02)	74.05 (6.05)	65, 94	0.11
Years of Education, *mean (SD)*	13.59 (2.73)	13.37 (2.70)	4, 20	0.14
Health status, *n (%)*				0.91
Excellent	57 (8.24%)	64 (9.29%)		
Very Good	247 (35.69%)	232 (33.67%)		
Good	283 (40.9%)	287 (41.65%)		
Fair	98 (14.16%)	100 (14.51%)		
Poor	7 (1.01%)	6 (0.87%)		
Sex, *n (% female)*	537 (76%)	514 (74%)		0.23
Ethnicity, *n (% white)*	521 (74%)	500 (72%)		0.30
MMSE score, *mean (SD)*	27.29 (2.05)	27.27 (2.00)	23, 30	0.87
HVLT, *mean (SD)*				
Sum of Trials 1–3	26.28 (5.57)	25.91 (5.57)	4, 36	0.22
Semantic clustering score (ICC = 0.53)	2.25 (1.78)	2.15 (1.70)	−1.24, 7	0.31
Subjective clustering score (ICC = 0.31)	0.96 (1.22)	0.83 (1.18)	−1.4, 8.66	0.06
Serial clustering score (ICC = 0.074)	0.62 (0.80)	0.61 (0.77)	−0.86, 6.75	0.79
AVLT, *mean (SD)*				
Sum of Trials 1–5	48.74 (10.72)	48.06 (10.84)	7, 73	0.24
Subjective clustering score (ICC = 0.42)	0.73 (0.93)	0.66 (0.91)	−0.72, 6.99	0.19
Serial clustering score (ICC = 0.41)	1.60 (1.24)	1.52 (1.28)	−0.62, 10.6	0.25
Composite functional ability, *mean (SD)*	100.24 (15.19)	99.31 (14.86)	43.42, 132.15	0.25
MDS-HC Raw Score	4.46 (5.08)	4.23 (4.62)	0, 26	0.38
OTDL Raw Score	17.70 (4.68)	17.38 (4.43)	1, 28	0.19
EPT Raw Score	18.84 (5.79)	18.25 (5.79)	0, 28	0.06
TIADL Raw Score	0.002 (0.61)	0.026 (0.63)	−0.86, 5.03	0.46

Legend: ICC: Intraclass Correlation Coefficient; MDS-HC: Minimum Dataset - Home Care; OTDL: Observed Tasks of Daily Living; EPT: Everyday Problems Test; TIADL: Timed Instrumental Activities of Daily Living

Table 2

Initial and Longitudinal Correlates of Strategy Clustering: Results from the ACTIVE Control Group (N=698)

	HVLT Clustering Scores						AVLT Clustering Scores			
	Semantic		Subjective		Serial		Subjective		Serial	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Initial Status Predictors										
Age	−0.34 *	(−0.45, −0.24)	−0.19 *	(−0.31, −0.08)	−0.02	(−0.15, 0.11)	−0.36 *	(−0.47, −0.25)	−0.30 *	(−0.42, −0.19)
Sex (1=Female)	0.41 *	(0.26, 0.56)	0.24 *	(0.08, 0.39)	0.08	(−0.08, 0.25)	0.39 *	(0.24, 0.54)	0.36 *	(0.20, 0.51)
Ethnicity (1=White)	0.43 *	(0.28, 0.58)	0.32 *	(0.16, 0.47)	−0.05	(−0.21, 0.12)	0.36 *	(0.22, 0.51)	0.38 *	(0.23, 0.54)
Self-rated Health Status	0.14 *	(0.00, 0.29)	0.08	(−0.07, 0.23)	−0.11	(−0.26, 0.05)	0.19 *	(0.04, 0.33)	0.20 *	(0.04, 0.35)
Education	0.09 *	(0.06, 0.11)	0.08 *	(0.05, 0.10)	0.02	(−0.01, 0.04)	0.06 *	(0.04, 0.09)	0.08 *	(0.05, 0.10)
Adjusted R^2	0.33		0.32		0.05		0.34		0.33	
Trajectory Predictors										
Age	−0.02	(−0.05, 0.01)	−0.06 *	(−0.10, −0.02)	−0.03	(−0.07, 0.02)	−0.04 *	(−0.07, 0.00)	−0.05 *	(−0.08, −0.01)
Sex (1=Female)	0.00	(−0.04, 0.05)	0.00	(−0.05, 0.06)	−0.08 *	(−0.14, −0.02)	0.01	(−0.04, 0.05)	0.01	(−0.04, 0.06)
Ethnicity (1=White)	0.00	(−0.05, 0.04)	0.04	(−0.02, 0.09)	−0.07 *	(−0.13, −0.02)	−0.02	(−0.07, 0.02)	0.02	(−0.03, 0.06)
Self-rated Health Status	0.00	(−0.04, 0.04)	0.00	(−0.05, 0.05)	0.03	(−0.03, 0.08)	0.04	(−0.01, 0.08)	0.02	(−0.03, 0.06)
Education	0.00	(0.00, 0.01)	0.00	(−0.01, 0.01)	−0.01	(−0.02, 0.00)	0.00	(−0.01, 0.01)	0.00	(−0.01, 0.00)
Residual variances										
Intercept	0.36 *	(0.30, 0.42)	0.2 *	(0.14, 0.25)	0.11 *	(0.07, 0.14)	0.30 *	(0.24, 0.35)	0.31 *	(0.24, 0.37)
Pre-post slope	0.10 *	(0.05, 0.14)	0.10 *	(0.05, 0.15)	0.05 *	(0.01, 0.09)	0.05 *	(0.02, 0.08)	0.04 *	(0.01, 0.08)
Post-fifth year slope	@0		@0		@0		@0		@0	
Observed indicators	0.53 *	(0.51, 0.56)	0.80 *	(0.76, 0.83)	1.07 *	(1.04, 1.11)	0.66 *	(0.63, 0.69)	0.71 *	(0.68, 0.74)
Model fit statistics										
CFI	0.917		0.922		0.914		0.933		0.927	
RMSEA (90% CI)	0.063	(0.060, 0.066)	0.058	(0.054, 0.061)	0.057	(0.053, 0.060)	0.055	(0.051, 0.058)	0.056	(0.053, 0.060)
SRMR	0.062		0.058		0.081		0.063		0.07	

* $p < 0.05$

Legend. Results from two-group latent growth curve models of standardized strategy clustering scores with piecewise linear growth in the ACTIVE control group. Linear regressions of intercepts (initial status) and linear slopes (trajectories) on demographic characteristics are displayed. Coefficients of determination (R^2) are shown for initial levels of strategy clustering scores. Residual variances of indicators for each wave were constrained to be equal across time. 95% CI: 95% Confidence interval.

Table 3

Memory Training Effect Sizes of Strategy Clustering Scores: Results from ACTIVE (N=1,401)

	HVLT Clustering Scores						AVLT Clustering Scores			
	Semantic		Subjective		Serial		Subjective		Serial	
	Estimate	**95% CI**	**Estimate**	**95% CI**	**Estimate**	**95%CI**	**Estimate**	**95% CI**	**Estimate**	**95% CI**
Effect Sizes of Training on Strategy Clustering Scores at Each Time										
Baseline to Immed. PT	0.73	(0.66, 0.88)	0.39	(0.30, 0.52)	−0.08	(−0.19, 0.02)	0.33	(0.24, 0.45)	0.36	(0.27, 0.49)
Baseline to Yr1	0.53	(0.44, 0.67)	0.32	(0.22, 0.45)	−0.12	(−0.23, −0.01)	0.30	(0.20, 0.43)	0.29	(0.20, 0.42)
Baseline to Yr2	0.45	(0.35, 0.60)	0.23	(0.12, 0.37)	−0.09	(−0.21, 0.03)	0.24	(0.13, 0.38)	0.17	(0.06, 0.30)
Baseline to Yr3	0.42	(0.32, 0.57)	0.24	(0.12, 0.37)	−0.20	(−0.34, −0.09)	0.31	(0.20, 0.45)	0.24	(0.13, 0.38)
Baseline to Yr5	0.42	(0.30, 0.57)	0.23	(0.11, 0.37)	−0.10	(−0.24, 0.03)	0.17	(0.05, 0.31)	0.13	(0.00, 0.27)

Legend. Interactions between treatment and time from GEE models are effect sizes for the standardized difference in strategy clustering score outcome gain between memory-trained and control groups. These models are adjusted for age, sex, ethnicity, self-rated health status, and education. 95% CI: 95% Confidence interval.

Table 4

Associations Between Strategy Clustering, Memory, and Everyday Functional Ability by Intervention Group: Results from ACTIVE (N=1,401)

Clustering score mediator	Outcome	Regressions of strategy clustering trajectories on training (Path A)		Regressions of outcome trajectories on strategy clustering trajectories (Path B)		Regressions of outcome trajectories on training (Path C)		Mediated path (A*B)	
		β	95% CI	β	95% CI	β	95% CI	Product	95% CI
HVLT Semantic	Functioning	0.61 *	(0.51, 0.71)	0.36 *	(0.11, 0.61)	−0.21	(−0.40, −0.02)	0.22 *	(0.06, 0.38)
	Memory			0.41 *	(0.19, 0.62)	−0.25	(−0.45, −0.05)	0.25 *	(0.11, 0.39)
HVLT Subjective	Functioning	0.31 *	(0.19, 0.43)	0.41 *	(0.09, 0.73)	0.00	(−0.17, 0.17)	0.13 *	(0.02, 0.24)
	Memory			0.49 *	(0.19, 0.79)	−0.02	(−0.25, 0.20)	0.15 *	(0.04, 0.26)
HVLT Serial	Functioning	−0.13	(−0.27, 0.01)	2.11	(−0.08, 4.30)	−0.31	(−1.14, 0.52)	−0.28	(−0.69, 0.12)
	Memory			2.29 *	(0.20, 4.37)	−0.37	(−1.27, 0.53)	−0.31	(−0.72, 0.11)
AVLT Subjective	Functioning	0.27 *	(0.17, 0.38)	0.77 *	(0.26, 1.29)	0.03	(−0.21, 0.27)	0.21 *	(0.05, 0.37)
	Memory			0.82 *	(0.42, 1.22)	0.01	(−0.26, 0.28)	0.22 *	(0.08, 0.36)
AVLT Serial	Functioning	0.27 *	(0.16, 0.38)	0.74 *	(0.11, 1.36)	−0.14	(−0.39, 0.11)	0.20 *	(0.01, 0.39)
	Memory			0.82 *	(0.25, 1.38)	−0.19	(−0.47, 0.10)	0.22 *	(0.04, 0.40)

Legend. Results from two-group parallel process latent growth curve models of standardized clustering scores with piecewise linear growth and composite memory growth processes. Models are adjusted for age, sex, ethnicity, self-rated health status, and education. 95% CI: 95% Confidence interval.