Psychology and Aging
2018, Vol. 33, No. 1, 93–108

© 2018 American Psychological Association
0882-7974/18/$12.00 http://dx.doi.org/10.1037/pag0000214

# Repetition Lag Training Eliminates Age-Related Recollection Deficits (and Gains Are Maintained After Three Months) but Does Not Transfer: Implications for the Fractionation of Recollection

Nicole D. Anderson
Baycrest Health Sciences, Toronto, Ontario, Canada, and University of Toronto

Patricia L. Ebert
Baycrest Health Sciences, Toronto, Ontario, Canada

Cheryl L. Grady
Baycrest Health Sciences, Toronto, Ontario, Canada, and University of Toronto

Janine M. Jennings
Wake Forest University

The objectives of this study were to replicate age-related decrements in recollection and source memory, and to determine if repetition lag training improves recollection and whether these effects maintain and transfer to other tasks. Sixteen young adults and 46 healthy older adults participated, the latter of whom comprised hi-old ($n$ = 16) and lo-old ($n$ = 30) based on neuropsychological memory tests. All participants completed memory tests and questionnaires at baseline, and then half of the lo-old underwent nine days of repetition lag training while the other half engaged in a 9-day active control program. The memory tests and questionnaires were repeated immediately after the training or control program, and again three months later. The baseline data replicated well-established age-related decrements in recollection. Repetition lag training improved objective measures of recollection, eliminated the age-related recollection decrement, and these improvements maintained over three months. However, training did not transfer to any other objective test of memory thought to rely on recollection, or to any subjective memory measure. The results demonstrate for the first time that repetition lag training improves objective measures of recollection, eliminates recollection differences between younger and older adults, and that these gains maintain over a 3-month period posttraining. The lack of transfer to other tasks, however, indicates that training one type of recollection (for the studied modality in this case) does not affect other types of recollection (e.g., of an item's recency). We suggest that recollection can be fractionated into many distinct types.

*Keywords:* aging, memory, recollection, training, transfer

*Supplemental materials:* http://dx.doi.org/10.1037/pag0000214.supp

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

Did your friend tell you about the new play or did you read it in the newspaper? Remembering the correct answer this question requires one to associate an item with its source, and age-related impairments in source and associative memory are well-documented (e.g., Cansino et al., 2013; Chen & Naveh-Benjamin, 2012; see Old & Naveh-Benjamin, 2008, and Mitchell & Johnson, 2009, for reviews). It has been established for some time that age-related deficits in source memory are reliably greater than they are for item memory (Spencer & Raz, 1995). One reason for these impairments may be age-related

Nicole D. Anderson, Rotman Research Institute, Baycrest Health Sciences, Toronto, Ontario, Canada, and Departments of Psychiatry and Psychology, University of Toronto; Patricia L. Ebert, Rotman Research Institute, Baycrest Health Sciences; Cheryl L. Grady, Rotman Research Institute, Baycrest Health Sciences, and Departments of Psychiatry and Psychology, University of Toronto; Janine M. Jennings, Department of Psychology, Wake Forest University.

Patricia L. Ebert is now at Alberta Health Services, Calgary, Alberta, Canada, and the Hotchkiss Brain Institute, University of Calgary.

Preliminary results were presented at the Cognitive Aging Conference in 2012. We thank Andrea Maione, Sandra Priselac, Magdelena Lysenko, Kashfia Alam, Brian Mainland, Lu Jin, Sarah Waters-Schulte, and Liesel-Ann Meusel for their assistance in recruitment, testing, data entry, and data double-checking, and Vinay Kansal for help in data double-checking. Thanks to Mariam Sidrak for administrative help with this article. This study was funded by the Canadian Institute of Health Research (MOP 67015) and was registered with ClinicalTrials.gov (NCT00643266).

Correspondence concerning this article should be addressed to Nicole D. Anderson, Rotman Research Institute, Baycrest Health Sciences, 3560 Bathurst Street, Toronto, ON M6A 2E1, Canada. E-mail: nanderson@research.baycrest.org

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

reductions in recollection (Naveh-Benjamin et al., 2009), the controlled, intentional process supporting the ability to remember information bound to its episodic context (Jacoby, 1991). In a recent meta-analysis of recollection in healthy younger and older adults, every one of 68 independent effect sizes indicated better recollection among younger adults, with an average weighted effect size of −0.75 (Koen & Yonelinas, 2014).

What can we do to improve the recollection abilities of seniors? Training elaborate encoding strategies, such as method-of-loci, story mnemonics, or face–name association improves performance on the trained memory strategy, but there are drawbacks to this approach: The average magnitude of memory improvement is small (Verhaeghen, Marcoen, & Goossens, 1992), training generalizes poorly to other tasks (cf. Ball et al., 2002; Rebok, Carlson, & Langbaum, 2007; Verhaeghen et al., 1992), and participants tend not to maintain use of the strategies once training is completed (see Craik & Anderson, 1999, for a review).

Jennings and Jacoby (2003) developed a novel approach to memory training that is based on the distinction between recollection (controlled, intentional, and effortful) and familiarity (quick and operating outside intentional control; Jacoby, 1991; Mandler, 1980). Grounded in the considerable evidence that aging is associated with decrements in controlled but not automatic processes (Hasher & Zacks, 1979; Jennings & Jacoby, 1993, 1997), Jennings and Jacoby aimed to train recollection. Older adults first studied a list of words. Then, a recognition test included words from the study phase, along with new words that were each presented twice with varying numbers of words intervening between the two presentations (the *lag*). Participants were instructed to respond "yes" to studied words and "no" both to new words and to repetitions of the new words. The critical items were the repeated new words; the first presentation of a new word boosts its familiarity (an automatic process), leading to an erroneous "yes" response to the second presentation unless the correct source of the repeated new word is recollected. Thus, in this paradigm, controlled processing is inferred by correct "no" responses to repeated new words.

Jennings and Jacoby (2003) used this "repetition lag" procedure in a group of healthy older adults by gradually increasing the lag between repeated new words as subjects met criterion. After 7 days of ~1-hr training, the trained older adults were able to recollect information over a lag of 28 items compared with a lag of just two items at the outset of training. Moreover, the training effect was far superior to the ~8 lag improvement seen in a yoked-control group who received a randomized order of identical lags. The success of repetition lag training has been since replicated in healthy aging (Bailey, Dagenbach, & Jennings, 2011; Jennings, Webster, Kleykamp, & Dagenbach, 2005; Lustig & Flegal, 2008; Stamenova et al., 2014, 2017), amnestic mild cognitive impairment (Finn & McDonald, 2015; Jennings, Lopina, & Dagenbach, 2015), Alzheimer's disease (Boller, Jennings, Dieudonné, Verny, & Ergis, 2012), and stroke (Stamenova et al., 2017).

It can be argued that repetition lag training offers a number of advantages over previous approaches to memory training. The first is that it trains a general memory process (e.g., recollection) rather than a specific memory strategy. As such, repetition lag training should generalize to a wider array of mnemonic situations requiring recollection, for which different strategies might be variably effective. Indeed, repetition lag training has transferred to n-back performance (Boller et al., 2012; Jennings et al., 2005, 2015), self-ordered pointing (Jennings et al., 2015), inhibitory attention (AX-CPT; Bailey et al., 2011), digit span forward and spatial source memory (Stamenova et al., 2014), delayed nonmatch to sample (Boller et al., 2012), and delayed verbal paired associates (Finn & McDonald, 2015). Second, repetition lag training targets the type of memory in which older adults show the largest decline, namely, associative or source memory. Participants become skilled at retrieving specific details of past events needed to differentiate their original source. Third, the magnitude of the memory benefit is far greater than that afforded by traditional approaches −10.3 standard deviation improvement in Jennings and Jacoby (2003) versus $M = 0.7$ standard deviation effect when strategies are trained (Verhaeghen et al., 1992).

However, a number of questions remain unanswered. First, it is not clear whether repetition lag training actually improves recollection. All of the studies cited in the preceding text have demonstrated improvements on the trained task that suggest recollection improvements, but none has derived actual estimates of the amount of recollection before and after training. In the current study, we measured recollection before and after training.

Second, the paradigm used in previous studies does not map on to the type of associative or source memory deficits that have been identified in the literature, which canonically have focused on extraitem features (e.g., the voice for aural stimuli, or the item with which another was paired), or on intraitem features (e.g., the font a word was presented in or whether it was seen or heard), with age-related deficits comparable across these source types (Old & Naveh-Benjamin, 2008). Anderson et al. (2008) conducted a modified repetition lag task to explore age differences in the ability to remember whether one had seen or heard an item before. In a continuous recognition task, half of the words were printed on the screen, and half were played over speakers. Each item was repeated after zero, three, or 12 intervening items. Participants were to respond "yes" to words repeated in the same modality and "no" both to new words and to words repeated in a different modality. Estimates of recollection and familiarity were derived based on the assumption that either recollection or familiarity could support a correct "yes" to words repeated in the same modality, but only familiarity in the absence of recollection would result in an incorrect "yes" to words repeated in a different modality. The results replicated previous findings of age-related reductions in recollection, whereas familiarity was spared. Moreover, recollection (but not familiarity) decreased as lag increased, particularly for the older adults.[1] We adapted this task into a training paradigm in the current study, given that it reflects the source memory deficits documented in the literature.

[1] Changing an item's modality could reduce its fluency or familiarity as well, which could confound estimates of recollection and familiarity. We think this is unlikely, however, as in our previous article (Anderson et al., 2008) we had both an inclusion task (say "yes" to all repeated items, regardless of modality change, where any effect of modality change on fluency or familiarity would also be present) and this exclusion task. Estimates of recollection and familiarity showed the same patterns across age (and amnestic mild cognitive impairment) and lag whether derived in the traditional way from both the inclusion and exclusion task or from a comparison of same and different items from within the exclusion task alone.

Finally, none of the previous studies have included a follow-up assessment after the training is completed. We thus repeated our assessments 3 months after completion of training (or an active control) to determine if training effects are maintained.

The primary objective of the current study was to evaluate the efficacy of repetition lag training, using our modified paradigm in healthy older adults, in terms of immediate gains, transfer, and maintenance. Toward this end, we split the older adult group into two groups (hi-old and lo-old), based on their performance on a set of neuropsychological tests of episodic memory (cf. Glisky, Polster, & Routhioux, 1995). This was motivated by two previous findings. First, in an early study comparing hi-old and lo-old (defined the same way), the hi-old activated the prefrontal lobes bilaterally during a source memory task in which participants indicated whether they had seen or heard words during the study phase, whereas the lo-old activated only right prefrontal cortex (Cabeza, Anderson, Locantore, & McIntosh, 2002). Second, our previous study using this paradigm found that recollection correlated with episodic memory performance, again on this same set of tests (Anderson et al., 2008).

In the current study, young adults, hi-old, and lo-old were assessed at baseline. Only the lo-old then received repetition lag training or an active control. We predicted that repetition lag training would eliminate the lo-old's deficit in recollection and source memory, compared with their hi-old counterparts at baseline. We included transfer tasks that rely on recollection: a 'near transfer' source memory task (which also included a comparison word cued-recall task), and four far transfer tasks. Participants also completed questionnaires selected to be sensitive to recollection training. We expected transfer to at least some of these tasks and questionnaires. To assess maintenance of training effects, trained and control participants were reassessed 3 months after completing repetition lag training or the active control. We expected the gains in recollection in the trained group, and possibly the transfer effects, to maintain over this time.

A third objective of the study was to examine the effects of repetition lag training on brain activity, assessed using functional MRI. Accordingly, the repetition lag task and the source memory tasks administered prior to and after training or control were conducted in the scanner; the current paper focuses on the behavioral data, with imaging data are reported elsewhere (Meusel, Grady, Ebert, & Anderson, 2017, and articles forthcoming).

## Method

### Participants

Eighteen younger adults (10 female; $M_{age}$ = 23.0, age range = 19–29) and 60 older adults (25 female; $M_{age}$ = 70.9, age range = 64–87) were recruited via the participant database at the Rotman Research Institute, flyers, newspaper advertisements, and community talks. Two younger adults were excluded from the study, one for poor neuropsychological performance, and the other after an incidental structural brain scan finding. Fourteen older adults were also excluded or withdrew: nine had MRI contraindications (e.g., claustrophobia, discomfort in the simulator), two refused to take part in the training or control sessions, and three were not able to be scheduled. This left 16 younger adults and 30 older adults in the study.

Participants were included if they were right-handed (defined as ≥.85 on the Edinburgh Handedness Scale, Oldfield, 1971), native English speakers, and high school graduates. The older adults also had to pass the Modified Telephone Interview for Cognitive Status (Welsh, Breitner, & Magruder-Habib, 1993). Hearing was assessed to ensure both the fidelity of neuropsychological testing and adequate hearing during two of the tasks in which auditory words were presented in an MR scanner. All participants had to pass a pure-tone audiogram, defined as ≤25 dB in at least one ear in the 250- to 4,000-Hz range or correctly identify 18/20 (90%) of polysyllabic words presented at 80 dB against a recording of 80 dB of MR scanner noise. Due to an administrative error, two older adults (one in the hi-old group and one in the lo-old train group, defined in the following text) did not meet this hearing criteria, but the effect of this error would be to underestimate rather than inflate to our group and training-related effects.

Exclusion criteria included a diagnosis of or belief that they had a learning disability, hearing aid use, MRI contraindications, and medical or psychiatric conditions affecting cognition or brain imaging. The conditions excluded were dementia; lupus; multiple sclerosis; brain injury; loss of consciousness lasting >5 min; encephalitis; meningitis; stroke; transient ischemic attack; epilepsy; brain tumor; migraines; diabetes or high blood sugar; uncontrolled thyroid or cholesterol conditions; hypertension; heart disease; prior myocardial infarct; arteriosclerosis or peripheral vascular disease; congestive heart failure; heart arrhythmia or murmur; exposure to toxic chemicals or fumes; chemotherapy; radiation to head or neck; major depressive, anxiety, or other psychiatric disorder requiring hospitalization or current depression or anxiety; excessive alcohol use exceeding the Canadian recommendations (Canadian Centre on Substance Abuse, 2011); regular drug (e.g., marijuana) use.

The Morningness–Eveningness Questionnaire (Horne & Ostberg, 1976) was administered by telephone. For all sessions, participants were scheduled only at their more optimal time of day (morning or afternoon). All participants were paid $110 for the first three visits. Older adults assigned to recollection training or to the active control condition were paid $230 for their additional 15 sessions. Parking or transit costs were also reimbursed. All participants provided written informed consent. The study was approved by the Baycrest Research Ethics Board.

### Audiology and Neuropsychological Assessment

All participants were administered a 3.5-hr audiology (the pure-tone hearing and speech-in-MR-noise tests described in the preceding text) and neuropsychological assessment in Session 1 (see Figure 1 for a timeline of the study). The neuropsychological assessment consisted of the Modified Mini-Mental State examination (Teng & Chui, 1987) to assess general cognitive status; the Lawton-Brody scale (Lawton & Brody, 1969) to assess daily functioning; the Shipley vocabulary test (Zachary, 1986) and Wechsler Abbreviated Scale of Intelligence (WASI) Matrix Reasoning (Wechsler, 1999) to estimate intelligence; the WASI Block Design test to measure visuospatial construction; the Wechsler Adult Intelligence Scale-III (WAIS-III; Wechsler, 1991) digit span and digit symbol tests to measure attention; semantic fluency (animals; Barr & Brandt, 1996) and a 15-item version of the

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

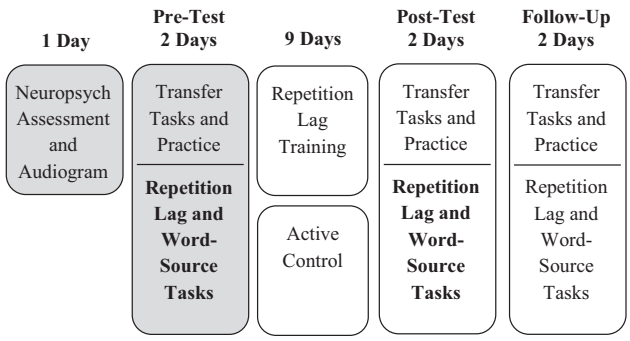


*Figure 1.* Timeline schematic of the study. Sessions shaded gray were administered to young, hi-old, lo-old trained, and lo-old control groups, and those in bold font were conducted in the fMRI scanner. Sessions unshaded were administered to lo-old trained and lo-old control groups only.

Boston Naming Test (Fastenau, Denburg, & Mauer, 1998) to assess semantic memory; phonemic fluency (FAS; Benton & Hamsher, 1989), Wechsler Memory Scale-III (WMS-III; Wechsler, 1997) Mental Control, Wechsler Adult Intelligence Scale–Revised Arithmetic (Wechsler, 1981), and a modified Wisconsin Card Sorting Task (Hart, Kwentus, Wade, & Taylor, 1988) to measure executive functioning; the California Verbal Learning Test-II (CVLT-II; Delis, Kramer, Kaplan, & Ober, 2000), WMS-III Logical Memory, the Wechsler Memory Scale-R (WMS-R; Wechsler, 1987) Visual Paired Associates, the WMS-R Verbal Paired Associates, and the WMS-III Faces I to assess episodic memory; and, the Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983) to measure mood.

Relative to a larger sample of 217 cognitively intact older adults who had received this same battery of assessments, the older adult group was split into 16 "hi-old" and 30 "lo-old", representing better or worse than average memory, respectively, on an age-regressed standardized composite of the CVLT-II long-delay cued recall, the WMS-III Logical Memory I (first recalls), the WMS-R Verbal Paired Associates I, the WMS-R Visual Paired Associates II, and the WMS-III Faces I (cf. Glisky et al., 1995). The lo-old group was then further split into two groups of 15 yoked for age, education, and standardized episodic memory scores. One group was assigned to the recollection training arm of the trial, and the other to the active control arm.

## Pretest, Posttest, and 3-Month Follow-Up Assessments

All groups participated in pretest assessment, but only the two lo-old groups participated in the posttest and 3-month follow-up assessment (see Figure 1). These assessments involved two sessions each, which occurred within 3 days of each other, and were designed to provide (a) an objective measure of recollection and familiarity, (b) a measure of near transfer, (c) measures of far transfer, and, (d) a measure of the efficacy of the active control program. The first session of each assessment lasted 3.5 hr, and the second session lasted 2 hr. Importantly, unique sets of words were used for the objective measures of recollection and familiarity, the measure of near transfer, measures of far transfer, and for the training sessions.

**Objective measure of recollection and familiarity.** Recollection and familiarity were measured using a fixed repetition lag task (with lags of 3 and 16). Participants practiced this task with lags of 0 and 3 on the first day of the pretest, posttest, and 3-month follow-up assessments in 16-trial blocks: Practice was discontinued when participants reached criterion of 50% accuracy on repeated items at both Lag 0 and Lag 3. On the second day of each of these assessments, participants completed the full task, with the pre- and posttest assessments conducted in the scanner. For the full task, 320 multisyllabic nouns were split into 10 sets of 32 words, which were then split into four subsets of eight words each, such that there were no significant Set × Subset main effects or interactions in word length, syllables, or word frequency. An additional set of 60 nouns was selected as filler words (each presented once) to make the tested lags possible. For each participant, the order of the 10 sets of words, subsets within sets, and words within subset was randomized, and the first five sets were assigned to the pretest and then reused at the 3-month follow-up, and the second five sets were assigned to the posttest. Subsets were then assigned to the four possible conditions (same visual, same auditory, different visual–auditory, and different auditory–visual). The filler words were randomized for each participant, with the first 30 assigned to pretest and 3-month follow-up and the second 30 assigned to posttest.

At each assessment, participants completed five blocks of 70 trials, consisting of 32 words each presented twice, half at Lag 3 and half at Lag 16, with eight in each repetition condition across the two lag intervals (same visual, same auditory, different visual–auditory, and different auditory–visual) and six filler words. There were thus totals of 40 same and 40 different modality repetitions at each lag, across all five blocks. Participants were instructed to press a button with the index finger of one hand if a word was new or repeated in a different modality, and to press another button with the index finger of the other hand if the word was repeated in the same modality. Assignment of response button to hand was counterbalanced across participants. Participants had four seconds to respond. The visual words remained centered on the screen in 40-point Tahoma font for 1,600 ms, whereas the auditory word duration depended on word length but was completed within 1 sec; auditory words were presented through headphones at 80 dB. A 2,400-ms interstimulus interval (ISI) with a fixation cross occurred between each trial. Between blocks, participants saw "(rest)" for 10 s.

We analyzed accuracy as a function of word type (new, same modality repetitions, different modality repetitions) and recollection and familiarity. According to process dissociation (Jacoby, 1991), either recollection (R) for the previous presentation of the word and its modality or familiarity (F) that the word had been presented before, but lacking recollection of its initial modality would lead to a correct "Yes" response to words repeated in the same modality. That is, $p(\text{Yes}|\text{Same}) = R + F(1 - R)$. By contrast, an incorrect "Yes" response to words repeated in a different modality would only occur because the word was familiar, but recollection its original modality failed, or $p(\text{Yes}|\text{Different}) = F(1 - R)$. Thus, an estimate of recollection was obtained by subtracting p(Yes|Different) from p(Yes|Same), and an estimate of familiarity was obtained by dividing p(Yes|Different) by (1 – R). Separate

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

estimates of recollection and familiarity were obtained for Lag 3 and Lag 16.[2]

**Measure of near transfer.** Near transfer was assessed using a source memory task (with a comparison word memory task, collectively referred to as the word-source task). In the first day of the pretest, posttest, and 3-month follow-up sessions, participants practiced the word-source task. On the second day of each of these sessions, participants completed the full word-source task, for which a list of 144 weakly related noun word pairs (e.g., minister-satin) was created and split into 12 sets such that word frequency, word length, and number of syllables did not differ across pair member or sets. An additional list of 72 individual nouns was created and split into 12 sets, also equated for the same word properties, for use in the test phase of the word task. The order of the sets for both lists and pairs within sets were randomized separately for each person. At each assessment point, participants performed three blocks of each task, with task order counterbalanced across participants within group. Each block began with an unscanned encoding phase, in which 12 pairs were presented. Half of the pairs were presented visually in black 36-point Tahoma font against a white background, and half were presented aurally at 80 dB, in a random order with the restriction that no more than four trials of the same modality occurred in a row. Each trial lasted 2 s, with either the visual noun pair presented for the full duration, or the first aural word presented at the beginning of the trial, and the second aural word presented starting at 1,000 ms into the trial. For the word task, participants were instructed to remember the word pairs, and for the source memory task they were instructed to remember whether they saw or heard each word pair.

After the last pair was presented, there was a 5-s break, after which the list was repeated in exactly the same way (pilot testing showed this avoided behavioral floor effects). After the second presentation of the list participants were shown eight numbers (1 through 8) sequentially in a random order, each for 1,500 ms, and indicated by button press if the number was odd or even.

For the scanned near transfer source memory task, each of the studied word pairs and six control trials (XXXXX–XXXXX) were presented visually for 2 s each, in a random order with the same restrictions as in the word task. Participants pressed a button with the index finger of one hand to indicate that they had "seen" that pair in the study phase, with the index finger of their other hand to indicate that they had "heard" that pair in the study phase, and with either index finger in response to a control trial. For the scanned test phase of the word task, the first word of each studied word pair (e.g., *minister*) and six unstudied stimulus words (e.g., *carton*) were presented visually for 2 s each, in a random order with the restriction that no more than four trials of each type (seen at study, heard at study, unstudied) occurred in a row. Participants pressed a button with the index finger of one hand to indicate that they could recall the second member of each pair, and another button with the other index finger to indicate that they could not recall the second member of each pair (to avoid motion artifacts associated with speaking). Then, the scanner was turned off, and participants once again saw the first word of each pair and recalled the second member of pair or said "pass." For both the word cued recall and source tasks, each test stimulus was followed by a jittered 2-, 4-, or 6-s fixation cross ISI ($M = 4$ s). Assignment of hand to response (seen, heard) was counterbalanced across participants. Participants had 4 s to respond from the time the stimulus appeared.

**Measures of far transfer.** In the first session of the pretest, posttest, and 3-month follow-up assessments, participants also completed four tasks to which we expected repetition lag training to transfer.

1. An AB–AC task requiring recollection of the current list state to avoid proactive interference (e.g., Winocur & Moscovitch, 1983; see Ebert & Anderson, 2009);

2. A self-ordered pointing task (SOPT; Petrides & Milner, 1982; Jennings et al., 2005) requiring recollection of items one had selected on previous trials to avoid repetitions;

3. A version of a Sternberg memory task requiring recollection of the most recent memory set to offset familiarity for recent sets (Jonides et al., 2000); and,

4. An n-back task with 1-back, 2-back, and 3-back blocks (Dobbs & Rule, 1989; see Guild, Vasquez, Maione, Mah, Ween, & Anderson, 2014) requiring recollection of the most recent stimuli to suppress familiarity for other stimuli that had been presented.

Detailed methods of these tasks are provided in the online supplemental material. Participants also completed the following questionnaires selected to be sensitive to recollection training:

1. The Memory Controllability Inventory (MCI; Lachman, Bandura, Weaver, & Elliot, 1995);

2. The Ability and Contentment scales of the Multifactorial Memory Questionnaire (MMQ; Troyer & Rich, 2002); and,

3. The Locus of Control, Anxiety, and Capability subscales of the Metamemory in Adulthood Questionnaire (MIA; Dixon & Hultsch, 1984).

**Measure of the efficacy of the control program.** A 27-item multiple choice questionnaire was created to measure uptake of the information presented in the active control program (see the online supplemental material). This questionnaire was administered to the lo-old trained and control groups at the pre- and posttest assessments.

## Recollection Training

Training words consisted of 2,304 nouns and verbs split into 72 sets of 32 words each, matched for word length, number of syllables, and Kuçera and Francis (1967) word frequency. An additional 36 sets of 26 nouns and verbs were selected as "filler" words, necessary to create the training lags. These filler word sets were also matched with the trained words for word length, number of syllables, and word frequency. The orders of the training word

[2] Auditory items were better remembered than visual items, but this was equally true for same (AA > VV) and different (AV > VA) repetitions and across groups. Thus, combining these conditions did not unduly influence group effects or estimates of recollection and familiarity.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

sets and filler sets, and words within those sets were randomized separately for each participant. In each training session, one set of words was assigned to one lag (i.e., the number of intervening words before a word was repeated), and the other set of words was assigned to a higher lag. Sixteen words in each set were assigned to same repetition condition (eight visual–visual, eight auditory–auditory), and 16 to the Different repetition condition (eight visual–auditory, eight auditory–visual).

In each session, participants were presented with 154 words: 90 new words (half auditory, half visual, with 26 of them filler words), and 64 repeated words. Participants were instructed to say "Yes" to words that were repeated in the Same modality, and "No" to new words and to words that were repeated in a Different modality. Training took place in 36 15-min sessions on 9 business days over 2 weeks, with four sessions per day, separated by a short break. Although previous studies have included 24 or 28 training sessions over 6 or 7 days, participants in Jennings and Jacoby (2003) had not reached asymptote by the end of training (7 days), and so we opted to extend training to maximize the potential for training gains.

Lag pairs were selected on the basis of Jennings and Jacoby (2003), where in each session participants were tested on one lag that they had already mastered, along with a lag that was higher than they had ever mastered. The lag pairs were 1 and 2, 1 and 3, 2 and 4, 2 and 8, 4 and 12, 4 and 16, 8 and 20, 8 and 24, 12 and 28, 12 and 32, 16 and 36, 16 and 40, 20 and 44, 20 and 48, 24 and 52, 24 and 56, 28 and 60, and 28 and 64.

The starting lag pairs in the first session were titrated to participants' performance with the 40 different modality repetitions at each lag in the pretest assessment. The passing criterion for Lag 3 was set at 90%. Participants who had failed Lag 3 started training at the lowest lag pair (1 and 2). For participants who had passed Lag 3, their starting lags depended on their performance at Lag 16. Training began at Lags 1 and 3 if Lag 16 performance this was less than chance ($<$50% correct); at Lags 2 and 4 if it was between 50 and 60%; at Lags 2 and 8 if it was between 63 and 75%; at Lags 4 and 12 if it was between 78 and 88%; and at Lags 4 and 16 if Lag 16 accuracy was $\geq$90%.

Passing criterion for training depended on the lags administered. For Lags 1 to 4, to pass participants had to respond correctly "No" to at least 96% of different repetitions and respond correctly "Yes" to at least 87% of same repetitions. On lags higher than 4, to pass participants had to respond correctly to at least 93% of different repetitions and to at least 81% of same repetitions. In training, if a participant passed both lags in a session then, in the next session they were presented with the next highest lag pair; otherwise, that lag pair was repeated. However, the first three sessions were used to determine participants' basal level of performance. If participants failed either lag in the first two sessions, then in the next session they were tested at the next lower pair (e.g., if their starting lags were 1 and 3, then in Session 2 they would have been tested at Lags 1 and 2). The highest lag passed by the end of Session 3 was identified as the basal level of performance; if a participant had not passed lag pair 1 and 2 by the end of Session 3, their basal level was entered as 0. The ceiling level of performance was the highest lag passed at the end of the entire 36 sessions.

### Active Control

The active control arm of this study was designed to mimic the social and intellectual exposure of the recollection training arm, but without training of recollection per se. Participants in the control arm came into the laboratory for nine days with four sessions each day. The first three sessions of the first day were identical to those in the recollection training group, in order to establish a basal level of performance in an identical manner to that of the trained group. The fourth session of that first day was an introduction to the active control "Baycrest Memory and Aging Education Program." Participants viewed, at their own pace, PowerPoint slides that described how each session would run, and then as a nonmemory and aging but everyday life example, learned about planning a birthday party over a series of four slides, followed by a Jeopardy game to test their knowledge for the information. In the second to eighth day of the control arm, participants completed four sessions per day, each with a PowerPoint lesson followed by a 12-item Jeopardy-like game format, on topics such as neuroanatomy; memory and how it changes with healthy aging; perceptual changes with age; the link between exercise, diet, mood and sleep disorders and how they affect memory; mild cognitive impairment and dementia; and aging stereotypes. A full list of topics is provided in the online supplemental material.

On the last day of the control arm, we attempted to ascertain the control participants' ceiling level of performance vis-à-vis their basal level of performance and their yoked trained participants' ceiling level of performance. In the four sessions of that last day, participants were tested at lag pairs as follows: Participants were first tested at their yoked control's ceiling lag pair; in the second session they were tested at one lag pair higher than their own basal lag pair; in the third session, if they had passed the first session, they were tested at the next highest lag pair, but if they had failed the first session, then they were tested at one lag pair lower than in the first session; in the final session, if they had passed the second session, they were tested at the next highest lag pair, but if they had failed the second session, then they were tested at one lag pair lower than their basal level (or were retested at Lag Pairs 1 and 2 if that was their basal level).

### Data Analysis and Presentation

Demographic, audiological, neuropsychological, and task data were analyzed using a chi-square test (gender) or analyses of variance (ANOVAs) with group as a between-subjects variable; significant group effects were explored with Sidak post hoc tests. All post hoc results noted were significant at the .05 level. Although we display the task results from all four groups, we focus our analyses on changes in the lo-old groups as a function of training; comparisons across groups in baseline task performance are presented in the online supplementary material.

## Results

### Demographic and Neuropsychological Data

Demographic, audiological, and neuropsychological test scores for the young, hi-old, lo-old train, and lo-old control groups are shown in

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

Table 1. The four groups did not differ significantly in the number males and females. The three older adult groups did not differ in terms of age. education was higher in the young and hi-old than in the two lo-old groups. The young had better hearing than all three older adult groups, but the older adult groups' hearing did not differ. Details of group differences on the cognitive measures are shown in the Table. For the sake of brevity, we highlight the critical fact that on no demographic, hearing, neuropsychological, or mood measures did the lo-old train and lo-old control groups differ.

## Training Efficacy

Basal and ceiling level performance for the lo-old train and lo-old control groups are shown in Figure 2. Because of an administrative error, the sessions necessary to calculate ceiling performance were not administered to one lo-old control participant. The data were analyzed using a Group × Time mixed ANOVA. The group difference, $F(1, 27) = 13.42$, $p = .001$, $\eta_p^2 = .33$, and time effect, $F(1, 27) = 28.07$, $p < .001$, $\eta_p^2 = .51$, were driven by a significant Group × Time interaction, $F(1, 27) = 19.82$, $p < .001$, $\eta_p^2 = .42$. Follow-up ANOVAs within group showed significantly higher performance at ceiling than basal for the trained group, $F(1, 14) = 27.08$, $p < .001$, $\eta_p^2 = .66$, but not for the control group, $F(1, 13) = 2.90$, $p = .112$, $\eta_p^2 = .18$.

## Fixed Repetition Lag Task: Objective Measure of Recollection and Familiarity

Accuracy on the fixed repetition lag task for new items, same modality repetitions, and different modality repetitions at pretest for the four groups, and at all three assessments for the lo-old groups is shown in Table 2. Analysis of the pretest data across groups is presented in the online supplementary material. Because these scores are used to calculate recollection and familiarity, we only point out here that improvements in accuracy were greater in the trained lo-old than lo-old control group, $F(2, 54) = 3.88$, $p = .037$, $\eta_p^2 = .126$, and most evident for different modality repetitions compared with new items and same modality repetitions, $F(2, 60) = 4.68$, $p = .010$, $\eta_p^2 = .15$.

Recollection and familiarity for the four groups at pretest and for the two lo-old groups at all three assessments are shown in Figure 3A and 3B, respectively. As described in the online supplementary material, our pretest results replicate previous reports of age-related declines in recollection, but relative sparing of familiarity (Anderson et al., 2008; see Koen & Yonelinas, 2014 for review). The effects and maintenance of training effects were analyzed in two Group (lo-old train, lo-old control) × Assessment (pre-, post-, 3-month) × Lag mixed ANOVAs, separately for recollection and familiarity. Recollection was higher at Lag 3 than at Lag 16, $F(1, 27) = 80.68$, $p < .001$, $\eta_p^2 = .75$. Recollection was also higher in the trained than in the control group, $F(1, 27) =$

Table 1
*Demographic and Neuropsychological Test Performance for the Young, Hi-Old, Lo-Old Train, and Lo-Old Control Groups*

| Measure | Young ($n = 16$) *M* (*SD*) | Hi-old ($n = 16$) *M* (*SD*) | Lo-old train ($n = 15$) *M* (*SD*) | Lo-old control ($n = 15$) *M* (*SD*) | *p* |
|---|---|---|---|---|---|
| Male to female ratio[a] | 6:10 | 4:12 | 10:5 | 7:8 | .122 |
| Age (in years)[b] | 23.0 (3.0) | 70.1 (3.6) | 71.5 (6.1) | 71.2 (4.6) | <.001 |
| Education (in years)[c] | 15.6 (1.6) | 17.3 (2.4) | 15.1 (2.2) | 15.1 (2.3) | .011 |
| Better Ear (dB)[b] | 3.3 (3.6) | 15.0 (6.1) | 20.1 (8.5) | 19.3 (9.0) | <.001 |
| 3MS[d] | 97.7 (2.0) | 97.1 (2.4) | 94.5 (3.6) | 94.2 (4.9) | .008 |
| Shipley vocabulary[b] | 31.9 (3.0) | 36.3 (3.1) | 34.9 (3.2) | 36.0 (2.0) | .001 |
| Matrix reasoning[c] | 29.6 (2.7) | 24.9 (4.5) | 21.6 (7.1) | 23.9 (5.0) | <.001 |
| Block design[b] | 59.5 (8.1) | 41.7 (13.3) | 35.9 (12.7) | 37.5 (13.0) | <.001 |
| Digit span total[c] | 21.7 (4.0) | 19.6 (3.9) | 17.6 (4.6) | 16.6 (3.5) | .004 |
| Digit symbol total[b] | 92.0 (13.0) | 67.5 (10.3) | 60.3 (9.7) | 71.6 (13.9) | <.001 |
| Boston naming[a] | 14.1 (1.0) | 14.3 (.8) | 14.3 (1.3) | 14.4 (1.1) | .822 |
| Semantic fluency[a] | 23.4 (5.4) | 18.8 (5.6) | 18.5 (6.9) | 18.4 (4.6) | .043 |
| Phonemic fluency[a] | 53.4 (11.1) | 44.88 (9.2) | 48.9 (14.9) | 43.9 (12.8) | .122 |
| Mental control[a] | 31.5 (4.6) | 28.1 (6.0) | 28.2 (6.5) | 28.5 (5.8) | .290 |
| Arithmetic[a] | 11.4 (3.1) | 13.1 (3.8) | 14.1 (3.3) | 12.7 (3.2) | .180 |
| WCST categories[e] | 6.0 (.0) | 5.3 (1.4) | 4.6 (1.6) | 5.1 (1.2) | .027 |
| CVLT long delay CR[c] | 13.6 (2.2) | 13.2 (1.8) | 10.2 (3.7) | 10.4 (2.3) | <.001 |
| Logical memory I[c] | 33.8 (5.9) | 28.9 (4.3) | 23.3 (5.8) | 23.7 (5.6) | <.001 |
| Verbal paired I[c] | 22.4 (1.3) | 20.3 (2.0) | 16.9 (2.9) | 17.1 (2.8) | <.001 |
| Visual paired II[c] | 6.0 (.0) | 5.9 (.3) | 4.5 (1.2) | 5.0 (1.4) | <.001 |
| Faces I[f] | 39.8 (3.4) | 37.1 (3.9) | 33.7 (3.7) | 33.5 (5.3) | <.001 |
| HADS Anxiety | 5.6 (2.9) | 4.8 (3.1) | 4.9 (3.8) | 4.7 (2.5) | .854 |
| HADS Depression | 3.5 (3.0) | 1.7 (1.5) | 2.2 (2.7) | 2.1 (2.2) | .178 |

[a] No difference between groups. [b] Young ≠ Hi-Old = Lo-Old Trained = Lo-Old Control. [c] Young = Hi-Old > Lo-Old Trained = Lo-Old Control. [d] Young > Lo-Old Control; Hi-Old and Lo-Old not significantly different from any group. [e] Young > Lo-Old Trained; Hi-Old = Lo-Old Trained = Lo-Old Control. [f] Young > Lo-Old Trained = Lo-Old Control; Hi-Old not significantly different from any group.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

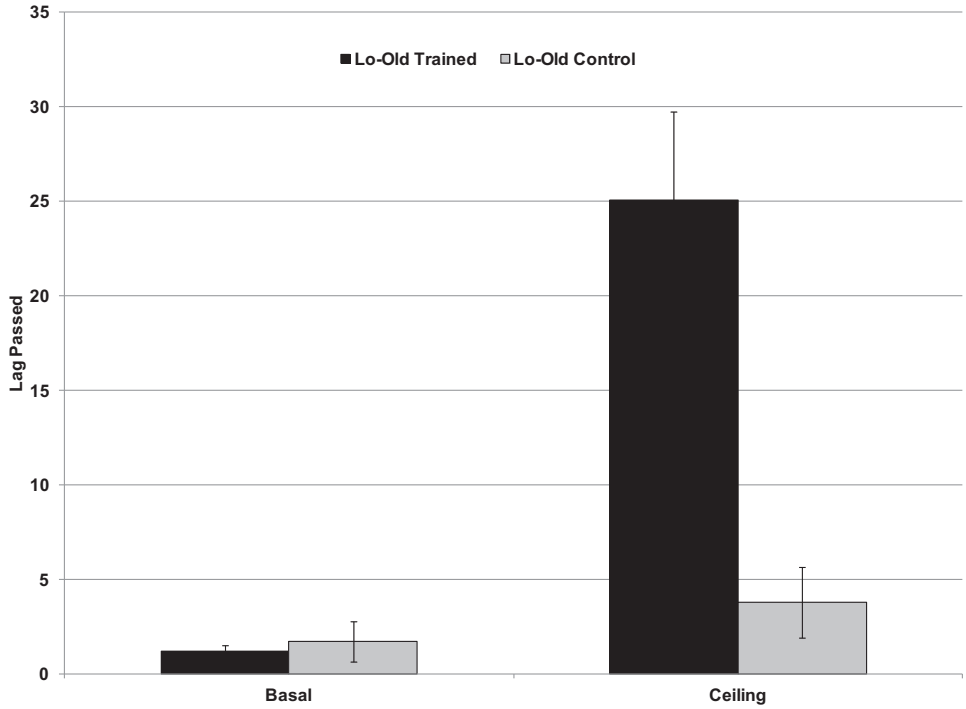


*Figure 2.* Basal and ceiling performance on the recollection training task for the lo-old trained and lo-old control groups. Error bars are ±1 standard error of the mean.

14.22, $p = .001$, $\eta_p^2 = .35$, and varied across assessments, $F(2, 45) = 19.21$, $p < .001$, $\eta_p^2 = .42$, but these effects were qualified by a Group × Assessment interaction, $F(2, 45) = 5.21$, $p = .013$, $\eta_p^2 = .16$. The Group × Assessment interaction was explored by examining the assessment effect within each group separately. In the lo-old trained group, recollection varied significantly across assessments, $F(2, 28) = 25.73$, $p < .001$, $\eta_p^2 = .65$, with post hoc tests revealing a significant rise in recollection from pretest to posttest, followed by maintenance of these gains at the 3-month follow-up assessment. By contrast, recollection did not vary reliably across assessments in the lo-old control group, $F(2, 26) = 2.08$, $p = .145$, $\eta_p^2 = .14$, for either lag (Assessment × Lag: $F(2, 26) = 2.34$, $p = .116$, $\eta_p^2 = .15$). The numerical increase in recollection at Lag 3 can likely be attributed to the exposure this group had to this task in pretesting and in ceiling determination. No other effects were significant.

Table 2
*Accuracy on the Fixed Repetition Lag Task*

| Assessment | Lag | Item type | Young *M* (*SD*) | Hi-old *M* (*SD*) | Lo-old train *M* (*SD*) | Lo-old control *M* (*SD*) |
|---|---|---|---|---|---|---|
| Pretest | 3 | New | .95 (.04) | .98 (.03) | .95 (.04) | .94 (.08) |
| | | Same | .86 (.07) | .77 (.09) | .71 (.17) | .70 (.13) |
| | | Different | .87 (.11) | .78 (.11) | .75 (.16) | .66 (.18) |
| | 16 | New | .97 (.03) | .98 (.02) | .98 (.01) | .94 (.08) |
| | | Same | .78 (.10) | .62 (.13) | .58 (.21) | .57 (.14) |
| | | Different | .84 (.12) | .80 (.12) | .73 (.16) | .71 (.14) |
| Posttest | 3 | New | | | .98 (.01) | .97 (.03) |
| | | Same | | | .84 (.08) | .70 (.11) |
| | | Different | | | .88 (.06) | .79 (.14) |
| | 16 | New | | | .97 (.02) | .97 (.03) |
| | | Same | | | .64 (.18) | .46 (.13) |
| | | Different | | | .89 (.07) | .81 (.09) |
| 3-month follow-up | 3 | New | | | .98 (.02) | .98 (.03) |
| | | Same | | | .85 (.11) | .77 (.11) |
| | | Different | | | .84 (.09) | .70 (.21) |
| | 16 | New | | | .98 (.02) | .97 (.04) |
| | | Same | | | .64 (.19) | .54 (.16) |
| | | Different | | | .81 (.11) | .74 (.17) |

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

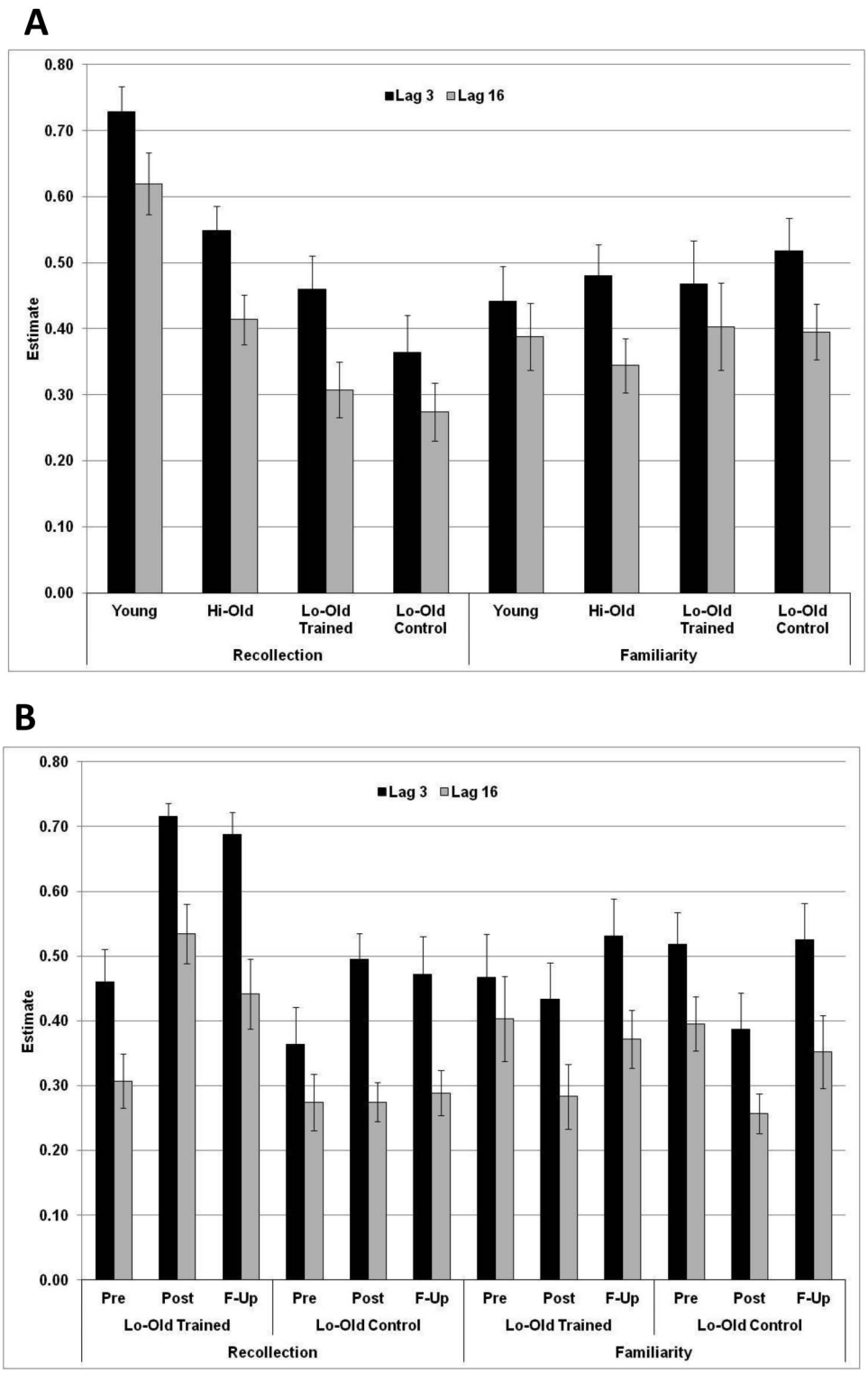


*Figure 3.* Recollection and Familiarity at pretest for the young, hi-old, lo-old trained, and lo-old control groups (Panel A). Recollection and familiarity at pretest, posttest, and follow-up (F-Up) for the lo-old trained and lo-old control groups (Panel B). Error bars are ±1 standard error of the mean.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

One of our predictions was that the lo-old's recollection after training would match that of their hi-old counterparts. Because it is clear from Figure 3 that was achieved, we instead compared the posttraining performance to that of the young, and we found that levels of recollection at both lags in the lo-old trained group at posttest were as high as in the young: Group $F(1, 29) < 1$, Group × Lag $F(1, 29) = 2.01$, $p = .167$, $\eta_p^2 = .07$.

The analysis of familiarity revealed higher familiarity at Lag 3 than Lag 16, $F(1, 27) = 61.99$, $p < .001$, $\eta_p^2 = .70$, and a dip in familiarity from pretest to posttest that rebounded by the 3-month follow-up, $F(2, 54) = 5.25$, $p < .001$, $\eta_p^2 = .16$. No other effects were significant. In summary, training had a preferential effect on recollection, and training gains in recollection were maintained 3 months later.

## Word-Source Task: A Measure of Near Transfer

Word-source performance at pretest for all four groups, and at all three time points for the two lo-old groups is shown in Figure 4A and 4B, respectively. The effects and maintenance of training effects were analyzed in a Group (lo-old train, lo-old control) × Task (Word, Source) × Assessment (Pre-, Post-, 3-Month) mixed ANOVA. Performance was better on the source memory task than item memory task, $F(1, 26) = 71.71$, $p < .001$, $\eta_p^2 = .73$, similarly for the trained and control groups, $F(1, 26) < 1$, but we remind readers that the source memory task was a two-alternative forced choice (seen/heard) with a chance rate of 50%, whereas the word task was a cued recall task. Performance improved across assessments, $F(2, 52) = 7.15$, $p = .002$, $\eta_p^2 = .21$, particularly for the word memory task, $F(1, 26) = 71.71$, $p < .001$, $\eta_p^2 = .73$. However, there was no main effect of group, $F(1, 26) < 1$, nor any interactions with group (all $F < 1.83$). Given that we failed to find an effect of repetition lag training on source memory, we did not compare the trained group's posttest performance to the other groups' performance at baseline.

## Measures of Far Transfer

Although measures of far transfer were administered to participants in all groups (young, hi-old, lo-old trained, lo-old control) at pretest—our primary interest here is in far transfer from recollection training. Table 3 displays the results from the objective far transfer tasks, and Table 4 displays the results from the subjective far transfer questionnaires. These data were analyzed in Group × Time (and where appropriate, condition or trial as specified) mixed ANOVAs. Remarkably, on not a single measure did the lo-old trained group show greater improvements over time compared with the lo-old control group: the $F$ value for all Group × Time interactions was <1, excepting MCI Potential Improvement, $F(2, 47) = 2.02$, $p = .151$, $\eta_p^2 = .067$, Effort Utility $F(2, 45) = 2.15$, $p = .137$, $\eta_p^2 = .07$, and Independence $F(2, 56) = 1.94$, $p = .153$, $\eta_p^2 = .07$; the MMQ Contentment scale value was $F(2, 54) = 2.32$, $p = .110$, $\eta_p^2 = .08$; and the MIA Capacity was $F(2, 50) = 1.13$, $p = .325$, $\eta_p^2 = .04$ scale. To the contrary, the lo-old control group but not their trained counterparts, reported improving Present Ability on the MCI, $F(2, 47) = 4.02$, $p = .030$, $\eta_p^2 = .13$, and increasing Locus of Control on the MIA questionnaire from pre- to posttest, $F(2, 56) = 3.47$, $p = .038$, $\eta_p^2 = .11$. In summary, there was no evidence that recollection training transferred to any of the many measures administered, near or far.

## Efficacy of the Control Program

The lo-old control group showed significant increases in knowledge about the material covered in that program (pre: $M = 10.47$, $SD = 2.0$; post: $M = 15.40$, $SD = 2.7$) that did not occur in the lo-old trained group (pre: $M = 12.33$, $SD = 3.0$; post: $M = 13.53$, $SD = 3.0$), as reflected in the Group × Time interaction, $F(1, 28) = 12.23$, $p = .002$, $\eta_p^2 = .30$.

# Discussion

The current study replicated previous findings of age-related reductions in source memory and recollection (with sparing of familiarity), as well as of significant repetition lag training gains. There are three novel contributions of this study. First, we confirmed for the first time that repetition lag training improves recollection. Second, we discovered that these effects maintain for 3 months. Last, our failure to find transfer raises important clinical and theoretical questions about transfer of recollection training, and, indeed, about recollection. We address these points in turn.

Our results add to the robust evidence for the efficacy of repetition lag training. At baseline, both lo-old groups could meet criteria in excluding items repeated in a different modality only if they occurred after less than two intervening items. By the end of training, however, the trained group met criteria with an average of 25 intervening items—a 19.78 standard deviation gain—compared with the control group's average ceiling of less than 4. Moreover, we show for the first time that repetition lag training was associated with increased recollection; familiarity was not influenced by training. In fact, training raised the level of recollection in older adults, whose episodic memory was normal but in the following text average, to the level of young adults. This result provides hope that in older adults, even in those with lower mnemonic skills, recollection can be improved through relatively brief but intense bouts of training. Similar gains have been shown in studies training other cognitive functions, such as working memory and executive functioning (see Karbach & Verhaeghen, 2014, for a meta-analysis).

Our results also show for the first time that training-related recollection improvements maintain (at least) 3 months after training cessation. It is unlikely that participants practiced training in the time intervening between testing visits. More likely, these results indicate that repetition lag training induced neuroplastic change in brain structure or function, as has been shown for other memory and cognitive training approaches (e.g., Chapman et al., 2015; Engvig et al., 2010; Nyberg et al., 2003; Takeuchi et al., 2010, 2014).

Finally, recollection training did not show significant near transfer to a source memory test with high face validity to the trained task, or far transfer to a host of other memory tasks that presumably rely upon recollection. Moreover, none of the 11 subjective indicators of memory functioning were affected by recollection training, and other studies that included subjective indicators of memory functioning and mood likewise did not find transfer to these measures (Finn & McDonald, 2015; Stamenova et al., 2014). In fact, the control group but not the trained group showed significant greater improvements in their assessment of the present capacity of their memory and in locus of control, and numerically greater improvements on all other subjective measures, likely because of topics covered in the control PowerPoint lessons.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

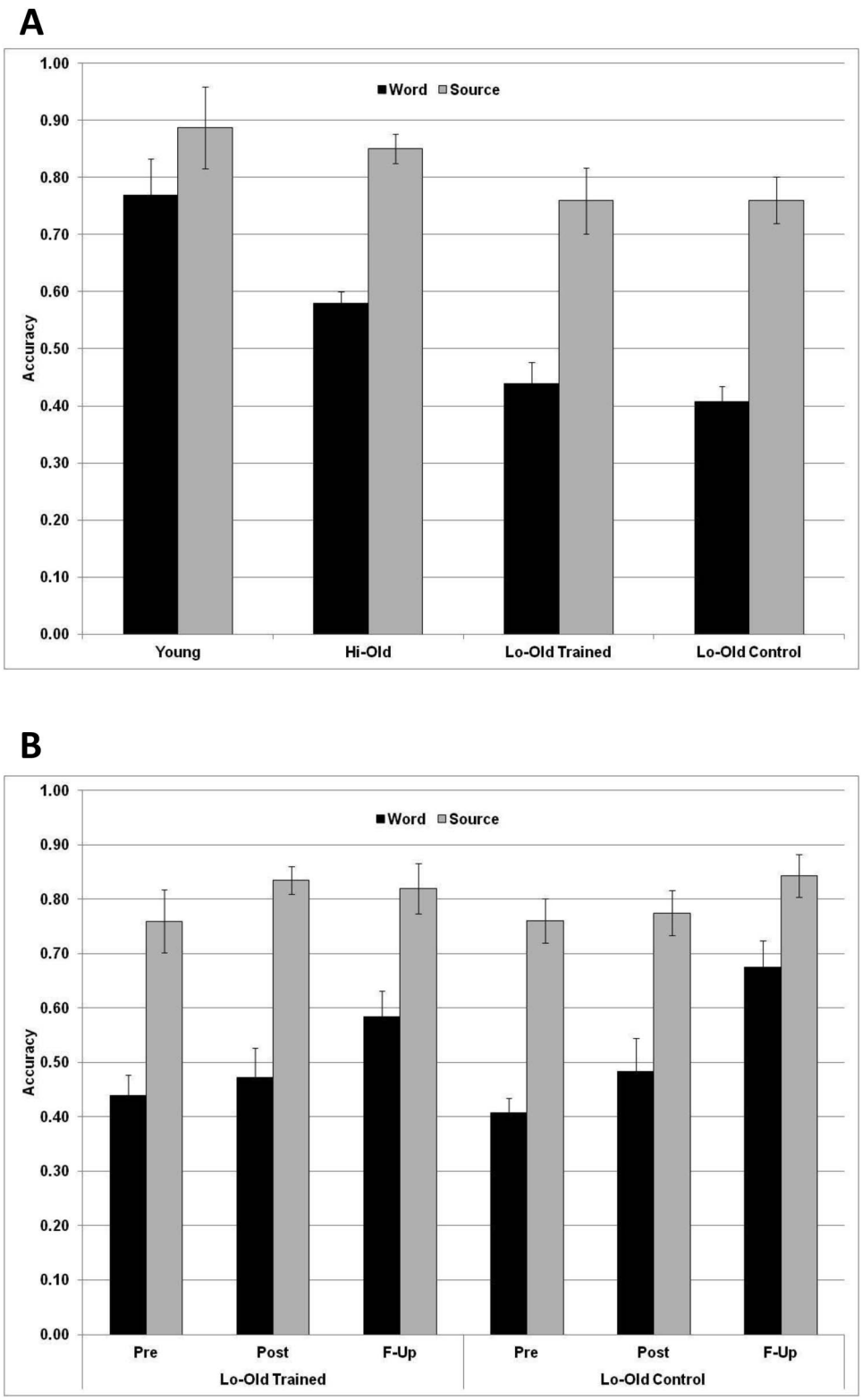


*Figure 4.* Word and source memory accuracy at pretest for the young, hi-old, lo-old trained, and lo-old control groups (Panel A). Word and source memory accuracy at pretest, posttest, and follow-up (F-Up) for the lo-old trained and lo-old control groups (Panel B). Error bars are ±1 standard error of the mean.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

Table 3
*Means (and Standard Deviations in Parentheses) of the Far Transfer Objective Tasks at Pretest, Posttest, and Follow-Up in the Lo-Old Trained and Lo-Old Control Groups*

| | Lo-old trained | | | Lo-old control | | |
|---|---|---|---|---|---|---|
| Task/measure | Pretest | Post | Follow-up | Pretest | Posttest | Follow-up |
| AB–AC | | | | | | |
| AB trials to criterion | 3.2 (1.1) | 3.9 (2.2) | 2.6 (.7) | 3.1 (1.1) | 3.6 (2.1) | 2.5 (1.5) |
| AC trials to criterion | 4.5 (1.5) | 4.5 (1.9) | 3.5 (1.5) | 4.5 (2.0) | 4.7 (2.4) | 3.9 (2.5) |
| SOPT | | | | | | |
| Trial 1 errors | 3.3 (1.7) | 3.2 (1.0) | 3.9 (1.4) | 3.3 (1.0) | 3.1 (.9) | 3.3 (1.4) |
| Trial 2 errors | 3.4 (1.5) | 3.7 (1.6) | 2.8 (1.1) | 3.9 (1.8) | 3.1 (1.5) | 3.4 (1.5) |
| Trial 3 errors | 3.5 (1.7) | 3.4 (1.5) | 2.9 (1.5) | 3.4 (1.6) | 3.2 (1.6) | 2.5 (1.3) |
| Total errors | 10.3 (4.4) | 10.3 (3.3) | 9.6 (2.9) | 10.5 (3.1) | 9.4 (3.0) | 9.2 (2.7) |
| Sternberg task | | | | | | |
| Target RT | 859 (101) | 799 (118) | 842 (127) | 855 (132) | 839 (116) | 847 (92) |
| Lo-recency lure RT | 902 (102) | 863 (128) | 907 (132) | 924 (142) | 884 (116) | 929 (128) |
| Hi-recency lure RT | 951 (95) | 902 (143) | 952 (131) | 954 (124) | 932 (120) | 971 (117) |
| n-back | | | | | | |
| 1-back discrimination | .90 (.14) | .91 (.11) | .95 (.07) | .88 (.13) | .96 (.05) | .95 (.05) |
| 2-back discrimination | .63 (.18) | .70 (.18) | .52 (.36) | .59 (.15) | .63 (.15) | .53 (.31) |
| 3-back discrimination | .56 (.15) | .58 (.16) | .41 (.35) | .55 (.20) | .53 (.20) | .43 (.30) |

*Note*. SOPT = Self-ordered pointing task.

In the introductory paragraphs, we mentioned that other studies have identified positive transfer effects to some objective tasks, but we did not mention all the other tasks in these studies where transfer was not found. Repetition lag training has not transferred to reading span or word list learning (Boller et al., 2012; Jennings et al., 2005; Stamenova et al., 2014), visuospatial learning (Stamenova et al., 2014), paired associate learning (Finn & McDonald, 2015), or other working memory measures (Boller et al., 2012; Finn & McDonald, 2015; Stamenova et al., 2014). These results are reminiscent of failures to find transfer in other forms of cognitive training (e.g., Owen et al., 2010). Some authors have viewed improvements in the trained group as evidence of transfer, based on planned comparisons motivated by a priori hypotheses about positive transfer, but these effects did not differ significantly between the trained and control groups (Jennings et al., 2005; Jennings et al., 2015). Other studies reporting transfer did not include a no-training control group (Bailey et al., 2011; Flegal & Lustig, 2016; Lustig & Flegal, 2008). In all of these cases, the gains could simply reflect practice effects. We argue that evidence of transfer requires significant Group (trained/control) × Time (pre/post) interactions, reflecting greater improvement in the trained than control group.

Nevertheless, why have some studies found reliable transfer effects that ours failed to show? Jennings et al. (2015) suggested that repetition lag training may ameliorate different types of memory processes depending on the integrity of the participants' memory systems: the more controlled processes involved in working memory in healthy older adults, long term memory in amnestic

Table 4
*Means (and Standard Deviations in Parentheses) of the Far Transfer Questionnaires at Pretest, Posttest, and Follow-Up in the Lo-Old Trained and Lo-Old Control Groups*

| | Lo-old trained | | | Lo-old control | | |
|---|---|---|---|---|---|---|
| Task/measure | Pretest | Post | Follow-up | Task/measure | Pretest | Post |
| MCI | | | | | | |
| Present ability | 16.9 (3.1) | 15.5 (3.3) | 15.4 (3.7) | 15.6 (3.0) | 16.4 (2.8) | 17.1 (3.2) |
| Potential improvement | 16.3 (3.5) | 16.4 (2.7) | 17.1 (2.4) | 16.7 (3.3) | 18.4 (2.1) | 18.3 (2.5) |
| Effort utility | 17.3 (2.8) | 16.9 (2.8) | 16.7 (2.6) | 16.1 (3.6) | 17.4 (2.9) | 17.3 (2.9) |
| Inevitable decrement | 9.7 (2.8) | 8.9 (4.1) | 8.9 (4.1) | 9.9 (3.9) | 7.8 (3.6) | 8.1 (3.6) |
| Independence | 14.7 (3.1) | 14.8 (3.1) | 14.3 (3.2) | 14.6 (2.5) | 16.4 (2.4) | 16.5 (3.1) |
| Alzheimer's likelihood | 13.1 (5.5) | 13.0 (4.8) | 13.3 (4.2) | 12.3 (4.3) | 10.2 (2.6) | 11.7 (3.3) |
| MMQ | | | | | | |
| Ability | 55.3 (10.1) | 56.3 (15.2) | 57.1 (9.2) | 55.1 (10.1) | 60.6 (10.7) | 57.6 (10.8) |
| Contentment | 48.2 (10.0) | 50.6 (12.3) | 51.9 (9.2) | 46.9 (11.4) | 48.6 (7.4) | 54.9 (8.2) |
| MIA | | | | | | |
| Anxiety | 42.0 (10.0) | 40.2 (10.7) | 38.1 (7.8) | 39.6 (8.9) | 37.3 (8.4) | 35.7 (9.1) |
| Capacity | 56.9 (7.9) | 57.1 (8.0) | 56.9 (9.1) | 56.3 (7.8) | 57.1 (9.4) | 59.3 (10.0) |
| Locus of control | 41.1 (4.7) | 40.9 (5.4) | 40.8 (5.4) | 39.9 (5.4) | 43.4 (6.1) | 42.7 (7.3) |

*Note*. MCI = Memory Controllability Inventory; MMQ = Multifactorial Memory Questionnaire; MIA = Metamemory in Adulthood.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

mild cognitive impairment, and recognition memory in Alzheimer's disease. Had we included less complex memory measures, we may have seen transfer; yet, the fact that our older adults were cognitively healthy suggests that this interpretation does not fully explain when recollection training does or does not transfer.

We propose another interpretation of our null transfer effects. All of the previous repetition lag studies used the original Jennings and Jacoby (2003) paradigm, where it could be argued that training success depends on recency—is the current item familiar because I studied it a few minutes ago, or because I saw it in the recognition test already? Many of the tasks in which firm transfer effects have been found likewise rely on recency memory (n-back, SOPT, AX-CPT, digit span, and even recognition memory). Perhaps, then, the Jennings and Jacoby (2003) paradigm and the current paradigm are training different types of recollection—recency recollection in the former case, and modality recollection in the current case. Thus, modality recollection training may not have transferred to our selected transfer tasks that rely, predominantly, on recency recollection. If this interpretation is correct, our training should have transferred to the source memory task. In fact, the lo-old trained group's performance on the source memory task did increase significantly from pre- to posttest, $F(1, 14) = 8.48$, $p = .011$, $\eta_p^2 = .38$, and this effect was maintained over 3 months (post-to follow-up), $F(1, 14) < 1$. By contrast, the lo-old control groups' source memory did not change from pre- to posttest, $F(1, 14) < 1$, although it did then increase at the follow-up assessment, $F(1, 14) = 7.78$, $p = .015$, $\eta_p^2 = .37$. These differing patterns in source memory changes over time in the two groups did not, however, result in a significant Group × Time interaction, and thus we do not have firm evidence for near transfer. It could also be that recency recollection and modality recollection differ in whether the context is extraitem (recency) or intraitem (modality). Yet, age-related differences in associative or source memory do not appear to differ along these lines (Old & Naveh-Benjamin, 2008), and standard repetition lag training has not always successfully transferred to tasks requiring recollection of other extraitem contexts (Finn & McDonald, 2015).

We suggest that transfer in recollection training is so limited because there is no single recollection process, but rather many, hyperspecific recollection processes. Representational models of memory argue that regions within the medial temporal lobes are extensions of pathways that begin in earlier regions of visual processing streams (e.g., Ranganath, 2010; Saksida & Bussey, 2010). Specifically, these models posit that objects are processed along a ventral visual cortex—perirhinal cortex—lateral entorhinal cortex stream, and scenes and spatial information along a dorsal visual cortex—parahippocampal cortex—medial entorhinal cortex stream, with progressively more complex and conjunctive representations at each successive stage. Evidence from studies on patients with focal lesions as well as from neuroimaging in healthy adults supports these models (Barense, Gaffan, & Graham, 2007; Barense, Henson, Lee, & Graham, 2010; Lee et al., 2005; Mundy, Downing, Dwyer, Honey, & Graham, 2013). The perirhinal and parahippocampal cortices, specifically, contribute differentially to recollection of objects and scenes, respectively (Staresina, Duncan, & Davachi, 2011). It is thus possible that the brain regions responsible for contributing to recency recollection and modality recollection are also separable, but yet to be discovered fully. Recency judgments have been linked to left dorsal parietal and right anterior temporal lobe regions (Kimura et al., 2010) as well as left dorsolateral prefrontal cortex (Dudukovic & Wagner, 2007), whereas subsequent memory effects (Kim, 2011) and cortical reinstatement effects at retrieval (Thakral, Wang, & Rugg, 2015) have been shown to overlap with same regions supporting processing that type of information (e.g., inferior frontal cortex for verbal materials, occipital cortex for pictorial materials). To our knowledge, no one has compared the brain regions supporting recollection for recency and modality, but our data, along with previous repetition lag training studies, encourage discovering the extent to which recollection can be fractionated based on representational content.

The primary limitation of the current study is the small sample sizes within each subgroup that potentially limited our ability to identify significant near transfer to the source memory task. Regardless, with one exception our failure to find far transfer was not an issue of power. There was very minimal numerical change from pre- to post- to 3-month follow-up testing, and the sometimes small changes that were evident were matched (or exceeded) by the control group. Indeed, the control group showed greater numerical improvements on every subjective measure administered, and we would have needed between 90 (3-back) and 268 (AB–AC) people per group for the greater improvements on the objective tasks to have been significant—numbers that are too large to be of import, theoretically or clinically. The only far transfer task that may have shown positive transfer had we tested more people was the Sternberg task. The small sample size of the lo-old trained group did hamper our power to examine individual differences in training success, which ranged from no gains to a ceiling lag of 56 intervening items. We found no significant association between training success and age, education, vocabulary, or memory composite, factors that have been associated with training success in previous studies (Bissig & Lustig, 2007; Flegal & Lustig, 2016; Lustig & Flegal, 2008; Stamenova et al., 2014, 2017), although all associations were in the expected direction. In addition, the word sets used in the repetition lag task and the word-source memory task at pretest were repeated at the 3-month follow-up, as we were unable to find additional words that did not overlap with any of the words used in training. We deem it unlikely that the words in the 3-month follow-up repetition lag task were remembered three-and-a-half months later, but the moderately related word pairs in the word-source task may have been, which might have contributed to maintenance or improvement at follow-up in both groups and hampered our ability to identify near transfer.

In conclusion, the current study replicated previous findings of repetition lag training success, extended these findings to a new paradigm, and demonstrated for the first time that repetition lag training elevates estimates of recollection. Indeed, after training recollection in this group of seniors, whose memory was normal but in the following text average, was indistinguishable from that of younger adults, and the recollection gains were maintained for three months. Nevertheless, repetition lag training did not transfer to any of a number of other tasks thought to rely on recollection, or to a number of questionnaires thought to be sensitive to subjective feelings of recollection. We urge the scientific community to delve deep into the possibility that there is no monolithic recollective memory process, but rather that recollection fractionates along very thin lines reflecting the very specific representations being remembered.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

## References


Anderson, N. D., Ebert, P. L., Jennings, J. M., Grady, C. L., Cabeza, R., & Graham, S. J. (2008). Recollection- and familiarity-based memory in healthy aging and amnestic mild cognitive impairment. *Neuropsychology, 22,* 177–187. http://dx.doi.org/10.1037/0894-4105.22.2.177

Bailey, H., Dagenbach, D., & Jennings, J. M. (2011). The locus of the benefits of repetition-lag memory training. *Neuropsychology, Development, and Cognition Section B: Aging, Neuropsychology and Cognition, 18,* 577–593. http://dx.doi.org/10.1080/13825585.2011.591921

Ball, K., Berch, D. B., Helmers, K. F., Jobe, J. B., Leveck, M. D., Marsiske, M., . . . the Advanced Cognitive Training for Independent and Vital Elderly Study Group. (2002). Effects of cognitive training interventions with older adults: A randomized controlled trial. *Journal of the American Medical Association, 288,* 2271–2281. http://dx.doi.org/10.1001/jama.288.18.2271

Barense, M. D., Gaffan, D., & Graham, K. S. (2007). The human medial temporal lobe processes online representations of complex objects. *Neuropsychologia, 45,* 2963–2974. http://dx.doi.org/10.1016/j.neuropsychologia.2007.05.023

Barense, M. D., Henson, R. N., Lee, A. C., & Graham, K. S. (2010). Medial temporal lobe activity during complex discrimination of faces, objects, and scenes: Effects of viewpoint. *Hippocampus, 20,* 389–401.

Barr, A., & Brandt, J. (1996). Word-list generation deficits in dementia. *Journal of Clinical and Experimental Neuropsychology, 18,* 810–822. http://dx.doi.org/10.1080/01688639608408304

Benton, A. L., & Hamsher, K. (1989). *Multilingual Aphasia Examination: Manual of instructions* (2nd ed.). Iowa City, IA: AJA Associates.

Bissig, D., & Lustig, C. (2007). Who benefits from memory training? *Psychological Science, 18,* 720–726. http://dx.doi.org/10.1111/j.1467-9280.2007.01966.x

Boller, B., Jennings, J. M., Dieudonné, B., Verny, M., & Ergis, A.-M. (2012). Recollection training and transfer effects in Alzheimer's disease: Effectiveness of the repetition-lag procedure. *Brain and Cognition, 78,* 169–177. http://dx.doi.org/10.1016/j.bandc.2011.10.011

Cabeza, R., Anderson, N. D., Locantore, J. K., & McIntosh, A. R. (2002). Aging gracefully: Compensatory brain activity in high-performing older adults. *NeuroImage, 17,* 1394–1402. http://dx.doi.org/10.1006/nimg.2002.1280

Canadian Centre on Substance Abuse. (2011). *Alcohol and health in Canada: A summary of evidence and guidelines for low-risk drinking*. Retrieved from http://www.ccsa.ca/Eng/topics/alcohol/drinking-guidelines/Pages/default.aspx

Cansino, S., Estrada-Manilla, C., Hernández-Ramos, E., Martínez-Galindo, J. G., Torres-Trejo, F., Gómez-Fernández, T., . . . Rodríguez-Ortiz, M. D. (2013). The rate of source memory decline across the adult life span. *Developmental Psychology, 49,* 973–985. http://dx.doi.org/10.1037/a0028894

Chapman, S. B., Aslan, S., Spence, J. S., Hart, J. J., Jr., Bartz, E. K., Didehbani, N., . . . Lu, H. (2015). Neural mechanisms of brain plasticity with complex cognitive training in healthy seniors. *Cerebral Cortex, 25,* 396–405. http://dx.doi.org/10.1093/cercor/bht234

Chen, T., & Naveh-Benjamin, M. (2012). Assessing the associative deficit of older adults in long-term and short-term/working memory. *Psychology and Aging, 27,* 666–682. http://dx.doi.org/10.1037/a0026943

Craik, F. I. M., & Anderson, N. D. (1999). Applying cognitive research to problems of aging. In D. Gopher & A. Koriat (Eds.), *Attention and performance XVII* (pp. 583–615). Cambridge, MA: MIT Press.

Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (2000). *California Verbal Learning Test* (2nd ed.). San Antonio, TX: The Psychological Corporation.

Dixon, R. A., & Hultsch, D. F. (1984). The Metamemory in Adulthood (MIA) instrument. *Psychological Documents, 14,* 3.

Dobbs, A. R., & Rule, B. G. (1989). Adult age differences in working memory. *Psychology and Aging, 4,* 500–503. http://dx.doi.org/10.1037/0882-7974.4.4.500

Dudukovic, N. M., & Wagner, A. D. (2007). Goal-dependent modulation of declarative memory: Neural correlates of temporal recency decisions and novelty detection. *Neuropsychologia, 45,* 2608–2620. http://dx.doi.org/10.1016/j.neuropsychologia.2007.02.025

Ebert, P. L., & Anderson, N. D. (2009). Proactive and retroactive interference in young adults, healthy older adults, and older adults with amnestic mild cognitive impairment. *Journal of the International Neuropsychological Society, 15,* 83–93. http://dx.doi.org/10.1017/S1355617708090115

Engvig, A., Fjell, A. M., Westlye, L. T., Moberget, T., Sundseth, Ø., Larsen, V. A., & Walhovd, K. B. (2010). Effects of memory training on cortical thickness in the elderly. *NeuroImage, 52,* 1667–1676. http://dx.doi.org/10.1016/j.neuroimage.2010.05.041

Fastenau, P. S., Denburg, N. L., & Mauer, B. A. (1998). Parallel short forms for the Boston Naming Test: Psychometric properties and norms for older adults. *Journal of Clinical and Experimental Neuropsychology, 20,* 828–834. http://dx.doi.org/10.1076/jcen.20.6.828.1105

Finn, M., & McDonald, S. (2015). Repetition-lag training to improve recollection memory in older people with amnestic mild cognitive impairment. A randomized controlled trial. *Neuropsychology, Development, and Cognition Section B: Aging, Neuropsychology and Cognition, 22,* 244–258. http://dx.doi.org/10.1080/13825585.2014.915918

Flegal, K. E., & Lustig, C. (2016). You can go your own way: Effectiveness of participant-driven versus experimenter-driven processing strategies in memory training and transfer. *Neuropsychology, Development, and Cognition Section B: Aging, Neuropsychology and Cognition, 23,* 389–417. http://dx.doi.org/10.1080/13825585.2015.1108386

Glisky, E. L., Polster, M. R., & Routhioux, B. C. (1995). Double dissociation between item and source memory. *Neuropsychology, 9,* 229–235. http://dx.doi.org/10.1037/0894-4105.9.2.229

Guild, E. B., Vasquez, B. P., Maione, A. M., Mah, L., Ween, J., & Anderson, N. D. (2014). Dynamic working memory performance in individuals with single-domain amnestic mild cognitive impairment. *Journal of Clinical and Experimental Neuropsychology, 36,* 751–760. http://dx.doi.org/10.1080/13803395.2014.941790

Hart, R. P., Kwentus, J. A., Wade, J. B., & Taylor, J. R. (1988). Modified Wisconsin Card Sorting Test in elderly normal, depressed and demented patients. *Clinical Neuropsychologist, 2,* 49–56. http://dx.doi.org/10.1080/13854048808520085

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General, 108,* 356–388. http://dx.doi.org/10.1037/0096-3445.108.3.356

Horne, J. A., & Ostberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International Journal of Chronobiology, 4,* 97–110.

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language, 30,* 513–541. http://dx.doi.org/10.1016/0749-596X(91)90025-F

Jennings, J. M., & Jacoby, L. L. (1993). Automatic versus intentional uses of memory: Aging, attention, and control. *Psychology and Aging, 8,* 283–293. http://dx.doi.org/10.1037/0882-7974.8.2.283

Jennings, J. M., & Jacoby, L. L. (1997). An opposition procedure for detecting age-related deficits in recollection: Telling effects of repetition. *Psychology and Aging, 12,* 352–361. http://dx.doi.org/10.1037/0882-7974.12.2.352

Jennings, J. M., & Jacoby, L. L. (2003). Improving memory in older adults: Training recollection. *Neuropsychological Rehabilitation, 13,* 417–440. http://dx.doi.org/10.1080/09602010244000390

Jennings, L. E. C., Lopina, E. C., & Dagenbach, D. (2015). Improving memory and executive function in older adults with memory impair-


This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

ments through repetition-lag training. In D. S. Lindsay, C. M. Kelley, A. P. Yonelinas, & H. L. Roediger III (Eds.), *Remembering: Attributions, processes, and control in human memory. Essays in honor of Larry Jacoby* (pp. 252–268). New York, NY: Psychology Press.

Jennings, J. M., Webster, L. M., Kleykamp, B. A., & Dagenbach, D. (2005). Recollection training and transfer effects in older adults: Successful use of a repetition-lag procedure. *Neuropsychology, Development, and Cognition Section B: Aging, Neuropsychology and Cognition, 12,* 278–298. http://dx.doi.org/10.1080/138255890968312

Jonides, J., Marshuetz, C., Smith, E. E., Reuter-Lorenz, P. A., Koeppe, R. A., & Hartley, A. (2000). Age differences in behavior and PET activation reveal differences in interference resolution in verbal working memory. *Journal of Cognitive Neuroscience, 12,* 188–196. http://dx.doi.org/10.1162/089892900561823

Karbach, J., & Verhaeghen, P. (2014). Making working memory work: A meta-analysis of executive-control and working memory training in older adults. *Psychological Science, 25,* 2027–2037. http://dx.doi.org/10.1177/0956797614548725

Kim, H. (2011). Neural activity that predicts subsequent memory and forgetting: A meta-analysis of 74 fMRI studies. *NeuroImage, 54,* 2446–2461. http://dx.doi.org/10.1016/j.neuroimage.2010.09.045

Kimura, H. M., Hirose, S., Kunimatsu, A., Chikazoe, J., Jimura, K., Watanabe, T., . . . Konishi, S. (2010). Differential temporo-parietal cortical networks that support relational and item-based recency judgments. *NeuroImage, 49,* 3474–3480. http://dx.doi.org/10.1016/j.neuroimage.2009.11.003

Koen, J. D., & Yonelinas, A. P. (2014). The effects of healthy aging, amnestic mild cognitive impairment, and Alzheimer's disease on recollection and familiarity: A meta-analytic review. *Neuropsychology Review, 24,* 332–354. http://dx.doi.org/10.1007/s11065-014-9266-5

Kuçera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English*. Providence, RI: Brown University Press.

Lachman, M. E., Bandura, M., Weaver, S. L., & Elliot, E. (1995). Assessing memory control beliefs: The Memory Controllability Inventory. *Aging and Cognition, 2,* 67–84.

Lawton, M. P., & Brody, E. M. (1969). Assessment of older people: Self-maintaining and instrumental activities of daily living. *Gerontologist, 9,* 179–186. http://dx.doi.org/10.1097/00006199-197005000-00029

Lee, A. C., Buckley, M. J., Pegman, S. J., Spiers, H., Scahill, V. L., Gaffan, D., . . . Graham, K. S. (2005). Specialization in the medial temporal lobe for processing of objects and scenes. *Hippocampus, 15,* 782–797. http://dx.doi.org/10.1002/hipo.20101

Lustig, C., & Flegal, K. E. (2008). Targeting latent function: Encouraging effective encoding for successful memory training and transfer. *Psychology and Aging, 23,* 754–764. http://dx.doi.org/10.1037/a0014295

Mandler, G. (1980). Recognizing: The judgment of previous occurrence. *Psychological Review, 87,* 252–271. http://dx.doi.org/10.1037/0033-295X.87.3.252

Meusel, L.-A., Grady, C. L., Ebert, P. E., & Anderson, N. D. (2017). Brain-behavior relationships in source memory: Effects of age and memory ability. *Cortex, 91,* 221–233. http://dx.doi.org/10.1016/j.cortex.2016.12.023

Mitchell, K. J., & Johnson, M. K. (2009). Source monitoring 15 years later: What have we learned from fMRI about the neural mechanisms of source memory? *Psychological Bulletin, 135,* 638–677. http://dx.doi.org/10.1037/a0015849

Mundy, M. E., Downing, P. E., Dwyer, D. M., Honey, R. C., & Graham, K. S. (2013). A critical role for the hippocampus and perirhinal cortex in perceptual learning of scenes and faces: Complementary findings from amnesia and fMRI. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience, 33,* 10490–10502. http://dx.doi.org/10.1523/JNEUROSCI.2958-12.2013

Naveh-Benjamin, M., Shing, Y. L., Kilb, A., Werkle-Bergner, M., Lindenberger, U., & Li, S. C. (2009). Adult age differences in memory for name-face associations: The effects of intentional and incidental learning. *Memory, 17,* 220–232. http://dx.doi.org/10.1080/09658210802222183

Nyberg, L., Sandblom, J., Jones, S., Neely, A. S., Petersson, K. M., Ingvar, M., & Bäckman, L. (2003). Neural correlates of training-related memory improvement in adulthood and aging. *Proceedings of the National Academy of Sciences of the United States of America, 100,* 13728–13733. http://dx.doi.org/10.1073/pnas.1735487100

Old, S. R., & Naveh-Benjamin, M. (2008). Differential effects of age on item and associative measures of memory: A meta-analysis. *Psychology and Aging, 23,* 104–118. http://dx.doi.org/10.1037/0882-7974.23.1.104

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 9,* 97–113. http://dx.doi.org/10.1016/0028-3932(71)90067-4

Owen, A. M., Hampshire, A., Grahn, J. A., Stenton, R., Dajani, S., Burns, A. S., . . . Ballard, C. G. (2010). Putting brain training to the test. *Nature, 465,* 775–778. http://dx.doi.org/10.1038/nature09042

Petrides, M., & Milner, B. (1982). Deficits on subject-ordered tasks after frontal- and temporal-lobe lesions in man. *Neuropsychologia, 20,* 249–262. http://dx.doi.org/10.1016/0028-3932(82)90100-2

Ranganath, C. (2010). A unified framework for the functional organization of the medial temporal lobes and the phenomenology of episodic memory. *Hippocampus, 20,* 1263–1290. http://dx.doi.org/10.1002/hipo.20852

Rebok, G. W., Carlson, M. C., & Langbaum, J. B. (2007). Training and maintaining memory abilities in healthy older adults: Traditional and novel approaches. *The Journals of Gerontology: Series B, Psychological Sciences and Social Sciences, 62,* 53–61. http://dx.doi.org/10.1093/geronb/62.special_issue_1.53

Saksida, L. M., & Bussey, T. J. (2010). The representational-hierarchical view of amnesia: Translation from animal to human. *Neuropsychologia, 48,* 2370–2384. http://dx.doi.org/10.1016/j.neuropsychologia.2010.02.026

Spencer, W. D., & Raz, N. (1995). Differential effects of aging on memory for content and context: A meta-analysis. *Psychology and Aging, 10,* 527–539. http://dx.doi.org/10.1037/0882-7974.10.4.527

Stamenova, V., Jennings, J. M., Cook, S. P., Gao, F., Walker, L. A. S., Smith, A. M., & Davidson, P. S. R. (2017). Repetition-lag memory training is feasible in patients with chronic stroke, including those with memory problems. *Brain Injury, 31,* 57–67. http://dx.doi.org/10.1080/02699052.2016.1222081

Stamenova, V., Jennings, J. M., Cook, S. P., Walker, L. A. S., Smith, A. M., & Davidson, P. S. R. (2014). Training recollection in healthy older adults: Clear improvements on the training task, but little evidence of transfer. *Frontiers in Human Neuroscience, 8,* 898. http://dx.doi.org/10.3389/fnhum.2014.00898

Staresina, B. P., Duncan, K. D., & Davachi, L. (2011). Perirhinal and parahippocampal cortices differentially contribute to later recollection of object- and scene-related event details. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience, 31,* 8739–8747. http://dx.doi.org/10.1523/JNEUROSCI.4978-10.2011

Takeuchi, H., Sekiguchi, A., Taki, Y., Yokoyama, S., Yomogida, Y., Komuro, N., . . . Kawashima, R. (2010). Training of working memory impacts structural connectivity. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience, 30,* 3297–3303. http://dx.doi.org/10.1523/JNEUROSCI.4611-09.2010

Takeuchi, H., Taki, Y., Nouchi, R., Hashizume, H., Sekiguchi, A., Kotozaki, Y., . . . Kawashima, R. (2014). Effects of multitasking-training on gray matter structure and resting state neural mechanisms. *Human Brain Mapping, 35,* 3646–3660. http://dx.doi.org/10.1002/hbm.22427

Teng, E. L., & Chui, H. C. (1987). The modified mini-mental state (3MS) examination. *The Journal of Clinical Psychiatry, 48,* 314–318.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

Thakral, P. P., Wang, T. H., & Rugg, M. D. (2015). Cortical reinstatement and the confidence and accuracy of source memory. *NeuroImage, 109,* 118–129. http://dx.doi.org/10.1016/j.neuroimage.2015.01.003

Troyer, A. K., & Rich, J. B. (2002). Psychometric properties of a new metamemory questionnaire for older adults. *The Journals of Gerontology Series B, Psychological Sciences and Social Sciences, 57,* 19–27. http://dx.doi.org/10.1093/geronb/57.1.P19

Verhaeghen, P., Marcoen, A., & Goossens, L. (1992). Improving memory performance in the aged through mnemonic training: A meta-analytic study. *Psychology and Aging, 7,* 242–251. http://dx.doi.org/10.1037/0882-7974.7.2.242

Wechsler, D. (1981). *The Wechsler Adult Intelligence Scale-Revised manual*. San Antonio, TX: The Psychological Corporation.

Wechsler, D. (1987). *The Wechsler Memory Scale—Revised manual*. San Antonio, TX: The Psychological Corporation.

Wechsler, D. (1991). *The Wechsler Adult Intelligence Scale-III manual*. San Antonio, TX: The Psychological Corporation.

Wechsler, D. (1997). *The Wechsler Memory Scale—III manual*. San Antonio, TX: The Psychological Corporation.

Wechsler, D. (1999). *The Wechsler Abbreviated Scale of Intelligence manual*. San Antonio, TX: The Psychological Corporation.

Welsh, K., Breitner, J., & Magruder-Habib, K. (1993). Detection of dementia in the elderly using telephone screening of cognitive status. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology, 6,* 103–110.

Winocur, G., & Moscovitch, M. (1983). Paired-associate learning in institutionalized and noninstitutionalized old people: An analysis of interference and context effects. *Journal of Gerontology, 38,* 455–464. http://dx.doi.org/10.1093/geronj/38.4.455

Zachary, R. A. (1986). *Shipley Institute of Living Scale: Revised manual*. Los Angeles, CA: Western Psychological Services.

Zigmond, A. S., & Snaith, R. P. (1983). The hospital anxiety and depression scale. *Acta Psychiatrica Scandinavica, 67,* 361–370. http://dx.doi.org/10.1111/j.1600-0447.1983.tb09716.x

Received March 8, 2017
Revision received October 10, 2017
Accepted October 17, 2017 ■

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.