

## **Improving memory in older adults: Training recollection**

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We explore a novel theory-guided approach for training memory in older adults that distinguishes between recollection and automatic influences. Participants were given multiple trials of a continuous recognition task in which they had to use recollection to identify repeated items. After each correct trial, the number of intervening items between repetitions was gradually increased (incremented-difficulty approach). Initially, accurate identification only occurred with two intervening items, which increased to 28 items following 6 hours of training. A second group of participants was given an equal amount of practice with the task but the number of intervening items was varied randomly across trials, independent of accuracy. These individuals showed significantly smaller gains in recollection. Results suggest that an incremented-difficulty approach can enhance the ability to recollect information across increasing delay intervals. Implications for future training efforts are discussed.

Age-related differences in episodic memory have fostered many studies seeking to improve performance in older individuals. Typically, these efforts to enhance memory have adopted elaborate encoding schemes, such as pegword or story mnemonics (Hill, Allen, & McWhorter, 1991; Wood & Pratt, 1987), the method of loci (Kliegl, Smith, & Baltes, 1989; Robertson-Tchabo, Hausman, & Arenberg, 1976; Rose & Yesavage, 1983; Yesavage & Rose, 1983), and face-name association techniques (Yesavage, 1983, 1984; Yesavage, Rose, & Bower, 1983). More recently, these methods have been

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combined in a more comprehensive learning programme that is often acquired through self-study (Andrews, Kinsella, & Murphy, 1996; Scogin, Storandt, & Lott, 1985) or accompanied by attention and relaxation training in a multi-factorial approach (Neely & Baeckman, 1993, 1995). When the outcome of these efforts are examined across a large number of studies, the general picture suggests that teaching mnemonics can produce significant improvements in memory performance (see Verhaeghen, Marcoen, & Goossens, 1992 for a metanalysis), with evidence of maintenance for at least 6 months (Neely & Baeckman, 1993; Scogin & Prohaska, 1992).

An alternative remediation approach, however, has focused on training individuals to acquire new information by having them repeatedly try to remember that material across gradually increasing delays. Known as the spaced retrieval technique (Camp & Schaller, 1989; Landauer & Bjork, 1978; Schacter, Rich, & Stamp, 1985)<sup>1</sup>, this approach is designed to create habitual, over-learned responses that allow memory disordered participants to acquire a small amount of critical information. In doing so, it has helped Alzheimer's patients learn new names in their social/care settings (Camp & Schaller, 1989; Clare, Wilson, Breen, & Hodges, 1999), has helped them learn important routines, such as sipping water after swallowing food (Brush & Camp, 1998), and has helped them remember everyday objects (Cherry, Simmons, & Camp, 1999). We too are interested in enhancing memory performance through use of an incremented-difficulty technique, but our approach is somewhat different in that the rationale rests on a dual process theory of memory, which draws a distinction between consciously controlled memory processes (recollection) and automatic influences (Jacoby, 1991; Mandler, 1980). Our technique is designed to build on prior work done to show the utility of that distinction for understanding memory function (e.g., Jacoby, 1991; Jacoby, Toth, & Yonelinas, 1993), and before describing it, we briefly discuss support for a procedure that distinguishes between these processes. To anticipate, our goal was to train recollection, a process that entails the conscious retrieval of specific details of an event, and that, when measured in the lab, has been shown to be highly correlated with everyday memory complaints endorsed by older adults (Jacoby, Jennings, & Hay, 1996).

The utility of distinguishing between recollection and automatic memory has been well established through the use of *opposition procedures* (e.g., Dywan & Jacoby, 1990; Jacoby, 1991; Jacoby et al., 1993; Jacoby, Yonelinas, & Jennings, 1997; Jennings & Jacoby, 1993, 1997). For example, Jennings and Jacoby (1997) introduced their application of this approach by noting that older adults are prone to tell a story repeatedly to the same audience. They argued that

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<sup>1</sup>See Glisky, Schacter, and Tulving (1986) for a similar approach known as the method of vanishing cues.

this unwanted repetition reflects an automatic, strengthening effect that arises from an earlier telling of the story, which is not successfully opposed by recollection for having already related it. The notion is that prior telling of the story makes it come more readily to mind later, and those with a well-functioning memory can avoid repeating themselves by recollecting information that lets them know it has already been told. In addition, the delay interval between repetitions can be important for diagnosing deficits in recollection. It would likely be disconcerting to learn that one had repeated a story within 5 min, but not be concerning to find one had done so after a month, since after a sufficiently long delay even those with a high functioning memory will sometimes repeat themselves. The experimental procedure used by Jennings and Jacoby (1997) was meant to measure a deficit in recollection similar to that involved in unwanted repetition. Young and older adults read aloud a list of words that they were asked to remember, and were then given a yes/no recognition test. For that test, they were shown words they had seen at study and new words. The new words were repeated after 0, 3, or 12 intervening items occurred (lags), and the second presentation of these new words was referred to as "repetitions". For the recognition test, participants were told to respond "yes" to words they had seen at study, but respond "no" to new words and repetitions. The repetitions were the critical items. The first test presentation of those items was expected to increase their familiarity, such that participants could misattribute this familiarity to the prior study phase, confuse repetitions with studied words, and mistakenly respond "yes". However, if participants could consciously recollect the source of a repeated test word's presentation, then any influence of familiarity would be opposed and they would correctly respond "no".

Telling participants to respond "no" to repetitions placed familiarity, an automatic influence of memory, and recollection in opposition. Familiarity would lead participants to mistakenly respond "yes" whereas recollection would allow participants to correctly respond "no". If participants responded "yes" significantly more when items were repeated than when they were first shown at test, one can conclude that they were unable to recollect the first presentation of those items, but were influenced by an increase in their familiarity. The results revealed that with only three intervening items, older adults showed an unwanted repetition effect. Repetition of a test word was more likely to be mistakenly called "old" than was its first presentation, showing an effect of familiarity in the absence of recollection. Moreover, older adults responded "yes" to more repeated items than young adults at Lag 3, revealing a significant age difference in recollection, which increased by Lag 12 (Jennings & Jacoby, 1997).

Because of this age-related deficit and the role that impaired recollection can play in everyday memory errors, such as repeating oneself (Jacoby et al., 1996), we targeted recollection for memory training by extending the repetition-lag procedure described above. In those experiments, elderly adults performed

well when only one item intervened between the first and second presentation of a repeated word (Jennings & Jacoby, 1997), which shows they were able to recollect information when the delay between repetitions was very short. In the experiment reported here, we explored the possibility that slowly moving the elderly from a situation in which they were able to use recollection accurately to more demanding circumstances would allow them to adapt their recollective process to meet those demands. Specifically, we employed the method from our repetition-lag experiment (Jennings & Jacoby, 1997) to see if we could train older adults to successfully recollect repeated items across ever-lengthening delays, by slowly increasing the lag intervals across training sessions as performance improved. We view this approach as an incremented-difficulty technique for improving recollection, since whatever it is participants do to recollect information at a short easy interval is being trained to be applied at longer delays. It was hoped that with repeated work and feedback, this incrementing procedure would lead the elderly to show accurate recollection across extended intervals.

Our training procedure is similar to the spaced retrieval technique (e.g., Brush & Camp, 1998; Camp & Schaller, 1989; Cherry et al., 1999; Clare et al., 1999) mentioned earlier. That technique has been adapted to utilise the form of memory preserved by amnesics and Alzheimer's patients, namely automatic influences of memory, by helping them to over-learn specific information through repeated retrieval across lengthening delays. Similar to the spaced retrieval technique, our procedure also gradually increases task difficulty to enhance memory performance. However, the critical difference between the two approaches is that we constantly change materials during training, using many different study and test lists rather than holding materials constant, as is done with the other approach. The goal of our procedure was to try to target the general use of recollection whereas the spaced retrieval technique is aimed at recovery of a particular response as a function of automatic processing. Learning a specific response has proven useful for teaching information to those with severe memory deficits, but our hope is to improve a retrieval process that has experienced age-related declines and is important for older adults to function well in everyday life (Jacoby et al., 1996).

In order to evaluate whether our incremented-difficulty approach could have a beneficial effect on recollection, we considered three questions: The first, and most obvious one, is whether recollection would improve across the training sessions. To gauge improvements, we compared the length of the interval between repetitions at which older adults could perform successfully at the beginning and end of training. If interval length increased significantly during the training procedure, it would indicate that our technique had some sort of positive effect. However, such an effect cannot necessarily be attributed to the incremental technique. Instead, an increase in lag interval may reflect a general practice effect in performing the task; so, the second question we

addressed was whether any influence of training was simply due to practice. To do so, we tested a control group who received the same amount of practice as our experimental participants without the gradual incrementing procedure. An advantage of the experimental over the control condition would provide evidence for the effectiveness of the incrementing approach. Assuming our incrementing technique does produce effects that extend beyond general practice, a third issue remains to be addressed. In order to perform successfully, participants must respond "no" to two-thirds of the test items (one third of the test items consist of new words presented for the first time, and one third comprise those same items repeated a second time), which means we may not have actually improved recollection. Instead, we may have only altered response bias such that participants learn to say "no" more frequently. Consequently, we also looked at whether there were any significant changes in response bias across our procedure for both the experimental and control groups.

## METHOD

### Participants

Twenty-eight elderly adults volunteered to take part in the current study. Participants were high functioning, well educated, living independently in the community, and were in self-reported good health. Data from four participants had to be discarded. One participant made key-pressing errors throughout training, consequently, performance could not be evaluated. The second participant showed extremely high recollection and performed at ceiling immediately so no effect of training was possible. Lastly, data for the other two participants were flawed due to experimenter error; these individuals had not been advanced through the training procedure with the performance-contingent increase in lag intervals that was requisite for our approach (see procedure section). The remaining 24 participants fell equally into the experimental and control groups. Participants in both groups were matched as closely as possible for age, gender, education, and level of recollection as indexed by previous performance (e.g., Jennings & Jacoby, 1997). The experimental group consisted of six males and six females with an average age of 73 years ( $SE = 1.60$ ), an average of 16.92 years of education ( $SE = 0.43$ ), and an average score of 81% ( $SE = 3.86\%$ ) on the Mill Hill Vocabulary Test (Raven, 1965). The control group consisted of seven males and five females with an average age of 73.25 years ( $SE = 1.59$ ), an average of 17.08 years of education ( $SE = 0.76$ ), and an average score of 74% ( $SE = 3.83\%$ ) on the Mill Hill Vocabulary Test (Raven, 1965). There were no significant differences in age,  $t(22) = -0.11$ ,  $p > .05$ , education,  $t(22) = -0.19$ ,  $p > .05$ , or Mill Hill scores,  $t(22) = 1.19$ ,  $p > .05$ , between the two groups.

## Materials

A total of 2100 concrete nouns were chosen from the Toronto Word Pool (Friendly, Franklin, Hoffman, & Rubin, 1982) and Thorndike and Lorge word norms (1944). Of these, 1680 words were divided into 56 lists of 30 words. These lists were balanced for frequency of occurrence in the language. Twenty-eight lists acted as study items for the training sessions while the other lists comprised the new items that were repeated. The remaining 420 words were divided into 28 lists of 15 words and acted as filler items. Six items from each filler list were randomly selected and presented as new words that were not repeated. These items were required to create the appropriate spacing for the lag intervals. Lists designated as study, new, and filler were identical for each participant; an approach that was adopted as consistent with neuropsychological tests of memory, such as the California Verbal Learning Task (Delis, Kramer, Kaplan, & Ober, 1987). Since we used a relatively large number of study and distractor lists that were balanced for word frequency, were randomly assigned to different conditions (study, new, filler), and were held constant across the training and control groups, it seemed highly unlikely that a list effect could be mistaken for one of training.<sup>2</sup> List items were presented on a PC compatible computer in lower case letters centered in the middle of the screen. The character size of the stimuli was approximately  $3 \times 5$  mm.

## Procedure

Participants were given four training sessions a day for 7 days with a weekend break from training scheduled after Day 3 or Day 4 depending on the individual participant's schedule (the occurrence of this break was balanced as well as possible across the two groups). Other than the weekend break, training days were consecutive. Each training session was an abbreviated version of the recognition lag procedure described earlier (Jennings & Jacoby, 1997), and consisted of a study and test phase, which made use of one study, one new, and one filler list. During the study phase each word was presented for 2 s, and participants were asked to read the word aloud and remember it. The opposition test phase followed, in which participants were shown the 30 study words, 30 "new" words, and these 30 new words were repeated at one of two different lags. Participants were asked to identify any words they had read aloud from study; so they were to respond "yes" to study words and "no" to new items during both their first and second presentation by pressing one of two keys.

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<sup>2</sup>This idea seems particularly valid given different participants showed improvements at different times (sessions) during training, which means improvements were unrelated to which study/test lists were being used.

When participants responded correctly, the computer beeped and the message "correct" appeared on the screen. When they made an error no message appeared. Participants were asked to pay attention to the feedback and to try to learn from their mistakes. They were given unlimited time during the test phase, and so each of the four sessions required about 10 to 15 min depending on the individual being trained.

*Experimental group.* The incrementing procedure was implemented by gradually increasing the lag intervals for the experimental group as a function of performance. Participants had to attain a certain criterion in order for the lag intervals to increase, and this criterion was based on the level of accuracy shown by young adults in previous work (Jennings & Jacoby, 1997). Criterion was set for each session such that participants could only make one error on the repeated items for Lags 1 to 4, and two errors for Lags 8 to 48. The incrementing procedure worked as follows. In Session 1, 15 words were repeated after one intervening item had occurred between the first and second presentation of each word. The other 15 words were repeated after two intervening items. If participants performed to criterion at both intervals, then in Session 2 the lag conditions were increased so that 15 words were again repeated after one intervening item and 15 words were repeated after three intervening items had been presented. If participants again reached criterion, the lags increased to two and four items and so on. The lag interval pairs used for training consisted of 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; and finally, 20 and 48. These pairs were chosen such that participants were always working at one lag interval they had already mastered and should therefore be easy, and a second interval that was new and more difficult. If participants did not achieve criterion at *both* lags, they continued to work at those intervals for as many sessions as needed to meet criterion. Once criterion was reached the lag intervals increased in the order listed above. An example of the performance-dependent increase in lag intervals administered to Experimental Participant 1 is shown in Table 1. As can be seen, this participant required two trials to meet criterion performance at Lags 1 and 2. He then needed two trials to achieve criterion at Lags 1 and 3, six trials to master criterion at Lags 2 and 4 and so on, until the last session when he reached criterion at Lags 8 and 24.

In order to evaluate gains in performance, we first determined the length of the interval at which participants could perform to criterion on the first day of training. This interval was believed to represent participants' ability to perform the task before training had much of an influence. To assess performance on the first day, we looked at the length of the lag interval at which participants could perform to criterion by the end of Session 3. This approach allowed Sessions 1 and 2 to provide experience with the mechanics of the task, such as acclimatising to the stimulus presentation, the beep associated with positive feedback,

TABLE 1  
Pattern of performance-dependent lag interval increases  
across 7 days of training for an experimental participant

<i>Day</i>	<i>Session number</i>	<i>Lags</i>	
1	1	1	2
	2	1	2
	3	1	3
	4	1	3
2	5	2	4
	6	2	4
	7	2	4
	8	2	4
3	9	2	4
	10	2	4
	11	2	8
	12	2	8
4	13	4	12
	14	4	12
	15	4	12
	16	4	12
5	17	4	16
	18	4	16
	19	4	16
	20	4	16
6	21	4	16
	22	8	20
	23	8	20
	24	8	20
7	25	8	0
	26	8	24
	27	8	24
	28	8	24

and which computer keys to use for responding without negatively influencing a participant's score. So if a participant failed to perform to criterion at Lags 1 and 2 during the first two sessions but met criterion at both these lags during Session 3 then we considered their starting performance to be two intervening items. If they only met criterion for Lag 1 during any of the first three sessions then their starting point was considered to be one intervening item. However, if participants did perform to criterion during Sessions 1 and/or 2 then we began increasing the lag intervals in the manner described above and included those prior sessions when establishing their initial performance level. For example,

the participant whose training is outlined in Table 1 performed to criterion at Lags 1 and 2 in Session 2, leading us to increase the lag intervals to 1 and 3 in Session 3. However, he was unable to meet criterion in Session 3 suggesting his level of initial performance was actually two intervening items.

To establish whether participants improved across training, we looked for the longest lag interval at which they were able to achieve criterion by the end of the 7-day procedure. Considering again Experimental Participant 1 (Table 1), one can see that he was working at Lags 8 and 24 on the very last session of his last day (Session 28). As mentioned above, he was able to reach criterion during that session and thus the longest lag interval at which he could perform accurately by the end of training consisted of 24 intervening items. However, if he had not met criterion during that session, then the highest lag interval that he would have completed successfully would have comprised 20 intervening items, which was passed during the first session of his last training day (Session 25).

*Control group.* Control participants received the same training programme as their experimental counterparts with the exception of the incrementing procedure. That is, they did not experience gradual increases in lag pairs as a function of successful criterion performance. Instead, each control was yoked to an experimental participant such that the control participant received the same pair intervals and the same number of sessions for each interval pair as his/her experimental partner. However, the sessions for a particular pair of intervals were not contiguous, and interval length did not increase gradually across trials when criterion was met. Instead, we wanted the pair intervals to be randomly ordered across sessions, such that a control participant might receive the following pairs during a single training day: Lags 2 and 8; followed by lags 12 and 32; followed by 1 and 2; followed by 4 and 16. In this manner, the participant gained as much experience and practice with the task as his/her experimental partner but did not experience a gradual increase in lag intervals.

One accommodation, however, had to be made to this random approach to evaluate a control participant's level of performance on the first versus last training day in a manner comparable to that used with the experimental group. To assess the control group's level of functioning on the first day of training, we gave them Lag intervals 1 and 2; 1 and 3; 2 and 4; and lastly 2 and 8. This sequencing across the four sessions was identical to what a good experimental participant could experience if he/she passed Lags 1 and 2 in Session 1, then passed Lags 1 and 3 in Session 2, then passed Lags 2 and 4 during Session 3, and was thus given Lags 2 and 8 for Session 4. We presented the interval pairs to the control group in this manner, rather than randomly ordering them across the four sessions, to determine the highest level at which each control participant

was capable of functioning before training could have much impact. Similar to the experimental group we determined the longest interval at which control participants could perform to criterion by the end of the third session. Thus if participants achieved criterion at Lags 2 and 4 in Session 3 then their level of performance would consist of four intervening items. If they failed to reach criterion in Session 3, but passed Lags 1 and 3 during Session 2, then their starting score was comprised of three intervening items. Alternatively, if they did not pass Lag 3, we then looked at whether criterion was met at either Lags 1 or 2 during any of the first three sessions to establish their starting score as one or two intervening items, as was done with the experimental individuals (see above). We chose this approach because random ordering on the first day would not have provided the ascending order of short lag intervals necessary to establish each control participant's initial performance. However, at the same time we did not want to use the performance-dependent procedure that we had applied with our experimental participants.<sup>3</sup>

To examine whether the control group showed any gains in performance by the end of training and to compare those gains with the experimental group we had to make a second accommodation to the random ordering of lags. Specifically, during the last session of the final day of training (Session 28) we gave the control participants the same lag interval pairs that their experimental partners received in their final session. So the control participant who was yoked with Experimental Participant 1 (Table 1) was also given Lags 8 and 24 during his final session. Giving both groups of participants the same lag intervals during their final session allowed us to determine whether they each benefited equally from their respective training experience and could achieve the same degree of performance (i.e., perform to criterion at the same lag intervals) after receiving the same amount of practice with the task. However, because our starting assumption was that the control group would not experience the same benefits as the training participants we also wanted to provide the opportunity to see how closely the controls were able to match their experimental partners on the last day. Consequently, for Session 27 we gave each control participant the second highest lag interval pairs that their experimental partner had achieved, and in Session 26, the controls were given the third highest lag interval pairs as their experimental counterpart. An

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<sup>3</sup>This approach to scoring the control group gave them the opportunity to achieve a higher starting score than the experimental participants because the control group could fail Lags 1 and 2 followed by Lags 1 and 3 but then pass Lags 2 and 4, achieving a score of 4 intervening items. However, an experimental participant who failed their first two sessions would still be working at Lags 1 and 2 during Session 3 and could therefore only achieve an initial score of two intervening items.

TABLE 2  
 Pattern of lag interval increases across 7 days of training for the  
 control participant yoked with the experimental individual from  
 Table 1

<i>Day</i>	<i>Session number</i>	<i>Lags</i>	
1	1	1	2
	2	1	3
	3	2	4
	4	2	8
2	5	4	12
	6	2	8
	7	8	20
	8	1	2
3	9	4	16
	10	1	3
	11	4	12
	12	8	24
4	13	2	8
	14	4	16
	15	8	20
	16	2	4
5	17	4	16
	18	2	4
	19	8	20
	20	4	16
6	21	2	4
	22	8	24
	23	2	4
	24	4	12
7	25	2	4
	26	4	16
	27	8	20
	28	8	24

example of the lag intervals administered to the yoked control for Experimental Participant 1 is shown in Table 2. As can be seen, this individual was given Lags 8 and 24 during Session 28, Lags 8 and 20 for Session 27, and Lags 4 and 16 for Session 26; in other words, he received the three highest lag interval pairs with which his experimental mate had worked. If this control subject did not reach criterion at Lags 8 and 24, then we looked to see whether he reached criterion at Lags 8 and 20 and Lags 4 and 16 to see how closely he could approach the 24 intervening items achieved by his experimental partner. We designed the last day of training in this manner to test control participants at the highest

possible lag intervals after they had the utmost practice with the task to maximise their chances of passing these intervals. If the controls did not achieve criterion at these three lag interval pairs, then we examined their performance from Session 25; a session that always consisted of a short lag interval pair from the first day of training, such as Lags 2 and 4, at which they had been unable to reach criterion. We included these shorter lag intervals on the final day to assess whether the control participants could show even some sort of minimal gain from the previous 6 days of training, given they could not meet criterion at the longer lags. If control participants could perform to criterion during Session 25 with these short intervals, then we looked at each of their previous sessions to determine the highest lag interval at which criterion performance was shown. Alternatively, if criterion was not met during Session 25 then we concluded that the control participants had not moved beyond their initial performance and their final score was the same number of intervening items that they had reached on their first training day.<sup>4</sup>

As can be seen in Table 2, the control participant yoked to Experimental Participant 1 was administered the lag intervals for Day 1 and 7 as described above. On Days 2 through 6, however, a random ordering of lag interval pairs was presented. For example, on Day 2, the control participant received Lags 4 and 12; followed by Lags 2 and 8; followed by 8 and 20; followed by 1 and 2. In this manner, he gained as much experience and practice with the task as his experimental partner without a gradual increase in lag interval contingent on successful performance. Moreover, sessions for any given lag pair were not presented consecutively. For example, the control participant received six training sessions of Lags 2 and 4 in total, as did his experimental mate, but the sessions were presented in random order across different days. With respect to performance, this individual was able to reach criterion at Lag 2 during Session 3 of his first training day and was able to meet criterion at Lags 8 and 24 during his final training session, suggesting that he had shown a gain in performance from 2 to 24 intervening items.

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<sup>4</sup>It should be noted that we also looked at the control participants' performance on the previous training days to ensure that any inability to reach criterion on the final four training sessions was not a chance occurrence, which was unrepresentative of their performance on other days. In other words, if a participant had failed to reach criterion at all on the last day of training but had shown consistently good performance prior to that day then we would have used the highest lag intervals they had achieved before their last day for their final score. However, this situation did not occur with any of our control participants. In short, the control participants appeared to show evidence of training gains on the last day or not at all. Moreover, five of the participants who did not show any improvements in performance actually failed to maintain the same level of performance they had shown on the first day of training. That is, during the rest of their training sessions they proved unable to reliably perform at the same lag interval that they had passed during their first day.

## RESULTS

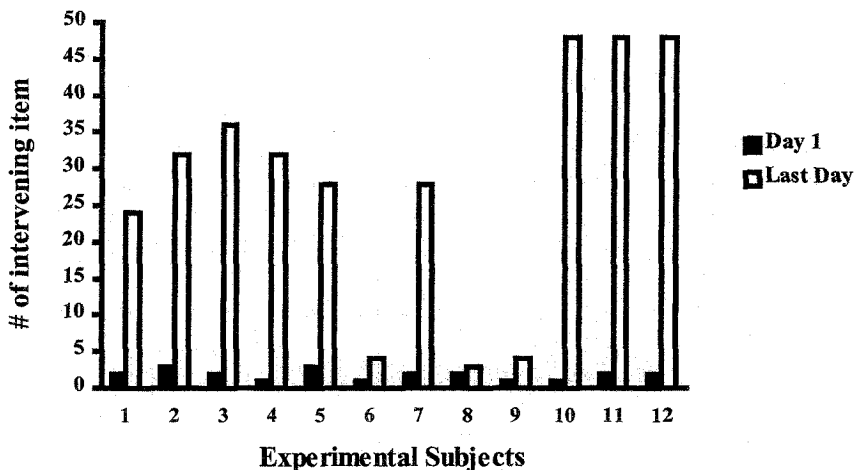
As mentioned, the effects of training on performance were evaluated by comparing the difference in interval length at which criterion was reached between the first and last days of the procedure for both groups. Once we established those intervals in the manner described above, we compared the two values to determine whether the lag intervals had increased in magnitude across training for either group. Specifically, we wanted to know whether the experimental and/or control participants were able to attain criterion at longer intervals by the end of Day 7 than at Day 1. As can be seen in Figure 1, 9 of the 12 experimental participants revealed a marked increase in interval length and the remaining 3 participants showed some improvement, although this effect was small. In contrast, the effect of the training procedure for the control group was less beneficial. Only 3 of the 12 control participants revealed marked gains in performance while the remaining 9 participants showed no progress (see Figure 2).

In order to compare the effects of training on the two groups, we took the lag interval at which criterion was achieved at the beginning and end of training for each participant, and carried out a group (experimental vs. control) by training day (beginning vs. end) analysis of variance (see Table 3 for group means). The results showed a significant main effect of group,  $F(1, 22) = 7.17, p < .05$ , and of training day,  $F(1, 22) = 26.88, p < .001$ . The latter result indicates that both groups experienced significant improvements in performance as a function of training. However, there was also a significant interaction,  $F(1, 22) = 7.02, p < .05$ , indicating that the experimental group showed much larger gains in lag interval size than the control group.<sup>5</sup> These findings suggest that the control group did improve somewhat, revealing a practice or training effect that was unrelated to the incremental aspect of our procedure. However, the experimental group displayed a benefit that more than doubled the control group's gains (Table 3) suggesting that the incrementing technique had an additional influence on performance. This difference in training effect also appears to be responsible for producing the group main effect, since the experimental group did much better than the control group overall after training, although the two groups showed similar scores on the first day.

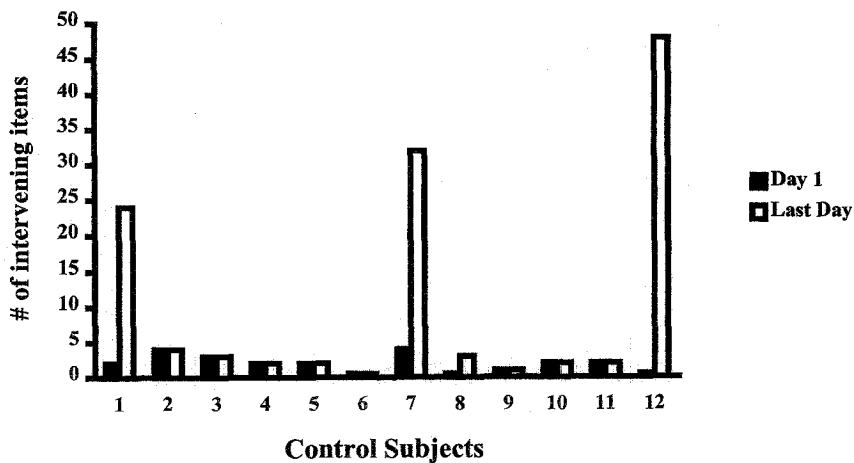
To ascertain whether the two groups were comparable prior to training, we carried out a  $2 \times 2$  analysis of variance comparing the experimental and control participants' recognition of the studied items at both the beginning and end of

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<sup>5</sup>Because of concerns about the normality assumption underlying the ANOVA we also calculated the difference between the lag intervals associated with the first and last training day and compared the experimental and control groups using a Kruskal-Wallis test. The results from this non-parametric test confirmed those of the ANOVA in showing a significant difference between the two groups in training gains,  $\chi^2(1) = 7.80, p = .005$ .



**Figure 1.** Level of performance at the beginning and end of training for individual experimental participants. Performance is measured as the number of intervening items at which participants can correctly recollect the prior occurrence of a repeated item.



**Figure 2.** Level of performance at the beginning and end of training for individual control participants. Performance is measured as the number of intervening items at which participants can correctly recollect the prior occurrence of a repeated item.

TABLE 3  
Length of lag interval at which participants could perform  
to criterion at the beginning and end of training  
for the experimental and control groups

<i>Group</i>	<i>Beginning of training</i>	<i>End of training</i>
Experimental		
<i>M</i>	1.92	27.92
<i>SE</i>	0.19	4.84
Control		
<i>M</i>	1.83	10.25
<i>SE</i>	0.41	4.52

TABLE 4  
Proportion of hits, false alarms, recognition performance and estimates of bias (C)  
at the beginning and end of training for the experimental and control participants

<i>Group</i>	<i>Beginning of training</i>				<i>End of training</i>			
	<i>Hits</i>	<i>False alarms</i>	<i>Recognition performance</i>	<i>Bias</i>	<i>Hits</i>	<i>False alarms</i>	<i>Recognition performance</i>	<i>Bias</i>
Experimental								
<i>M</i>	0.82	0.09	0.73	0.25	0.72	0.05	0.69	0.60
<i>SE</i>	0.03	0.03	0.05	0.10	0.04	0.01	0.04	0.06
Control								
<i>M</i>	0.78	0.13	0.65	0.24	0.68	0.12	0.56	0.42
<i>SE</i>	0.03	0.03	0.04	0.09	0.04	0.03	0.04	0.11

training. To measure recognition performance, we calculated the difference between the probability of responding "yes" to both study items (hits) and new items on their first presentation (false alarms). These values were obtained from the same session used to determine participants' interval length at the beginning of training (Session 3), and from the very last session of training (Session 28). The resulting difference scores (see Table 4) were compared using a group crossed with training day ANOVA, and revealed a significant main effect of group,  $F(1, 22) = 4.61, p < .05$ , and of training day,  $F(1, 22) = 4.49, p < .05$ , but no significant interaction,  $F(1, 22) = 0.53, p > .05$ . These findings indicate that the two groups did not appear to be comparable at either the beginning or end of training in terms of general recognition performance as the experimental group showed a higher level of recognition at both times. However, both groups displayed a significant drop in overall recognition across training. In hindsight, a decrease in recognition performance is not surprising given the possible proactive interference accrued from presentation of multiple

study lists across training. However, the initial recognition differences between the groups was slightly worrisome given it implies that the experimental group may have had better memory function overall. To determine whether these group differences in memory ability could account for the differential gains in training between the two groups, we carried out an analysis of covariance comparing both groups on the level of performance (lag interval size) achieved by the end of training while covarying out the effect of recognition performance measured at the beginning of training. The results showed that a significant difference between the groups in training performance remained,  $F(1, 21) = 4.98, p < .05$ , with a non-significant effect of recognition ability  $F(1, 21) = 1.63, p > .05$ , suggesting that the incrementing approach, rather than memory aptitude, was responsible for differences between the two groups.

Although these analyses suggest that recollection has improved due to our incrementing procedure, we still needed to determine whether we may have merely altered participants' bias to respond "no". Participants may have recognised that they should respond "no" to 2/3 of the trials (30 new and 30 repeated items out of 90 stimuli) and adjusted their responses accordingly. The results from the control group make this possibility unlikely. If bias alone was affected then the control group should show the same degree of bias and therefore the same amount of improvement as the experimental group. However, to ensure more directly that bias was not a confound we determined bias estimates across training for each participant by calculating  $C$ , which locates the bias criterion relative to the intersection of old and new distributions, from the hits and false alarm data obtained during the third and last sessions of training (see Snodgrass & Corwin, 1988, for a discussion of advantages of  $C$  over alternative measures of bias). If participants are responding with a completely neutral bias, then  $C$  will have a value of 0, whereas a conservative bias, or a tendency to respond "no", will produce a positive  $C$  value and a liberal bias will produce a negative  $C$  value. According to these  $C$  estimates (Table 4), there was no significant difference in the tendency to respond "no" between the two groups at the beginning or end of training,  $F(1, 22) = 0.84, p > .05$ . However, there was a significant increase in conservative bias between the first and last day of testing,  $F(1, 22) = 10.47, p < .005$ , which did not differ as a function of group,  $F(1, 22) = 1.08, p > .05$ . Given the final estimates of bias look similar for the two groups, and both groups show a change in bias from the beginning to end of training, it does not appear that a shift in the tendency to respond "no" can completely account for the improvements in accuracy that we found with our experimental participants. However, to more effectively rule out any role of bias, we conducted a second analysis of covariance comparing both groups on the level of performance (lag interval size) achieved by the end of training while covarying out the effects of bias measured at both the beginning and end of the procedure. The results showed that a significant difference between the groups in training performance remained,  $F(1, 20) = 5.53, p < .05$ , with

non-significant effects of the two bias covariates ( $F \leq 1.5$ ), suggesting that the incrementing approach, rather than bias, can account for the changes in the experimental group's performance.

Given these effects of the incrementing approach, we also wanted to examine the rate of learning across training for the nine participants in the experimental group who showed training effects. To explore learning, we determined the average lag interval these participants had achieved at the end of each training day (Figure 3). These results suggest that participants showed gradual improvements across the first three days of training, which started to accelerate from Day 4 to the end of the procedure. To test this qualitative impression, we carried out six *t*-tests at a corrected alpha level of .008 to compare performance on consecutive training days (i.e., Day 1 vs. Day 2, Day 2 vs. Day 3, etc.). The results indicated a non-significant improvement in performance between Days 1 and 2,  $t(8) = -1.85$ ,  $p = .10$ , Days 2 and 3,  $t(8) = -3.28$ ,  $p = .01$ , and Days 3 and 4,  $t(8) = -2.79$ ,  $p = .02$ , with significant improvements between Days 4 and 5,  $t(8) = -4.27$ ,  $p = .003$ , Days 5 and 6,  $t(8) = -5.37$ ,  $p = .001$ , and Days 6 and 7,  $t(8) = -4.86$ ,  $p = .001$ . These analyses confirmed our impression that learning seemed to accelerate as training continued.

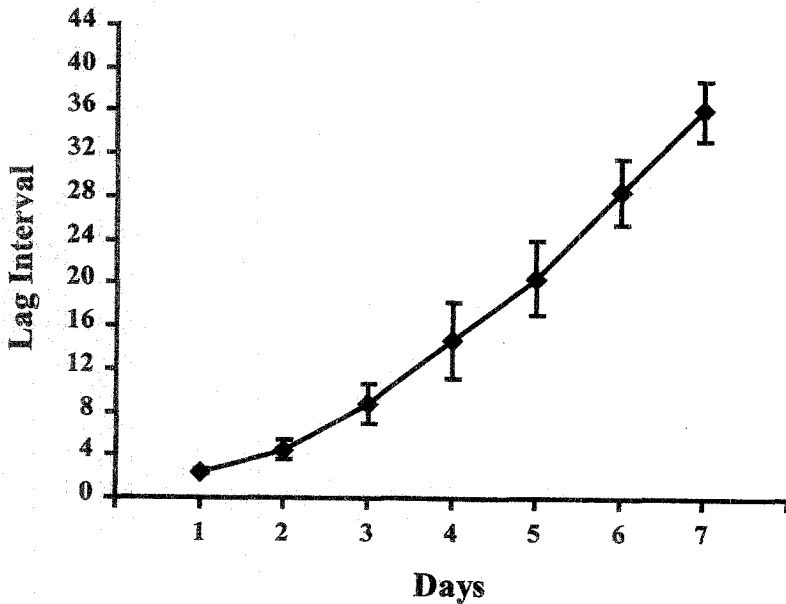


Figure 3. Level of performance across the seven training days for the nine experimental participants who showed gains as a function of training. Performance is measured as the number of intervening items at which participants can correctly recollect the prior occurrence of a repeated item.

## DISCUSSION

In the current study we tested the efficacy of a memory training technique with older adults that was based on the theory that memory consists of two processes—an automatic process, known as familiarity, and a consciously controlled process referred to as recollection (e.g., Jacoby, 1991; Mandler, 1980). Research with elderly adults has shown that ageing affects consciously controlled processes but leaves automatic processes intact (e.g., Hasher & Zacks, 1979; Jennings & Jacoby, 1993). Consequently, we wanted to target the consciously controlled process of recollection specifically for training. Other theoretically driven process-specific approaches to cognitive training have proven effective with head injured patients (Sohlberg & Mateer, 1987, 1989; Wood, 1988). For example, Sohlberg and Mateer (1987, 1989) have designed a rehabilitation technique targeting five specific types of attention (focused, sustained, selective, alternating, and divided) with repeated practice on tasks that gradually become more difficult for each type, which has resulted in good success. Similarly, we adopted an incremented-difficulty approach to training by having participants recollect information across gradually increasing delay intervals.

Our results suggest this procedure had a beneficial effect on recollection in older adults. At the start of training, experimental participants were only able to perform to criterion when approximately two items intervened between the first and second presentation of a repeated word. However, by the end of training, which consisted of 5 to 6 hours in total, older participants were able to perform to criterion when 28 items intervened between repetitions. In contrast, our control participants did not prove to be as successful. They received the same amount of practice with the task and the same lag intervals as their experimental partners, but the lags were not increased in a systematic manner. We tested the control group in this manner to assess the utility of the incremented-difficulty approach by ruling out effects of general practice or increases in conservative responding, and although these influences may have helped to facilitate the experimental group's improvements, they cannot account for the full training effect. More experimental participants improved than controls, such that, on average, the experimental group showed benefits that were more than two times greater than the control group's gains despite an equal amount of practice. Moreover, the experimental group maintained a significantly higher level of performance than the controls even when bias effects were removed.

Given the successful increase in performance of the experimental group, one must ask what it is these participants have learned. Previous research examining recollection has viewed it as a process that entails the conscious retrieval of one or more specific details from a prior learning event (e.g., Jacoby et al., 1993, 1996, 1997; Yonelinas, 2002). Depending on the task used to explore recollection, these details have included the source of an item's presentation

(e.g., first list vs. second list), the modality of a word's presentation (e.g., read vs. heard; font colour), what one was thinking with respect to a target item at the time it was encountered, and so on. The design of our incremented-difficulty approach is such that participants may respond correctly to a repeated item by recollecting one or more different pieces of information, which allow them to distinguish between study and repeated items. More specifically, they could recollect whether a word was first presented in the study versus test list (source information), recollect whether they had already responded to a word during the test phase (output monitoring), recollect how recently the word occurred during the experiment (recency information), or even recollect whether the word was one they had read aloud (word characteristics). Although the results with the experimental group indicate that they seem to become better able to recollect such information across increasing delays, it remains to be understood what specifically has been modified or adapted to allow them to do so.

To shed some light on this question we debriefed participants after their last session to see what they felt they were doing to improve. The common theme from both groups was that they were trying to associate list words during the study phase and working to concentrate more on the task overall. The claim that they increasingly associated words during study is intriguing given training did not enhance recognition memory performance. As mentioned earlier, it is not surprising that studying/testing multiple lists may have resulted in proactive interference, which overshadowed any effects of training on recognition. However, an additional possibility, which is more in line with our dual process view of memory, is that training may have resulted in a qualitative change in the basis for recognition. According to a dual process model of recognition (e.g., Jacoby, 1991; Mandler, 1980), decisions can be based on either recollection or automatic influences. Thus training may have led participants to rely more heavily on recollection, altering the basis for their response but not their overall level of accuracy. That is, participants may have recognised approximately the same number of items following training, but more of their recognition decisions may have come from recollection than familiarity. This possibility seems particularly plausible as earlier work has shown that the opposition technique is a more sensitive index of changes in recollection than is recognition-memory performance (Jennings & Jacoby, 1997).

Regardless, despite our participants' self-reports, the gains we observed during training cannot have arisen solely from changes in encoding. Control participants had the same opportunity to improve their encoding as the experimental group, yet the latter individuals achieved significantly greater performance. This pattern of results implies that the effect of our training technique was on retrieval ability in conjunction with encoding operations, and indicates that targeting recollection can produce improvements in memory performance. Moreover, this approach to training is a significant departure from previous studies with healthy older adults, which have focused on teaching mnemonics

(see introduction). In this respect, our work is similar to training studies that make use of the spaced retrieval procedure (Camp & Schaller, 1989; Schacter, Rich, & Stampp, 1985; for review see Wilson, 1999), which is also based on an incremented-difficulty procedure rather than mnemonics. However, a critical difference between our work and the spaced retrieval technique is that the latter is aimed at teaching a particular response and the material that is to be acquired is held constant while the retention interval is gradually increased. In contrast, we continuously changed materials during each session and asked participants to discriminate between study and repeated items so as to attempt to train their general aptitude for recollection of event details rather than teaching them habitual over-learned responses.

Baddeley and Wilson (1994) have shown that habitual over-learned responses acquired through implicit learning can allow amnesics to correctly complete word stems with studied words. However, they have also shown that relying on implicit learning can be problematic under certain circumstances in that it provides no basis for error elimination. Consequently, they suggest that the postulation of a second form or use of memory that is capable of error correction is also necessary. In this respect, their view can be seen as a call for the distinction made between recollection and automatic influences of memory. Interpreting Baddeley and Wilson's results from a dual-process theory would lead one to conclude that amnesia reflects a severe deficit in recollection, which is important for error correction, with preserved automatic influences of memory (implicit memory) that can be exploited through rehabilitation. By using an incremented-difficulty procedure similar to that used for spaced retrieval but modified to allow us to focus on recollection rather than on automatic influences, our procedure was designed to improve that aspect of memory which may be beneficial for error correction in populations that are still able to utilise it, such as older adults.

Finding that older adults can improve their ability to retrieve information in the form of recollecting the prior occurrence of a repeated item across increasing delays supports other studies that have found that older individuals retain a reserve capacity or cognitive plasticity that can be utilised to improve memory function (Kliegl, Smith, & Baltes, 1989). It also extends that work by showing that such plasticity can be accessed in situations other than those that teach mnemonics. However, despite the effectiveness of our technique, several experimental participants were unable to benefit, leading us to wonder whether limited attainments in training could be indicative of a specific pattern of cognitive decline. In particular, the type of information that needs to be recollected for successful performance with our incremented-difficulty procedure, such as source details, recency information and output monitoring, are aspects of memory that have been associated with frontal functioning in older adults and head-injured patients (e.g., Fabiani & Friedman, 1997; Glisky, Rubin, & Davidson, 2001; Petrides & Milner, 1982; Schacter, 1987). Moreover, there is

neuropsychological and neuroimaging evidence that the process of recollection itself relies on the prefrontal cortex (for review see Yonelinas, 2002) and, more specifically, that recollection of repeated items in the repetition lag procedure is associated with frontal activity (Kane, Picton, Moscovitch, & Winocur, 2000). Consequently, the effectiveness of training may depend on the severity and locus of anatomical degeneration with age.

Moreover, the minimal gains achieved by some participants suggest that they may require more than seven days to show substantial improvements with our training procedure or, in fact, may not benefit at all. In particular, individuals suffering from advanced Alzheimer's disease or other memory disorders that have virtually diminished any capacity for consciously controlled memory are probably better served by techniques that enlist their spared automatic processing, such as the spaced retrieval technique. However, to the extent that some ability for recollection remains, modifications of the repetition-lag procedure with easier task instructions may be valuable. For example, Ste-Marie, Jennings, and Finlayson (1996) have used a modified version of the repetition-lag procedure with traumatic head-injured patients to measure their ability for recollection. In this task, participants were shown a mixed list of study words and three-letter word stems that could be completed with the study words, but were asked to avoid completing the stems with a word that they had seen earlier, which required recollection of the previous items. The traumatic head injured group proved able to follow these task instructions and to show a limited amount of recollection. Consequently, it is possible that gradually increasing the lag intervals between a word and its matching stem may produce similar improvements to those found here, and may, accordingly, act as a simpler version of the incremented-difficulty technique that could be applied to benefit populations besides healthy older adults.

The hallmark of a good memory remediation technique though is not only that it can be applied to a variety of populations, but also that it can produce improvements that transfer to other tasks and real world requirements. Although generalisation of the repetition-lag technique remains to be tested, our assumption is that this training procedure improves one's general skill for recollecting specific information (e.g., source, recency, output details, etc.), and therefore that training should lead to gains in other situations with similar demands. For example, if participants have truly improved at recollecting output information then we would predict that a reduction in perseverative behaviour on a word fluency task or on the Wisconsin Card Sorting Task should also be seen. Similarly, improvements in recollecting source information should facilitate performance on tasks in which individuals are asked to distinguish whether they have read or heard information, or which of two speakers relayed information. As for whether our training results can transfer outside of the lab setting, there is evidence that lab measures of recollection correlate highly with the self-reported frequency of everyday memory errors, which

include repeating oneself, forgetting whether one has already taken medication, forgetting whether one has turned off the stove, and so on (Jacoby et al., 1996). Given that lab indices of recollection can relate to everyday memory functioning it is possible that training recollection in a lab paradigm may also generalise to analogous demands in the real world, thus decreasing the types of everyday memory errors listed above that can have serious repercussions. Although research needs to be done to explore the scope of transfer that is attainable with our incremented-difficulty procedure, we believe that, at the very least, this technique may act as a new starting point for developing successful memory interventions.

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