Research Article

Who Benefits From Memory Training?

David Bissig[1] **and Cindy Lustig**[2]

[1]*Wayne State University and* [2]*University of Michigan*

ABSTRACT—***Cognitive training programs can have significant benefits. However, their efficacy is often reduced for individuals of advanced age or lower cognitive ability. Using older adult subjects, we examined the role of self-initiation of cognitive control in a training program that targets recollection memory. Relative time spent on an open-ended, intentional encoding task that requires the self-initiation of cognitive control was highly predictive of improvement in the training task, and fully accounted for individual differences related to age and crystallized intelligence. Analyzing training programs from the perspective of cognitive theory may help clarify how these programs have their effects and suggest ways to optimize such programs for the individuals who need them most.***

Training programs are an increasingly popular way of treating the cognitive deficits associated with a wide variety of conditions, including schizophrenia, head trauma, multiple sclerosis, normal aging, and Alzheimer's disease (Ball et al., 2002; Balota, Duchek, Sergent-Marshall, & Roediger, 2006; Clare & Woods, 2004; Jennings & Jacoby, 2003; Jennings, Webster, Kleykamp, & Dagenbach, 2005; Loewenstein, Acevedo, Czaja, & Duara, 2004; McGurk, Mueser, & Pascaris, 2005; Prosiegel & Michael, 1993; Rund & Borg, 1999; Twamley, Jeste, & Bellack, 2003; Verhaeghen, Marcoen, & Goossens, 1992; Whyte, 2006). The benefits of training can extend beyond the trained task and lead to significant changes in both behavior and brain function (Ball et al., 2002; Jennings et al., 2005; Loewenstein et al., 2004; Lustig & Buckner, 2004; Nyberg et al., 2003). However, it is often unclear what factors contribute to the success of a training program. What processes are being trained? Why do some individuals benefit more than others?

In this study, we asked if individual differences in controlled processing, an important concept in basic theories of cognition, can account for individual differences in memory training. Training programs are successful at the group level, but individual differences in the degree of improvement are quite large. Unfortunately, the benefits of training are often smallest for the individuals who need them most: Both lower initial cognitive status and more advanced age are associated with smaller improvements (Verhaeghen et al., 1992; Yesavage, Sheikh, Friedman, & Tanke, 1990). Understanding the reasons for these individual differences could guide the design of future training programs to better benefit disadvantaged groups.

Individual differences in controlled processing contribute to individual differences on many cognitive tasks. The production-deficit hypothesis suggests that many of older adults' cognitive deficits stem from failures to self-initiate controlled, effortful processes that support successful performance (Craik & Byrd, 1982). By this view, deficits may be remediated by appropriate environmental support or instruction. For example, older adults fail to activate brain regions associated with successful memory if given open-ended, intentional learning instructions ("memorize the words"), but activate these regions as much as do young adults if instructed to perform a semantically based deep encoding task that supports later memory (Logan, Sanders, Snyder, Morris, & Buckner, 2002).

Recent models extend the production-deficit hypothesis to differences in when and how control is engaged. One account posits dual mechanisms of cognitive control. According to this framework, variation in performance on cognitive tasks is linked to whether control is engaged in a proactive or reactive fashion (Braver, Gray, & Burgess, 2007). High-ability individuals (e.g., young adults with high fluid intelligence) emphasize *proactive* control to maintain task goals that "set the stage" for successful cognition. In contrast, low-ability young adults and older adults engage control in a more *reactive* fashion, in response to immediate task demands. Likewise, aging is associated with a "load shift" away from early processes that constrain retrieval to relevant events, and toward later processes that evaluate information after retrieval (Velanova, Lustig, Jacoby, & Buckner, 2007). Neuroimaging suggests an even more extreme version of the load-shift model in some cases; specifically, older adults may

---

Address correspondence to Cindy Lustig, Department of Psychology, University of Michigan, 530 Church St., Ann Arbor, MI 48109-1043, e-mail: clustig@umich.edu.

fail to activate control-related frontal regions under intentional encoding instructions, but activate them more than young adults at retrieval, possibly in an attempt at compensation (Head, Lustig, Isom, & Buckner, 2006).

The training program we examined in the present study focuses on *recollection*, or deliberate, consciously controlled memory retrieval processes considered to be distinct from more automatic, familiarity-based processes (Jacoby, 1991). Recollection requires more effort and cognitive control, and involves specific, analytic details, such as information about the source ("Was that from the news or an advertisement?") or modality ("Did I hear it or read it?"). Recollection's control-demanding, effortful aspects lead to its frequent failure in individuals with reduced cognitive control, such as older adults, brain-damaged patients, or individuals with low working memory spans (Dockree et al., 2006; Jennings & Jacoby, 1993; Oberauer, 2005). These failures can have social and practical consequences. A classic example is the older individual who consistently retells a favorite story to a group of acquaintances, failing to recollect having done so on previous occasions. There can be more serious consequences, too, as when scam artists introduce false information (e.g., about pricing) into a conversation to increase its familiarity, and individuals fail to recollect the lower price agreed upon earlier (Jacoby, 1999).

Recollection failures can be reduced by a training program that gradually increases the demand to respond on the basis of controlled, analytic processes (Jennings et al., 2005, 2006; Jennings & Jacoby, 2003). Subjects complete multiple sessions during which they learn lists of words and then must discriminate studied words from unstudied lures. Lures are repeated during the test. Recollection is required to correctly identify repeated items as lures, and to avoid the urge to designate them as "studied" on the basis of their familiarity. Recollection demands are gradually increased by increasing the number of items between lure repetitions.

The benefits of this training program have shown transfer to other tasks (Jennings et al., 2005), but only those that also require discrimination between correct and incorrect but familiar items (e.g., the *n*-back task, which requires subjects to identify whether a probe stimulus occurred exactly *n* trials previously in a series). This pattern of results supports the idea that training benefits specific processes, rather than producing a generic improvement due to increased attention or social stimulation (cf. Ball et al., 2002). Both healthy and cognitively impaired individuals showed training-related improvements, but with large individual differences (Jennings & Jacoby, 2003; Jennings et al., 2005, 2006). Some individuals reached maximal success, ultimately performing perfectly even with 40 items between lure repetitions. Others showed almost no improvement despite 28 sessions of training.

What drives these individual differences in training efficacy? The most intuitive answer is that they reflect processes engaged at retrieval, especially those involved in discriminating studied from repeated but unstudied items. However, processes engaged at encoding can have important downstream effects, especially for recollection. Controlled processing at encoding (especially deep, meaning-based processing) typically provides better support for later retrieval than does more shallow or automatic processing (Craik & Lockhart, 1972). Reaction time, accuracy, and brain activation at retrieval are strongly influenced by prior encoding processes (Velanova et al., 2003). Of particular interest, encoding processes influence the retrieval-test processing of lure items, not just studied items, although this relationship may break down with age (Jacoby, Shimizu, Daniels, & Rhodes, 2005; Jacoby, Shimizu, Velanova, & Rhodes, 2005). Both encoding and retrieval involve cognitive control, but encoding may require more self-initiation of control and thus may be more vulnerable to disruptions (e.g., from divided attention). By contrast, retrieval appears to be more "obligatory" and takes priority when competing with other tasks (Anderson, Craik, & Naveh-Benjamin, 1998; Naveh-Benjamin, Craik, Guez, & Dori, 1998).

In the present study, we asked whether differences in controlled processing could account for individual differences in the efficacy of recollection training. This training program uses intentional encoding, an open-ended task that requires the self-initiation of controlled encoding strategies to support later memory. By contrast, although the retrieval task also requires control—especially to discriminate between studied words and familiar, but unstudied, repeated lures—its structure (a recognition task) makes those demands more obvious, reducing the demand for self-initiation. We hypothesized that individual differences in training efficacy related to age and initial ability would be related to self-initiation of cognitive control, as measured by the tendency to emphasize processing at encoding rather than retrieval.

METHOD

Subjects

Subjects were 19 adults (mean age = 74.5 years, *SD* = 6.1; mean years of education = 18.0, *SD* = 3.3). None were taking medications or had conditions affecting attention, memory, or movement. An additional subject's data were dropped because of low accuracy on studied words (59%, a 2.5-*SD* outlier from the group mean).

Materials and Procedure

The recollection training procedure was modified (from Jennings & Jacoby, 2003; Jennings et al., 2005) to allow for self-paced presentation at all stages and feedback after every test trial. Stimuli were chosen from the English Lexicon Project (Balota et al., 2002; mean word length = 5.76 letters, range: 3–9 letters; mean frequency = 20,487 out of 131 million; length and

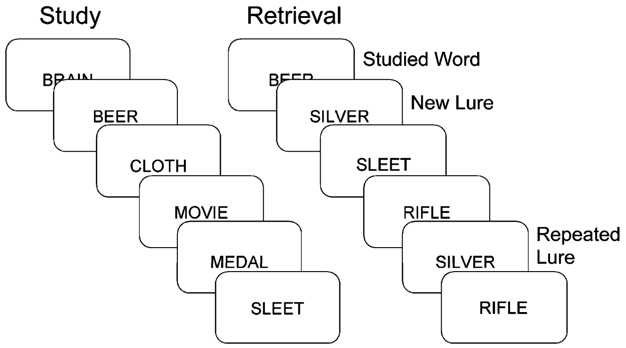

Fig. 1. Illustration of the study and test conditions. Subjects first engaged in self-paced intentional encoding of individually presented words (left). At retrieval (right), they indicated whether each word was from the study list or was an unstudied lure. Unstudied lures (e.g., *SILVER*, *RIFLE*) were repeated within the test list. Within each test list, half of the repetitions occurred at a short lag, and the other half occurred at a long lag. The list illustrated here had a short lag of one intervening item (between the first and second presentations of *RIFLE*) and a long lag of two intervening items (between the first and second presentations of *SILVER*). Difficulty was increased by increasing the lag between items once subjects reached criterion performance (see the text).

frequency balanced across lists and conditions) and presented using E-Prime. Response times were collected via key press.

Subjects completed four study-test sessions per day for 7 days, scheduled over the course of 2 weeks. During the study phase, subjects studied 30 individually presented words. During the test phase, they performed an old/new recognition test, requiring discrimination of studied words from unstudied lures. Unstudied lures were repeated within the test list. Each recognition test had 90 items, pseudorandomly intermixed: the 30 studied words, the first presentations of 30 unstudied lures, and the second presentations of those same unstudied lures. Each response on the retrieval test was followed by a feedback screen indicating accuracy (correct or incorrect) and trial type (studied, new, or repeated).

The critical manipulation was the lag between lure repetitions. Subjects started at an easy level, with half the lures repeated after one intervening word, and the other half repeated after two intervening words (i.e., lag level 1 and 2; see Fig. 1). Difficulty gradually increased, with possible lag-interval combinations 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, and 16 and 40. Thus, subjects were always working at one relatively easy interval and one that might be more challenging. Lag level was increased when the subject reached criterion at the current level (96% correct on the more challenging interval for the first four levels, i.e., up to 2 and 8; 93% correct on the more challenging interval for higher levels).

Subjects gave their informed consent prior to the first training session and also completed a health and demographics questionnaire, the Extended Range Vocabulary Test (ERVT, Version 3; Educational Testing Service, 1976), the Mini-Mental State Evaluation (MMSE; Folstein, Folstein, & McHugh, 1975), and other forms.

RESULTS

Ranking

Subjects were ranked (1 = best, 19 = worst) by final lag level (e.g., better rank for a subject who achieved lag level 4 and 16 by Session 28 than for one who had achieved only level 2 and 8). Eight subjects achieved the maximum lag level, 16 and 40. Ties between subjects at the same level at the end of the experiment were resolved by assigning the better rank to the subject who had reached criterion earlier in training (e.g., reaching level 16 and 40 in Session 12 vs. Session 15). Remaining ties were broken by assigning the better rank to the subject with better overall correct rejection of repeated lures.

Because two thirds of the items were unstudied, a potential concern is that subjects could reach a high ranking by simply responding "unstudied" to most items, rather than using memory. This was not the case: Better rank was correlated with higher accuracy on studied items, $r = -.85$, $p_{\text{rep}} > .999$.

Replication of Age and Ability Effects

Age was negatively related to performance, accounting for 25% of the variance in rank, β (standardized regression coefficient) = .54, $p_{\text{rep}} = .95$ (see Fig. 2a). In a separate analysis, crystallized intelligence (ERVT score) was positively related to performance, accounting for 22% of the variance in rank, $\beta = -.51$, $p_{\text{rep}} = .94$ (see Fig. 2b). The MMSE dementia scale showed similar trends (adjusted $R^2 = .17$, $\beta = -.41$, $p_{\text{rep}} = .89$), but its relation to rank did not reach significance because of ceiling

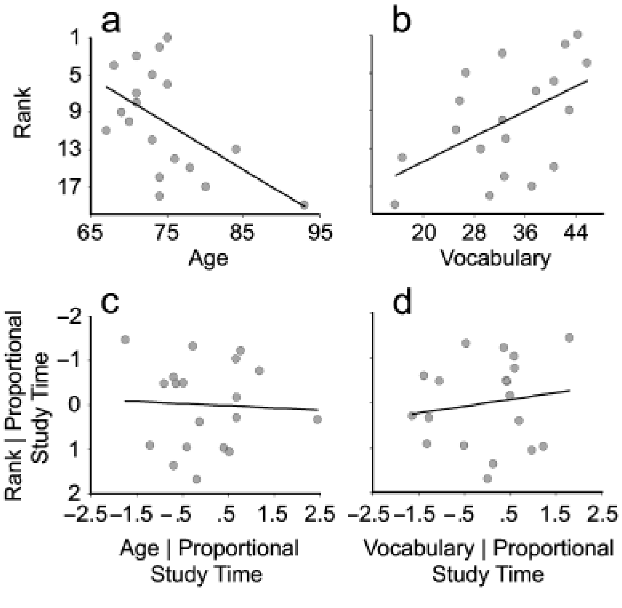

Fig. 2. Age and crystallized intelligence as predictors of rank before and after accounting for proportional study time. In the top row (a, b) are the scatter plots for rank on the training task (1 = best, 19 = worst) as a function of age (range: 67–93 years) and vocabulary score (range: 16–46), a measure of crystallized intelligence. The scatter plots in the bottom row (c, d) show the reduction of these relations after accounting for proportional study time.

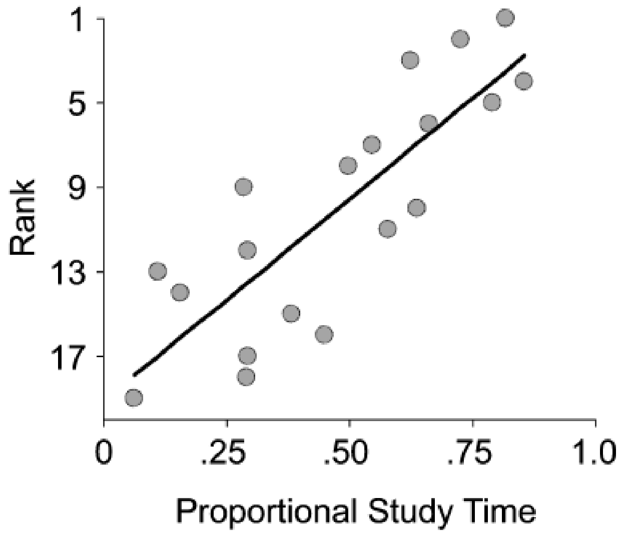

Fig. 3. Performance rank as a function of proportional study time.

effects (range: 25–30; all but 3 subjects scored 28 or above). These patterns replicate previous findings that age and lower initial cognitive ability are negatively related to training efficacy (Verhaeghen et al., 1992; Yesavage et al., 1990).

Time Spent on Encoding Versus Retrieval

No subject spent more time on retrieval trials ($M = 1.5$ s, $SD = 0.38$) than on study trials ($M = 5.7$ s, $SD = 4.07$). Study and retrieval time were not related to one another ($r = .07$), and their relations to rank were opposite in sign ($r = -.76$ for study; $r = .20$ for retrieval). To measure the relative amount of time spent on study versus retrieval, we calculated a proportional index: (mean study time − mean retrieval time)/(mean study time + mean retrieval time). We preferred this measure of proportional study time (PST) over raw study time because the latter might reflect a general tendency to be slow, rather than an emphasis on encoding. PST was positively related to performance (Fig. 3), accounting for 67% of the variance in rank ($\beta = -.83$, $p_{\text{rep}} > .999$). PST showed a small but significant increase over sessions, a pattern consistent with the idea that training enhanced an emphasis on encoding, mean slope = 0.004, $SD = 0.007$, $t(18) = 2.61$, $p_{\text{rep}} = .95$.

Does PST Account for Age and Ability Effects?

PST was negatively related to age ($r = -.62$, $p_{\text{rep}} = .999$) and positively related to ERVT ($r = .53$, $p_{\text{rep}} = .95$). Could it account for the relationships of age and ERVT with rank? A combined model with PST entered first and age second accounted for 69% of the variance in rank, and age was no longer a significant contributor ($\Delta R^2 = .001$, $\beta = .04$, $p_{\text{rep}} = .55$; see Fig. 2c). Similar patterns were found for ERVT ($\Delta R^2 = .001$, $\beta = -.10$, $p_{\text{rep}} = .66$; see Fig. 2d) and MMSE ($\Delta R^2 = .02$, $\beta = -.17$, $p_{\text{rep}} = .79$). The standardized regression coefficient (β) for PST changed very little depending on what other variables were in the model (from −.83 to −.81 if age was included and to −.77 if ERVT or MMSE was included).[1]

Contributions at Retrieval?

The analyses reported so far support the hypothesis that emphasizing encoding processes improves training efficacy. An exploratory analysis for retrieval-based effects found that proportional retrieval time for repeated (familiar) versus new items only marginally predicted rank (adjusted $R^2 = .11$, $\beta = -.40$, $p_{\text{rep}} = .88$). The slope of the relationship between proportional retrieval time and rank did not change over sessions ($M = -0.0008$, $SD = .006$, $p_{\text{rep}} < .70$).

The relation between retrieval time and rank was primarily driven by long-lag trials: Individuals who spent proportionally more time on long-lag relative to short-lag trials had *worse* ranks (adjusted $R^2 = .21$, $\beta = .51$, $p_{\text{rep}} = .94$). Proportional time spent on long-lag trials did not account for age and ability effects: Age remained a significant predictor ($\Delta R^2 = .17$, $\beta = .43$, $p_{\text{rep}} = .92$), and ERVT was a marginal predictor ($\Delta R^2 = .12$, $\beta = -.37$, $p_{\text{rep}} = .87$). Proportional time spent on long-lag items did not correlate with PST and made a unique contribution to the prediction of rank (omnibus adjusted $R^2 = .73$, $\Delta R^2 = .07$, $\beta = .28$, $p_{\text{rep}} = .92$).

Individual differences in retrieval-stage processing might also appear in sensitivity to feedback. Proportional time spent on feedback screens for incorrect versus correct items had a marginally beneficial influence after accounting for PST ($\Delta R^2 = .06$, $\beta = -.33$, $p_{\text{rep}} = .91$). This effect should be interpreted cautiously, given the different number of incorrect trials for good versus poor performers.

DISCUSSION

What leads to successful memory training? At least for the procedure examined in this study, a major influence is the self-initiation of controlled processes that support memory. The relative amount of time individuals spent on an open-ended,

---

[1] A potential concern is that advancement could represent only preexisting recollection skills, rather than training-related improvement. We also tested 10 young adults (mean age = 20 years, $SD = 1.3$ years). For them, progression reflected initial ability: Almost all quickly achieved criterion at each lag level, usually with no more than one session at each level. (Uniformly high performance made it impossible to rank the young adults.) This was not the case for older adults: All but 4 remained at the lowest two lag levels for the first four study-test cycles. All conclusions remain the same if these 4 subjects are removed from analysis. No large differences for improvers versus nonimprovers were evident until the 3rd day. These findings are consistent with those of Jennings and Jacoby (2003) and Jennings et al. (2005), and with the idea that for older adults, improvement reflects training, rather than initial ability.

Compared with older adults, young adults had longer study times (11.85 s vs. 5.71 s) and shorter retrieval times (0.92 s vs. 1.48 s), $F(1, 27) = 16.12$, $p_{\text{rep}} = .98$. This cross-group comparison supports the idea that the emphasis on study over retrieval contributes importantly to age differences in recollection. The study-time difference represents a rare instance of faster response times associated with worse performance and greater age.

intentional encoding task was strongly related to improvement on the test portion of this recollection training procedure. Furthermore, relative study time accounted for age and ability differences in the amount of improvement. This result fits well with theories that emphasize group and individual differences in self-initiation of cognitive control as a source of performance differences (Braver et al., 2007; Craik & Byrd, 1982; Velanova et al., 2007). They may also relate to findings of paradoxical increases in age differences after training (e.g., Baltes & Kliegl, 1992). If young adults are more likely to self-initiate and practice successful strategies during training than are older adults, they might well show larger improvements.

Study time served as a measurable predictor for regression analyses, but was presumably a proxy for processes engaged at encoding. Individual differences in encoding strategies correlate with brain activation patterns, which in turn predict memory performance (Kirchhoff & Buckner, 2006). In debriefing, several top performers reported strategies such as creating a narrative using the to-be-remembered words, or relating the words to experiences in their own lives. These strategies would lead to the deep, meaning-based encoding that typically supports later memory, and might also create a narrative structure integrating the words from the study list into a unit (Radvansky, 2005). By contrast, poor performers either demonstrated little insight about strategies ("I just used my memory") or used superficial strategies such as rote rehearsal.

At first, it may seem counterintuitive that an emphasis on encoding should be the primary influence on performance: The manipulation of difficulty (lag between repeated lures) occurred at retrieval. However, this result is predicted by theoretical perspectives that consider the degree to which different tasks (intentional encoding vs. recognition memory) require the self-initiation of controlled processing, as well as individual and group differences in how such processes are engaged (Braver et al., 2007; Craik & Byrd, 1982; Craik & Lockhart, 1972; Velanova et al., 2007). Encoding processes can have important downstream effects for how control is engaged at retrieval (e.g., Jacoby, Shimizu, Daniels, & Rhodes, 2005). In a false-memory procedure, warnings presented at encoding reduced false recognition by older adults, whereas warnings presented at retrieval did not (McCabe & Smith, 2002).

From a practical perspective, the somewhat surprising importance of encoding underscores the value of carefully analyzing training programs to understand the locus of their effects. Many training programs show limited transfer to other tasks despite large improvements on the training task itself, and those benefits that do transfer are typically domain- or process-specific (cf. Ball et al., 2002). Our data suggest that processes engaged at encoding could be a highly effective target for memory training.

The link between controlled processing at encoding and training efficacy suggests a potential method of modifying training programs to benefit those individuals who initially do not show improvement. Providing environmental support improves older adults' performance by reducing the need to self-initiate control (Craik & Byrd, 1982). Older or lower-ability individuals might benefit from environmental support in the form of explicit coaching (e.g., requiring a verbal response that links to-be-remembered words across trials) and gradual shaping to initiate these processes on their own. It remains to be seen whether this modification would be successful, or whether similar modifications would apply to other training programs. However, the general approach of using basic theoretical perspectives to analyze training programs holds promise for understanding how these programs have their effects, and how to improve them.

These data may also be relevant to general questions about recognition memory, particularly when subjects must discriminate between different sources of familiarity (Jacoby, Shimizu, Daniels, & Rhodes, 2005; Jacoby, Shimizu, Velanova, & Rhodes, 2005). Jacoby and his colleagues have argued that a theoretically important distinction can be drawn between proactively restricting retrieval attempts and memory access to the target source (*source-constrained retrieval*) and retroactively evaluating information once it has been retrieved (*source identification*). In their experiments, young adults showed evidence for source-constrained retrieval (better memory for first-test foils on a second, surprise recognition test for those foils if the to-be-remembered words for the first test had been encoded using an incidental deep, meaning-based task rather than a shallow or intentional encoding task), but as a group, older adults did not.

In a repeated-lure procedure like the one used here, source-constrained retrieval might be used to limit the familiarity or memory access of lure items. Previous work suggests that better encoding supports better source-constrained retrieval (Jacoby, Shimizu, Daniels, & Rhodes, 2005). In the current data set, there was no overall difference in response time for new lures versus repeated lures (1.49 s vs. 1.53 s, $p_{\mathrm{rep}} = .75$). This pattern suggests that subjects, especially successful ones, did not follow a strategy of first assessing global familiarity (which would not differ for studied words vs. repeated lures, but would differ for new lures vs. repeated lures) and subsequently attempting to identify the source. Instead, they may have evaluated the fit of each word presented at retrieval with the narrative structure (or other cognitive set) created at encoding. This dimension differentiated studied from unstudied words, but not new from repeated lures (cf. Jacoby, Shimizu, Daniels, & Rhodes, 2005).

Source identification might have been used to discriminate words that were familiar because they were on the studied list from those that were familiar because they were repeated lures. Although there was no overall difference in response time for new versus repeated items, subjects took longer to judge long-lag repeated lures than to judge short-lag repeated lures (1.43 s vs. 1.64 s, $p_{\mathrm{rep}} = .99$). The longer time for long-lag items might reflect time spent trying to identify their source, and made a unique contribution even after accounting for PST. However, the increase in retrieval time for long-lag relative to short-lag items had a negative relation to performance, and including it in the analysis did not eliminate age or ability effects.

A speculative interpretation of these patterns is that the optimal strategy is to proactively constrain retrieval to the studied list, and that advanced age and lower ability are associated with reduced self-initiation of the encoding processes that will support this strategy downstream. When constrained retrieval fails, subjects must engage in source identification, and the effects of this strategy on performance are separate from the effects of age and ability. Greater difficulty with this process is associated with worse recollection.

In summary, we used principles from theories about self-initiation and proactive control to understand individual differences in the efficacy of training in recollection memory. Self-initiation of control, here indexed by the relative amount of time spent on an intentional, open-ended encoding task, was a powerful predictor of individual differences in performance. Furthermore, it accounted for age and ability differences. Better encoding may have had its effects at least in part by supporting more proactive, source-constrained retrieval, allowing easier rejection of repeated lures. By contrast, a potential measure of retroactive attempts at source identification (time spent on long- vs. short-lag repetitions), also predicted individual differences in performance, but did not account for those differences related to age and ability.

We have focused on the self-initiation of controlled processes at encoding, but similar principles may apply in any situation that creates strong demands for the self-initiation of control. For example, we predict that on a free-recall task, the degree to which individuals spontaneously engage organizational strategies (e.g., semantic clustering) would be strongly related to age and ability differences in performance overall, and in the ability to benefit from recall training. Issues for future research include the link between putative measures of self-initiated processing and individual differences in executive function, working memory, and processing speed, and how the processes engaged at encoding may influence the tendency to engage in source-constraining or source-identifying processes at retrieval (see also work by Jacoby and his colleagues, e.g., Jacoby, Shimizu, Daniels, & Rhodes, 2005, and Jacoby, Shimizu, Velanova, & Rhodes, 2005).

More generally, we suggest that translating basic theory to the analysis of cognitive training programs holds great promise for understanding how those programs have their effects, and for improving them to benefit those individuals most in need. In turn, observing which people improve, and how they improve, over the course of training can inform understanding of the processes people apply to cognitive tasks.

Acknowledgments—We thank Janine Jennings for advice, Andrew Reinenke for assistance in preparing materials, and Megan Walsh, Lindsay Nelson, Mary Askren, and Elise Demeter for assistance with data collection. This work was supported by University of Michigan Office of Vice President of Research Grant 5167.

REFERENCES

Anderson, N.D., Craik, F.I.M., & Naveh-Benjamin, M. (1998). The attentional demands of encoding and retrieval in younger and older adults: 1. Evidence from divided attention costs. *Psychology and Aging*, *13*, 405–423.

Ball, K., Berch, D.B., Helmers, K.F., Jobe, J.B., Leveck, M.D., Marsiske, M., et al. (2002). Effects of cognitive training interventions with older adults: A randomized controlled trial. *Journal of the American Medical Association*, *288*, 2271–2281.

Balota, D.A., Cortese, M.J., Hutchison, K.A., Neely, J.H., Nelson, D., Simpson, G.B., & Treiman, R. (2002). *The English lexicon project: A web-based repository of descriptive and behavioral measures for 40,481 English words and nonwords*. Retrieved June 7, 2005, from http://elexicon.wustl.edu/

Balota, D.A., Duchek, J.M., Sergent-Marshall, S.D., & Roediger, H.L., III. (2006). Does expanded retrieval produce benefits over equal-interval spacing? Explorations of spacing effects in healthy aging and early stage Alzheimer's disease. *Psychology and Aging*, *21*, 19–31.

Baltes, P.B., & Kliegl, R. (1992). Further testing of limits of cognitive plasticity: Negative age differences in a mnemonic skill are robust. *Developmental Psychology*, *28*, 121–125.

Braver, T.S., Gray, J.R., & Burgess, G.C. (2007). Explaining the many varieties of working memory variation: Dual mechanisms of cognitive control. In A. Conway, C. Jarrold, M. Kane, A. Miyake, & J. Towse (Eds.), *Variation in working memory* (pp. 76–106). Oxford, England: Oxford University Press.

Clare, L., & Woods, R.T. (2004). Cognitive training and cognitive rehabilitation for people with early-stage Alzheimer's disease: A review. *Neuropsychological Rehabilitation*, *14*, 385–401.

Craik, F.I.M., & Byrd, M. (1982). Aging and cognitive deficits: The role of attentional resources. In F.I.M. Craik & S. Trehub (Eds.), *Aging and cognitive processes* (pp. 191–211). New York: Plenum Press.

Craik, F.I.M., & Lockhart, R.S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, *11*, 671–684.

Dockree, P.M., O'Keeffe, F.M., Moloney, P., Bishara, A.J., Carton, S., Jacoby, L.L., & Robertson, I.H. (2006). Capture by misleading information and its false acceptance in patients with traumatic brain injury. *Brain*, *129*, 128–140.

Educational Testing Service. (1976). *Kit of factor-referenced tests*. Princeton, NJ: Author.

Folstein, M.F., Folstein, S.E., & McHugh, P.R. (1975). "Mini-mental state": A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, *12*, 189–198.

Head, D., Lustig, C., Isom, M., & Buckner, R.L. (2006, October). *Age differences in frontal recruitment between encoding and retrieval*. Paper presented at the annual meeting of the Society for Neuroscience, Atlanta, GA.

Jacoby, L.L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language*, *30*, 513–541.

Jacoby, L.L. (1999). Deceiving the elderly: Effects of accessibility bias in cued-recall performance. *Cognitive Neuropsychology*, *16*, 417–436.

Jacoby, L.L., Shimizu, Y., Daniels, K.A., & Rhodes, M.G. (2005). Modes of cognitive control in recognition and source memory: Depth of retrieval. *Psychonomic Bulletin & Review*, *12*, 852–857.

Jacoby, L.L., Shimizu, Y., Velanova, K., & Rhodes, M.G. (2005). Age differences in depth of retrieval: Memory for foils. *Journal of Memory and Language*, *52*, 493–504.

Jennings, J.M., Carello, E.A., Dagenbach, D., Rapp, S.R., Brenes, G.A., & Atkinson, H.H. (2006, April). *Improving recollection in individuals with mild cognitive impairment: Training and transfer effects*. Paper presented at the Cognitive Aging Conference, Atlanta, GA.

Jennings, J.M., & Jacoby, L.L. (1993). Automatic versus intentional uses of memory: Aging, attention, and control. *Psychology and Aging*, *8*, 283–293.

Jennings, J.M., & Jacoby, L.L. (2003). Improving memory in older adults: Training recollection. *Neuropsychological Rehabilitation*, *13*, 417–440.

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. *Aging, Neuropsychology, and Cognition*, *12*, 278–298.

Kirchhoff, B., & Buckner, R.L. (2006). Functional-anatomic correlates of individual differences in memory. *Neuron*, *51*, 263–274.

Loewenstein, D.A., Acevedo, A., Czaja, S.J., & Duara, R. (2004). Cognitive rehabilitation of mildly impaired Alzheimer disease patients on cholinesterase inhibitors. *American Journal of Geriatric Psychiatry*, *12*, 395–402.

Logan, J.M., Sanders, A.L., Snyder, A.Z., Morris, J.C., & Buckner, R.L. (2002). Under-recruitment and nonselective recruitment: Dissociable neural mechanisms associated with aging. *Neuron*, *33*, 827–840.

Lustig, C., & Buckner, R.L. (2004). Preserved neural correlates of priming in old age and dementia. *Neuron*, *42*, 865–875.

McCabe, D.P., & Smith, A.D. (2002). The effect of warnings on false memories in young and older adults. *Memory & Cognition*, *30*, 1065–1077.

McGurk, S.R., Mueser, K.T., & Pascaris, A. (2005). Cognitive training and supported employment for persons with severe mental illness: One-year results from a randomized controlled trial. *Schizophrenia Bulletin*, *31*, 898–909.

Naveh-Benjamin, M., Craik, F.I.M., Guez, J., & Dori, H. (1998). Effects of divided attention on encoding and retrieval processes in human memory: Further support for an asymmetry. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*, 1091–1104.

Nyberg, L., Sandblom, J., Jones, S., Neely, A.S., Petersson, K.M., Ingvar, M., & Backman, L. (2003). Neural correlates of training-related memory improvement in adulthood and aging. *Proceedings of the National Academy of Sciences, USA*, *100*, 13728–13733.

Oberauer, K. (2005). Binding and inhibition in working memory: Individual and age differences in short-term recognition. *Journal of Experimental Psychology: General*, *134*, 368–387.

Prosiegel, M., & Michael, C. (1993). Neuropsychology and multiple sclerosis: Diagnostic and rehabilitative approaches. *Journal of the Neurological Sciences*, *115*, S51–S54.

Radvansky, G.A. (2005). Situation models, propositions, and the fan effect. *Psychonomic Bulletin & Review*, *12*, 478–483.

Rund, B.R., & Borg, N.E. (1999). Cognitive deficits and cognitive training in schizophrenic patients: A review. *Acta Psychiatrica Scandinavica*, *100*, 85–95.

Twamley, E.W., Jeste, D.V., & Bellack, A.S. (2003). A review of cognitive training in schizophrenia. *Schizophrenia Bulletin*, *29*, 359–382.

Velanova, K., Jacoby, L.L., Wheeler, M.E., McAvoy, M.P., Petersen, S.E., & Buckner, R.L. (2003). Functional-anatomic correlates of sustained and transient processing components engaged during controlled retrieval. *Journal of Neuroscience*, *23*, 8460–8470.

Velanova, K., Lustig, C., Jacoby, L.L., & Buckner, R.L. (2007). Evidence for frontally-mediated controlled processing differences in older adults. *Cerebral Cortex*, *17*, 1033–1046.

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.

Whyte, J., & Hart, T. (Eds.). (2006). Characterizing treatments in TM rehabilitation: Issues for research and practice [Special issue]. *Journal of Head Trauma Rehabilitation*, *21*(2).

Yesavage, J.A., Sheikh, J.I., Friedman, L., & Tanke, E. (1990). Learning mnemonics: Roles of aging and subtle cognitive impairment. *Psychology and Aging*, *5*, 133–137.

(RECEIVED 6/12/06; REVISION ACCEPTED 7/26/06;
FINAL MATERIALS RECEIVED 2/5/07)