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Separating Habit and Recollection in Young and Older Adults: Effects of Elaborative Processing and Distinctiveness

Janine F. Hay and Larry L. Jacoby
McMaster University

An extension of L. L. Jacoby's (1991) process-dissociation procedure was used to examine the effects of aging on recollection and automatic influences of memory (habit). Experiment 1 showed that older adults were impaired in their ability to engage in recollection but did not differ from young adults in their reliance on habit. Elderly adults were also less able to exploit distinctive contextual information to enhance recollection. Experiments 2 and 3 showed that with more supportive conditions, older adults were able to benefit from distinctive contextual information. Quantitative and qualitative deficits in recollective abilities are interpreted within a dual-process model of memory. The problem of distinguishing between a deficit in recollection and a deficit in inhibitory processes in older adults (e.g., L. Hasher & R. T. Zacks, 1988) and the importance of this distinction for purposes of repairing memory performance are discussed.

The interplay between consciously controlled and automatic processes is evident in daily life through the memory slips that people commit. These errors in performance occur when automatic responding (habit) and recollection are opposed, leading to conflicting responses (e.g., Norman, 1981; Reason, 1979). For example, consider the story of an aging math professor in Winnipeg who went to a conference in Chicago and was unable to find his airline ticket when he was ready to return home. After an extensive search for his ticket failed, he bought another and, on arriving in Winnipeg, called his wife to pick him up at the airport. She responded that she would be unable to do so because he had driven the car to Chicago.

How should one interpret the memory slip produced by the aging professor? It is likely that such errors increase as one grows older. One explanation for why this might be the case is that elderly adults may experience greater interference from prior learning than young adults (e.g., Winocur & Moscovitch, 1983) because of a deficit in inhibitory processes (e.g., Hasher & Zacks, 1988). Indeed, memory slips may result from a failure in older adults to inhibit the effects of habit. An alternative account, the one we favor, espouses a dual-process view of memory that distinguishes between automatic and consciously controlled responding. By that account, memory slips result when a failure in recollection leaves habit unopposed. If older adults are more likely to experience failures in recollection than are young adults, they will be more susceptible to memory slips as a result. In the current research, we sought to gain a better understanding of memory slips by separating out the contribution of habit and recollection to performance in young and older adults.

Hay and Jacoby (1996) used a process-dissociation procedure (Jacoby, 1991) to show the usefulness of distinguishing between habit (automatic responding) and consciously controlled uses of memory (recollection). A situation in which the effects of habit are counter to one's purposes, as in a memory slip case, is one of the two conditions required for the process-dissociation procedure. For example, the memory slip made by the professor likely reflected a habit from frequently flying to conferences, combined with a failure in recollection. Had the elderly professor recollected driving to the conference, he would have avoided the error of flying back to Winnipeg, leaving his car in Chicago. The other condition required for the process-dissociation procedure is an in-concert condition, in which the effects of habit produce a response that is the same as that produced by recollection. In such a situation, habit facilitates performance by leading to a correct response. For example, had the math professor flown to the conference as he typically did, his habit formed by flying to previous conferences would have helped him on his way home. The process-dissociation procedure is based on the assumption that the same habit that is a source of error in an opposition condition facilitates performance in an in-concert condition. Results from the two types of conditions are used in combination to separate the contributions of habit from recollection.

Using the process-dissociation procedure, Hay and Jacoby (1996) showed that fast responding reduced recollection but left the effects of habit unchanged. Other variants of the process-dissociation procedure have also shown factors traditionally identified with diminished intentional control, such as divided attention and aging, selectively affect recollection (for reviews, see Jacoby, Jennings, & Hay, 1996; Jacoby, Yonelinas, & Jennings, 1997). On the basis of that prior research, we expected older adults to be less

Janine F. Hay and Larry L. Jacoby, Department of Psychology, McMaster University, Hamilton, Ontario, Canada.

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Correspondence concerning this article should be addressed to Janine F. Hay, who is now at the Rotman Research Institute, Baycrest Centre for Geriatric Care, 3560 Bathurst St., North York, Ontario, Canada M6A 2E1. Electronic mail may be sent to jhay@rotman-baycrest.on.ca.

able than young adults to recollect an earlier event but not to differ in their reliance on habit. Next, we briefly describe the paradigm used in Experiment 1 to illustrate the process-dissociation procedure. We then consider the problem of distinguishing between a deficit in inhibitory processes and a deficit in recollection in older adults and the importance of doing so for purposes of rehabilitating memory performance.

Measuring Automatic and Consciously Controlled Influences of Memory: The Process-Dissociation Procedure

The process-dissociation procedure builds on findings of dissociations between performance on direct and indirect tests of memory. Older adults, compared with younger adults, are typically disadvantaged in their performance on direct tests of memory, such as tests of recognition and recall, but are less impaired in their performance on indirect tests of memory (for reviews, see Craik & Jennings, 1992; Hultsch & Dixon, 1990). For an indirect memory test, participants are not instructed to use memory but to engage in a task, such as word fragment completion, that reflects their memory for a prior event. Results of early experiments indicated that elderly participants showed an amount of priming on indirect tests that was comparable to that demonstrated by younger participants. Although these findings were taken as evidence that implicit memory does not change with age, there has been contradictory evidence to suggest small age-related differences exist in performance on indirect tests (for a review, see LaVoie & Light, 1994; Light, 1991).

A problem associated with direct and indirect tests is that they do not provide a pure measure of the different memory processes contributing to performance (Jacoby, Toth, & Yonelinas, 1993; Reingold & Merikle, 1990; Toth, Reingold, & Jacoby, 1994) and that the use of these tests does not allow researchers to measure intentional and automatic processes as they occur together. The process-dissociation procedure (Jacoby, 1991) avoids such difficulties by separating the contributions of consciously controlled and automatic uses of memory within the same task. In our extension of Jacoby's original procedure (Hay & Jacoby, 1996), we created habits during an experimental session and then examined memory performance when habit opposed, as well as worked in concert with recollection of a previous event. Our paradigm differed from previous procedures in that we created automatic influences, or familiarity, from multiple presentations of stimuli rather than one single prior presentation. Nevertheless, our conceptualization of automatic influences remains consistent with previous definitions of automaticity (e.g., Hasher & Zacks, 1979; Schneider & Shiffrin, 1977), in that it is viewed as a rapid basis for responding, as largely under the control of stimuli rather than intention, and as requiring minimal attentional capacity and awareness.

In the experiments reported here, we created opposition and in-concert conditions by manipulating the relation between test items and prior learning. Responses were made "typical" or "atypical" by an initial training session designed to create habits of specific strengths. During this initial phase, participants were exposed to pairs of associatively related words in which the probabilities of the pairings were varied. For example, a stimulus word *organ* was paired with a related response word *music* on 75% of its occurrences (a "typical" response), whereas for the other 25% of its occurrences, it was paired with the response *piano* (an "atypical" response). This initial training session was designed to create a habit "strength" of 75%, similar to having our aging math professor fly to 75% of conferences he attends. Once a habit was established, the second phase of the experiment had participants study specific word pairs (e.g., organ–music) for a cued-recall test that followed. At test, participants received a stimulus word and were asked to recall the response word with which it was paired in the immediately preceding study list (e.g., *music* or *piano*). This test was similar to our professor remembering on a particular occasion whether he had flown or driven to a conference.

Process-dissociation estimates were derived on the basis of performance on these short tests. On congruent trials, participants studied items that were made typical in the training session. Performance on congruent trials represented a facilitation condition in which participants could give the correct answer at test either by recollecting (R) the item in the short study list presented in Phase 2, or by relying on habit (H) to produce the response that was made typical by training in Phase 1, when recollection failed $(1 - R)$. Recollection of typical items was congruent with the habit participants had formed during training. The probability of correctly producing a typical response on congruent trials can be written as follows: congruent: prob(typical) $= R + H(1 - R)$.

In contrast, on incongruent trials, participants studied items that were made atypical in the training session; therefore, habit was a source of error (opposition condition). To make this type of error, participants would have to fail to recollect the atypical response they had just studied in the short list of word pairs, $(1 - R)$, and rely on their habit (H) of giving the typical response. This condition was the memory slip case. The probability of incorrectly producing a typical response on incongruent trials can be written as follows: incongruent: prob(typical) $= H(1 - R)$.

Using these two equations, we can derive estimates of habit and recollection. Subtracting the probability of an error on incongruent trials from the probability of a correct response on congruent trials provides an estimate of recollection: R = congruent − incongruent.

Given an estimate of recollection, an estimation of habit can be obtained by simple algebra, dividing the probability of an error on incongruent trials by the estimated probability of a failure in recollection: H = incongruent/$(1 - R)$.

An important difference between our experiments and other experiments carried out with the process-dissociation procedure is that we constructed "opposition" and "facilitation" conditions by manipulating congruency with prior learning, whereas in other experiments, those conditions were constructed by manipulating inclusion versus exclusion instructions at the time of test. For example, for an inclusion test, Jacoby et al. (1993) instructed participants to complete word stems by recollecting an earlier-studied word or, if they were unable to do so, to complete the stem with the first word that came to mind. Recollection and automatic influences of memory act in concert for an inclusion test just as they do when effects of recollection are congruent with a habit created by prior training. For an exclusion test, participants were instructed to use stems as cues to recollect an earlier-studied word but not to use recalled words as completions. For an exclusion test, recollection opposes automatic influences of memory and, therefore, producing an earlier-studied word as a completion on an exclusion test is similar to a memory slip.

The process-dissociation procedure has been controversial because of its underlying assumptions. Some critics have argued that inclusion and exclusion instructions are too complicated for people to comprehend and that they may produce differential biases in responding across the two conditions (Curran & Hintzman, 1995; Graf & Komatsu, 1994). We believe that such criticisms are unfounded (see Jacoby, 1998; Toth et al., 1994). However, creating in-concert and opposition conditions by manipulating congruency with prior learning allows us to avoid some of the complexities associated with instructions yet produces dissociations that are the same as those found using the inclusion–exclusion procedure (Hay & Jacoby, 1996). The most controversial assumption underlying the process-dissociation procedure is the assumption that recollection and automatic influences of memory independently contribute to performance (see Curran & Hintzman, 1995, 1997, and Hintzman & Curran, 1997, with replies by Jacoby, Begg, & Toth, 1997, and Jacoby & Shrout, 1997). If these memory processes operate independently of each other (i.e., if recollection can occur with or without automatic processing and vice versa), it should be possible to show that variables affect one memory process while leaving the other unchanged. Indeed, many dissociations of this sort have been found (e.g., Jacoby, 1991; Jacoby, Begg, & Toth, 1997; Jacoby et al., 1996, 1993). We expected results of the experiments reported here to show that age-related differences in memory are specific to recollection and, in doing so, provide further support for the viability of the independence assumption.

Distinguishing Between Deficits in Inhibition and Deficits in Recollection

Hay and Jacoby (1996) demonstrated that memory slips were more likely when people were required to respond rapidly at the time of test, supporting the commonplace observation that errors reflecting habit are more likely when one is rushed. These findings might be interpreted as a failure to inhibit, or "keep out," the effects of habit. However, a weakness of such an inhibition account is that it focuses only on the opposition condition. In contrast, Hay and Jacoby argued that memory slips result from a failure to "bring in," or recollect, a particular event when speeded responding is required. Fast responding reduced performance accuracy in situations in which habit and recollection operated in opposition and in situations in which the two processes acted in concert (facilitation condition). If participants are impaired in their ability to inhibit typical responses from training, they should not be disadvantaged in a facilitation condition in which habit is a source of correct responding rather than a source of error. Hay and Jacoby used the process-dissociation procedure to combine results from the in-concert and opposition conditions and found that fast responding reduced the probability of recollection but left habit unchanged.

We expected age-related differences in memory to be restricted to a difference in recollection, just as Hay and Jacoby (1996) found for the effects of speeded responding. We predicted that older adults would produce more memory slips than young adults in the opposition condition. However, we also expected older adults to be disadvantaged in the condition in which habit and recollection acted in concert, showing that the problem is one of recollection rather than a deficit in inhibitory processes. According to our dual-process account, recollection serves as an alternative basis for responding to habit, rather than inhibiting the effects of habit when the two act in opposition. The difference between recollection and inhibition accounts of age-related memory deficits has implications for the strategies researchers adopt to repair memory in elderly adults. An inhibition account would train older adults to suppress, or "keep out," interfering information, whereas our dual-process account focuses on means of enhancing recollection by helping older adults to "bring in" and expand on the information that is available.

Aging, Elaborative Processing, and Distinctiveness

An age-related deficit in controlled processing might prevent older participants from exploiting the meaning of items in a manner necessary to produce elaborated, context-specific encoding of information. The difference between general and context-specific encoding of information is illustrated in an experiment reported by Craik and Simon (1980). In that study, participants were instructed to recall target words from earlier-presented sentences (e.g., "The highlight of the circus was the clumsy BEAR") when given either context-specific cues (e.g., "clumsy") or general descriptions of the words as cues (e.g., "wild animal"). Results showed that young adults recalled more words given specific versus general cues but that this pattern was reversed for elderly participants. Older adults performed better when they were given general cues, suggesting that they encode material more generally in terms of global semantic characteristics, and were less likely to integrate unique features of the experimental context.

If elderly adults have difficulty adding richness and depth to memorial processing, they should produce less distinctive representations, reducing the likelihood that such information will be retrieved at a later time (e.g., Craik & Jacoby, 1979; Moscovitch & Craik, 1976; Till & Walsh, 1980). Such an account suggests that there are qualitative differences in processing between young and older adults that may contribute to age-related deficits on tests using specific retrieval cues (e.g., Burke & Light, 1981; Craik & Byrd, 1982; Craik & Simon, 1980; Rabinowitz & Ackerman, 1982; Rabinowitz, Craik, & Ackerman, 1982) and in monitoring contextual information to make source judgments (e.g., Ferguson, Hashtroudi, & Johnson, 1992; McIntyre & Craik, 1987). Johnson (e.g., 1991; Johnson, Hashtroudi & Lindsay, 1993) has suggested that older adults are impaired in the process of "binding" contextual details, such as source, to form distinctive memory representations. An alternative explanation has been offered by Moscovitch (Moscovitch, 1992, 1994; Moscovitch & Winocur, 1992), who suggested that older adults have deficits in strategic uses of memory caused by frontal lobe deterioration. Indeed, these studies provide support for our argument that older adults have difficulties expanding on, rather than inhibiting, available information in memory. In Experiment 1, we examined these issues further by investigating the extent to which young and older adults would be able to exploit distinctive contextual information afforded in the experimental materials. We expected age-related deficits in elaborative processing to reduce the extent to which older adults would be able to take advantage of distinctive contextual information to enhance recollection.

The stimuli in our experiments were homographs paired with typical and atypical responses such that the distinctiveness of the atypical response words was manipulated between subjects. One half of the participants were randomly assigned to a *nondistinctive condition* in which the typical and atypical responses reflected the same meaning of the homograph (e.g., organ–music, organ–piano). The other half of the participants were assigned to a *distinctive condition* in which the typical and atypical responses reflected different meanings of the same stimulus word (e.g., organ–music, organ–heart). Manipulating the semantic relatedness of the typical and atypical responses was expected to affect recollection. Young adults should process associative information in an elaborative, integrative manner, showing a benefit in performance in the distinctive over the nondistinctive condition. In contrast, we expected that older adults would not show a difference in recollection across distinctiveness conditions because they would be less able to elaborate the semantic relation between the stimulus and response words to take advantage of the unique meanings in the distinctive condition. Estimates of habit were not expected to differ across distinctiveness condition or by age. Rather, we expected estimates of habit to reflect training from the first phase of the experiment by approximating the probability with which typical items were presented (75%).

Experiment 1

Method

Participants and materials. The young adults were 32 introductory psychology students at McMaster University who participated in the experiment for course credit. The elderly adults were 32 volunteers older than 60 years of age who were alumni of either McMaster University or the University of Toronto. All participants reported that they were in good health and were randomly assigned to a distinctiveness condition with the constraint that participants in each condition be approximately equal in age. For the young adults in the nondistinctive condition (11 women and 5 men), the mean age was 19.2 years (SD = 0.66). In the distinctive condition, the mean age of participants (12 women and 4 men) was 19.6 years (SD = 3.1). Mill Hill Vocabulary Scale (MHVS) scores (Raven, 1965) were not available for the young adults; however, a mean score of .63 was obtained in an earlier study for a comparable group of young adults (Jennings & Jacoby, 1993). For the older adults, the mean age of the participants in the nondistinctive condition (8 women and 8 men) was 71.1 years (SD = 5.8). They had a mean score of .81 (SD = .10) on the MHVS and had an average of 17.7 years of education (SD = 1.7). The mean age of the older adults in the distinctive condition (7 women and 9 men), was 71.2 years (SD = 6.5). They had a mean score of .83 (SD = .11) on the MHVC and had 17.8 years of education (SD = 1.4). The data from 1 additional elderly participant were discarded because he was not able to complete the task.

A pool of 16 homographs (i.e., words with one spelling but multiple meanings) was selected from the norms collected by Perfetti, Lindsey, and Garson (1971). Two pairs of highly related associates were chosen for each homograph, with each reflecting a different interpretation (e.g., organ–music/piano and organ–body/heart). For each typical response (e.g., organ–music), there was an atypical response assigned to the nondistinctive condition (e.g., organ–piano) and an atypical response assigned to the distinctive condition (e.g., organ–heart) that reflected the same and different meaning as compared with the typical response, respectively. Lists were counterbalanced for preexperimental familiarity, and all items occurred equally often as typical and atypical responses and equally often across distinctiveness conditions.

Design and procedure. Participants were tested individually on a IBM-compatible PC using Schneider's (1990) Micro-Experimental Laboratory software. Words were presented in the middle of the screen in lowercase letters. The character size of the stimuli was approximately 3 × 4 mm, and participants were seated approximately 70–75 cm from the screen.

In the training phase, participants were presented with a stimulus word and instructed to guess an associated word (e.g., organ–____). They were told that the correct response would be related to the word on the screen and that they had 2 s to respond aloud with an answer. The response we had chosen as correct was then presented for 1 s (e.g., organ–music). There were always two possible responses for each stimulus item, but only one was presented as correct on a particular trial. Participants were instructed to pay attention to the responses that were presented. They were informed that more than one response would appear with each stimulus word throughout the experiment and that some responses would appear more often than others. The purpose of the guessing task was to keep participants engaged so that they would attend to the multiple presentations of stimuli throughout the training session. Two examples that did not appear elsewhere in the experiment were used to illustrate the procedure. Participants then performed three successive blocks of training, with a short break between each block. Responses were recorded by the experimenter but were not of primary interest. The structure of the training session was consistent across distinctiveness conditions, with the only difference being whether the atypical responses reflected the same or different meaning as the typical responses.

The training session consisted of three blocks of 128 presentations, with each block containing eight presentations of each stimulus item with six typical and two atypical responses. The typical responses appeared with a probability of 75% in each block of training. Across the three training blocks, 24 presentations of each of the 16 stimulus words were shown to participants (18 typical responses and 6 atypical responses). The order of the items in each block was random, with the restriction that the same item could not be presented more than three times in a row. The entire training session contained 384 presentations and lasted approximately 25 min. The distinctiveness of typical and atypical items was manipulated between subjects.

After training, participants received 16 successive study–test lists divided into two blocks of eight lists. Each study list contained eight of the word pairs seen earlier in training (e.g., organ–music). Participants were instructed to read the word pairs silently and to remember them for a memory test that would follow. After each study list, participants received a cued-recall test for the word pairs they had just seen. A stimulus word was presented as a test cue (e.g., organ–____) to which participants were instructed to report the response with which it was paired in the preceding study list. They were told that if they could not remember the item, they were to guess. Participants were also cautioned that some word pairs could appear in the test that had not been presented in the immediately preceding study list. For these items, participants were instructed to guess with the first word that came to mind. Again, the experimenter recorded all responses.

Study lists were presented at a 1-s rate, with a 500-ms interpair interval. For each study list of eight items, six typical items and two atypical items were presented, maintaining the 75–25 probabilities from Phase 1. Test cues were presented at a 3-s rate for all eight study words and for two additional stimulus words that were not seen in the preceding study list but had been presented during the training session. Because these two additional "guessing items" never appeared in the preceding study list, they could not be recollected and therefore provided a baseline measure of automatic influences to which we could compare our estimates of habit. If habit and guessing scores converged, it would provide support for the validity of estimates gained from the process-dissociation procedure. Within each block of eight tests, all stimulus words appeared as guessing items once and it was ensured that they never overlapped with items presented in the study list. The presentation order of items in the study and test lists was randomly determined and remained fixed across participants with the constraint that no item was repeated within a list. For each block, typical items appeared three times and atypical items were presented once across lists.

Participants performed a short distractor task between each study and test list. A random number between 30 and 100 was presented on the computer screen for 1 s immediately after each study list, followed by a blank screen for 6.5 s. During this 7.5-s interval, participants were required to count backward by 3s aloud, as quickly as possible, starting with the number that appeared on the screen. The experimenter emphasized to participants that the backward counting should continue until a message appeared that instructed them to begin the test. The purpose of the distractor task was to prevent participants from rehearsing study items in short-term memory. Different numbers were presented for the distractor task between each study–test trial.

After each test, the procedure started again with a new study list until all 16 lists had been studied and tested. After completing eight study–test blocks, participants rested for a few minutes while the second set of eight study–test blocks was loaded into the computer. The entire study–test session lasted 20–25 min.

Results and Discussion

The significance level for all statistical tests was set at the .05 level. Tests revealing significant main effects are not reported when variables producing those main effects entered into significant interactions unless the comparison was of particular interest.

During the training session, our intention was to create a habit strength of 75% by presenting typical items as responses on 75% of the trials. The mean probability of responding with a typical item in the final block of training was .68 for the young adults and .60 for the elderly adults, suggesting that responding was biased away from chance levels. The probability of responding with a typical item in the training session, analyzed across age, training block, and distinctiveness condition, revealed significant effects of age $F(1, 60) = 17.82$, $MSE = 0.02$, distinctiveness condition, $F(1, 60) = 4.54$, $MSE = 0.02$, and block, $F(2, 120) = 117.11$, $MSE = 0.01$ (see Figure 1). These results demonstrate that young adults produced more typical responses in training than did the

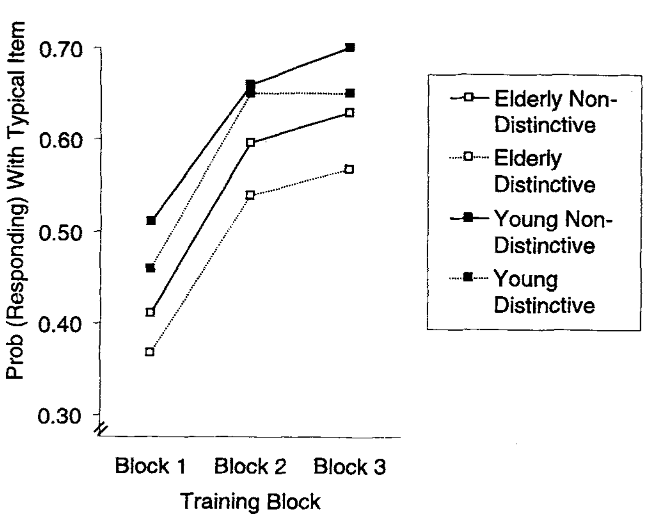

Figure 1. Probability of responding with a typical item in training by age, block, and distinctiveness condition.

older adults (Ms = .61 and .52, respectively), a finding that is discussed in more detail after the analyses of automatic estimates at the end of this section. Results also show that a greater number of typical responses were produced in the nondistinctive condition than in the distinctive condition (Ms = .58 and .54, respectively). Not surprisingly, overall performance improved across successive blocks (Ms = .44, .61, and .64 across Blocks 1–3, respectively). The effect of distinctiveness in training did not replicate across Experiments 2 and 3 and thus is not considered further. There were no significant interactions.

The data of interest came from Phase 2 of the experiment in which participants attempted to remember specific study lists. Study lists consisted of congruent trials, in which habit and recollection worked together to facilitate responding with typical responses, and incongruent trials, in which habit opposed responding with atypical responses. The probabilities of correctly giving a typical item as a response on congruent trials and incorrectly producing a typical item as a response on incongruent trials are shown in Table 1 for both distinctiveness conditions and age groups.

The probability of producing a typical response on congruent trials (correct responses) was significantly greater for young adults than for elderly adults, $F(1, 60) = 11.48$, $MSE = 0.005$, but there was no effect of distinctiveness condition, $F(1, 60) = 1.41$, $MSE = 0.005$, and the interaction did not approach significance ($F < 1$).

The probability of incorrectly responding with a typical item on incongruent trials was a measure of memory slips. Analysis of performance on incongruent trials confirmed that older adults were more susceptible to memory slips overall, $F(1, 60) = 27.02$, $MSE = 0.015$, but, more specifically, there was a significant interaction between age and distinctiveness condition, $F(1, 60) = 3.89$, $MSE = 0.015$. Further investigation of the interaction showed that errors on incongruent trials were significantly greater in the nondistinctive than in the distinctive condition for the young adults, $F(1, 30) = 6.66$, $MSE = 0.018$; however, for the older adults, there was no difference in performance between distinctiveness conditions ($F < 1$).

Using the equations from the process-dissociation procedure presented earlier, we estimated recollection as the difference between the probability of giving a typical response on the congruent and incongruent trials (see Table 1). Analysis of the recollection estimates revealed a main effect of age, $F(1, 60) = 36.80$, $MSE = 0.021$, as well as a significant interaction between age and distinctiveness condition, $F(1, 60) = 4.40$, $MSE = 0.021$. For the young adults, further analyses confirmed that recollection estimates were greater in the distinctive condition than in the nondistinctive condition, $F(1, 30) = 8.23$, $MSE = 0.025$. In contrast, recollection estimates did not differ between distinctiveness conditions for elderly adults ($F < 1$). This result did not reflect any insensitivity in our measure because the power to detect an effect on recollection for the older adults, as large as that observed for the younger adults, was .96 ($\alpha = .05$, Cohen's $d = 1.23$). These findings support our prediction that recollection would be enhanced in the distinctive condition only for the young adults.

The process-dissociation equations were also used to derive estimates of habit (see Table 1). As a source of converging evidence for our estimates of habit, we examined performance on guessing items. The guessing scores were calculated as the total proportion of typical responses given at test for items that were not presented in the preceding study list (see Table 1). An Age ×

Table 1
Probabilities of Responding With a Typical Item and Mean Estimates of Recollection and Automatic Influences as a Function of Age and Distinctiveness Condition in Experiment 1

Age and condition	Trial type: Congruent *M*	*SD*	Incongruent *M*	*SD*	Estimates: Recollection *M*	*SD*	Habit *M*	*SD*	Guessing *M*	*SD*
Young										
Nondistinctive	0.84	0.05	0.41	0.12	0.44	0.14	0.72	0.07	0.77	0.10
Distinctive	0.88	0.07	0.29	0.15	0.60	0.18	0.70	0.14	0.77	0.09
Older										
Nondistinctive	0.80	0.09	0.51	0.10	0.29	0.14	0.72	0.10	0.76	0.07
Distinctive	0.80	0.09	0.50	0.11	0.30	0.12	0.72	0.10	0.74	0.09

Distinctiveness × Measure of Automatic Influences ANOVA performed on these data did not reveal a significant effect of age ($F < 1$) or distinctiveness condition ($F < 1$). However, the type of automatic measure did have a significant effect, $F(1, 60) = 13.28$, $MSE = 0.005$, such that guessing scores were higher than estimates of habit (*M*s = .76 and .71, respectively). This difference between habit and guessing did not replicate across Experiments 2 and 3 and therefore is not considered further. The interactions did not approach significance. Using a conservative estimate of effect size in comparison to that found for habit estimates in previous studies using this paradigm (Hay & Jacoby, 1996), we found reasonable power (.59) to detect an effect of distinctiveness on habit or guessing estimates for each age group ($\alpha = .05$, Cohen's $d = 0.80$). Note that estimates of habit and guessing approximated the actual probability with which participants saw the typical items during training, and thus probability matching was apparent in the automatic component. (The importance of this probability matching is considered in the General Discussion section.)

Analyses of habit estimates in Experiment 1 revealed that once a habit was established, its contribution to performance did not differ between young and elderly adults. However, reliance on an established habit may differ from the process by which a habit is acquired. That is, the age difference that emerged in the training scores in Experiment 1 suggests that young adults may learn habits more readily than older adults because young adults were more likely to produce typical responses by the end of training (Phase 1). An age-related difference in habit acquisition would converge with results from experiments using classical conditioning of eyeblink responses as a measure of nondeclarative learning (Soloman, Pomerleau, Bennett, James, & Morse, 1989; Woodruff-Pak & Finkbiner, 1995; Woodruff-Pak & Thompson, 1988). However, even if habit acquisition in older adults was incomplete by the end of the training phase, the word pair associations continued to be strengthened in Phase 2 because the study–test lists maintained the training probabilities. Moreover, it is important to note that the training scores are a contaminated index of habit learning in that participants were instructed to intentionally guess during training and likely used conscious strategies to derive their responses. Therefore, although age differences may sometimes exist in habit learning under some conditions, there is no clear evidence from Experiment 1 to suggest that the overall level of habit acquisition differed between young and older adults.

The results of Experiment 1 demonstrate that aging produces deficits in recollection but that it does not affect estimates of habit and guessing. These findings support results from other process-dissociation studies that have shown age effects on recollection while leaving automatic processing relatively unchanged (Jacoby et al., 1996; Jennings & Jacoby, 1993, 1997). We found that older adults committed more memory slips than young adults on opposition trials and performed more poorly than young adults when habit and recollection acted in concert (congruent trials). Inhibition accounts of age-related deficits in memory do not predict age differences in both of these situations but instead posit that older adults will have difficulties inhibiting the effects of habit only in the opposition condition, in which habit leads to errors in performance. Therefore, we suggest that a better explanation of these findings is that elderly adults have deficits in recollective processing, which also seem to impair their ability to make use of distinctive contextual information.

For the young adults, we found that recollection was higher in the distinctive condition, in which typical and atypical responses reflected different meanings of the stimulus word, as compared with the nondistinctive condition, in which the same meaning was maintained for both responses. This finding suggests that young adults elaborate the associative relation between the stimulus and response words to enhance recollection. If participants were less able to elaborate contextual information, there would be no advantage afforded by the distinctive materials and recollection estimates would not differ across distinctiveness conditions. Indeed, this was the pattern of responding observed for older adults. Consistent with previous research on aging (e.g., Burke & Light, 1981; Craik & Byrd, 1982; Craik & Simon, 1980), the results of our experiment support the hypothesis that elderly adults have difficulties elaborating information and thus do not effectively exploit contextual information to assist their memory performance. Older adults might encode information in a more general manner that involves less associative processing (e.g., Craik & Simon, 1980).

Experiment 2

It is possible that the recollection estimates of older adults did not differ across distinctiveness conditions in Experiment 1 because the older adults simply did not have enough time to elaborate the associative relation between the stimulus and response words at encoding. The use of consciously controlled processes requires time and attentional resources, as shown by the reduction in recollection when young participants study under conditions of divided attention (Jacoby et al., 1993) or speeded presentation rate

(Hay & Jacoby, 1996). The purpose of Experiment 2 was to focus only on the performance of older adults to help them take advantage of distinctive contextual information in a manner similar to young adults. General slowing hypotheses of aging (e.g., Salthouse, 1991, 1994, 1996) suggest that older adults may require additional time to process information compared with young adults. On the basis of a slowing account of age differences in memory, elderly adults should be better able to exploit distinctive contextual information when they receive more processing time at encoding. If older adults are able to exploit the distinctive associative relations in the experimental materials, a difference in recollection should emerge between distinctiveness conditions at a slow presentation rate. In contrast, automatic influences of memory should not be affected by presentation rate manipulations.

Method

Participants and materials. The participants were 32 elderly volunteers older than 60 years of age who were alumni of either McMaster University or the University of Toronto. Participants were randomly assigned to a distinctiveness condition with the constraint that participants in both groups be approximately equal in age. In the nondistinctive condition, the mean age of participants (8 women and 8 men) was 71.9 years (SD = 6.0). They had a mean score of .85 (SD = .09) on the MHVS and had 17.6 years (SD = 1.6) of education. In the distinctive condition, the mean age of participants (7 women and 9 men) was 72.7 years (SD = 6.1). They had a mean score of .84 (SD = .11) on the MHVS and had 18.6 years (SD = 1.7) of education. Data from 2 additional older adults were discarded because of difficulties completing the task. The materials and details of list construction were identical to those used in Experiment 1.

Design and procedure. The initial training session of Experiment 2 was identical to that of Experiment 1, but the following changes were made to the study–test sessions: The presentation rate of study items was manipulated within subjects, such that all participants received eight study lists at a slow rate (3,000 ms) and eight study lists at a faster rate (1,000 ms) maintained from Experiment 1. A random ordering of fast and slow lists was determined and then divided into two blocks of eight, with four at each rate appearing in each set of eight study–test blocks. The position of the fast and slow lists was counterbalanced across participants. All other details of the procedure were the same as Experiment 1, as were the analyses of results.

Results and Discussion

During the training session, our intention was again to create a habit strength of 75% by presenting typical items as responses on 75% of the trials. The mean probability of responding with a typical item in the final block of training was .60 in the nondistinctive condition and .59 in the distinctive condition. An analysis of typical responses produced across training blocks and distinctiveness conditions revealed improved performance across blocks, $F(2, 60) = 165.63$, $MSE = 0.004$. No other effects approached significance.

The mean probability of responding with a typical item on congruent trials was investigated across presentation rate manipulations and distinctiveness conditions (see Table 2). Analyses revealed a significant effect of presentation rate, $F(1, 30) = 5.54$, $MSE = 0.004$, as participants were more likely to correctly produce a typical response when items were studied at a slow than a fast presentation rate. The interaction was not significant ($F < 1$).

The mean probability of incorrectly responding with a typical item on incongruent trials across fast and slow presentation rates and distinctiveness conditions was analyzed (see Table 2). This analysis revealed a significant effect of presentation rate, $F(1, 30) = 28.41$, $MSE = 0.016$, as more memory slips were produced when items were studied at a fast rate. Again, there was no significant interaction ($F < 1$).

An analysis of recollection estimates across presentation rate manipulations and distinctiveness conditions showed that recollection was higher when items were presented at a slow than at a fast presentation rate, $F(1, 30) = 48.05$, $MSE = 0.014$. The interaction did not approach significance ($F < 1$; see Table 2). A null effect of distinctiveness on recollection estimates was likely not caused by any insensitivity in our measure because the power to detect an effect as large as that observed for the young adults in Experiment 1 was .72 at the fast presentation rate ($\alpha = .05$, Cohen's $d = 0.80$) and .75 at the slow presentation rate ($\alpha = .05$, Cohen's $d = 0.84$).

The type of automatic measure (habit estimates and guessing scores) at each presentation rate and in each distinctiveness condition was analyzed but did not reveal significant effects for type of automatic measure, $F(1, 30) = 1.22$, $MSE = 0.007$, presentation rate ($F < 1$), or distinctiveness condition ($F < 1$), and there were no significant interactions (see Table 2). Again, probability matching was apparent in both measures across manipulations. These results support the proposal that habit estimates and guessing scores reflect similar underlying processes. Using a more conservative estimate of effect size than that found for habit estimates obtained in previous studies (Hay & Jacoby, 1996), we found that

Table 2
Probabilities of Responding With a Typical Item and Mean Estimates of Recollection and Automatic Influences for Older Adults as a Function of Presentation Rate and Distinctiveness Condition in Experiment 2

	Trial type				Estimates					
	Congruent		Incongruent		Recollection		Habit		Guessing	
Presentation rate and condition	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Fast										
Nondistinctive	0.82	0.05	0.60	0.20	0.22	0.20	0.76	0.08	0.75	0.13
Distinctive	0.82	0.08	0.56	0.15	0.26	0.12	0.75	0.11	0.73	0.16
Slow										
Nondistinctive	0.85	0.07	0.41	0.18	0.44	0.19	0.72	0.13	0.79	0.15
Distinctive	0.87	0.09	0.41	0.14	0.46	0.15	0.75	0.14	0.77	0.10

the power to detect an effect of presentation rate on habit or guessing estimates in each distinctiveness condition was .59 (α = .05, Cohen's d = 0.80). This analysis revealed reasonable power to detect an effect on the automatic component if an effect existed.

In summary, the results of Experiment 2 show that a slow presentation rate reduced the probability of a memory slip but also increased the probability of a correct response on congruent trials. This pattern of results shows an influence of presentation rate on recollection but is not readily understood by arguing that memory slips reflect a deficit in inhibitory processes. Although we found that elderly adults can improve their overall level of recollection when they are given additional processing time at encoding, this manipulation failed to induce elderly adults to exploit distinctive semantic information in a manner similar to the young adults. That is, even with additional time to study, older adults did not effectively elaborate the associative relation between the stimulus and response words. These results suggest that in addition to quantitative age-related deficits in recollection, there are qualitative differences in the nature of recollective processing carried out by young and elderly adults. Finally, a process dissociation was revealed in that manipulations of presentation rate affected the recollection performance of older adults but did not influence estimates of habit or guessing (automatic influences of memory).

Experiment 3

Rather than focus on encoding deficits, several researchers have suggested that older adults are more affected by difficulties experienced at the time of retrieval (e.g., Burke & Light, 1981). Furthermore, Craik (1983, 1986) has suggested that age decrements in memory can be reduced to the extent that the task environment supports retrieval processes. For our final experiment, we sought to guide retrieval as well as encoding to determine whether older adults were able to exploit associative contextual information under highly supportive circumstances. To start, all study lists were presented at the slow rate maintained from Experiment 2. Participants were also given an unlimited deadline to respond at test, allowing them more time to retrieve information. However, because elderly adults may also have difficulties spontaneously initiating elaborative strategies (e.g., Craik & Byrd, 1982), we reduced reliance on self-initiated processing by describing the semantic relation between the stimulus and response words to participants in both distinctiveness conditions and by explicitly encouraging them to elaborate the associative information. Our intention was to guide the processing of elderly adults in the distinctive condition by having them focus on the different meanings associated with the typical and atypical responses. If older adults are able to elaborately process distinctive contextual information, they should show greater recollection in the distinctive condition than in the nondistinctive condition under these supportive task conditions. Again, automatic influences of memory should not be affected by the amount of time to respond at test or the distinctiveness manipulations.

Method

Participants and materials. Thirty-two elderly adults older than 60 years of age who were alumni of McMaster University or the University of Toronto volunteered to participate in the study. Participants were randomly assigned to a distinctiveness condition, with the constraint that participants in both groups be matched in age. In the nondistinctive condition, the mean age of participants (5 women and 11 men) was 71.1 years (SD = 7.1). They had a mean score of .87 (SD = .08) on the MHVS and had 18.3 years (SD = 2.2) of education. For the distinctive condition (9 women and 7 men), the mean age was 71.9 years (SD = 6.1). The mean MHVS score for these participants was .87 (SD = .09), and they had 17.4 years (SD = 2.1) of education. Data from 1 additional elderly adult were discarded because the participant was not able to complete the task. The materials and details of list construction from Experiments 1 and 2 were the same in this experiment.

Design and procedure. The training and study–test sessions of Experiment 3 were identical to those used in the previous experiments with the following exceptions: The presentation rate of study list items in Phase 2 was maintained at a slow rate (3,000 ms) for all lists, but the amount of time for responding was manipulated within subjects. The 16 study–test sessions were divided into two sets of eight sessions, with one set having a 3000-ms deadline and the other having an unlimited deadline. The ordering of response deadlines (3,000 ms, unlimited) was counterbalanced across participants.

Before the training session was initiated, all participants were informed that two semantically related responses would appear with each stimulus word. The relation between the stimulus and response words was then explicitly described. Participants in the distinctive condition were told that each stimulus word would be paired with responses that reflected different interpretations of the stimulus word, whereas participants in the nondistinctive condition were informed that both responses would reflect the same meaning of the stimulus word. During the study–test phase, participants were especially encouraged to think about the semantic interpretations of the responses when they encoded the items. Focusing on the different meanings of the responses in the distinctive condition was expected to make the two responses more unique, leading to better retrieval at the time of test. In contrast, responses in the nondistinctive condition were more similar to each other because of their shared meaning. Therefore, recollection of these items was expected to be reduced in comparison.

Results and Discussion

Again, during the training session, our intention was to create a habit strength of 75% by presenting typical items as responses on 75% of the trials. The mean probability of giving a typical item as a response in the final block of training for older participants in the nondistinctive and distinctive conditions was .68 and .60, respectively. Analysis of typical responses produced in the training phase across blocks and distinctiveness conditions revealed a significant effect of block, $F(2, 60) = 128.40$, $MSE = 0.004$. No other effects approached significance.

The probability of responding with a typical item on congruent trials was examined for both the deadline and distinctiveness conditions (see Table 3). This analysis did not reveal a significant effect of distinctiveness condition ($F < 1$) or response deadline ($F < 1$), and the interaction was not significant $F(1, 30) = 3.35$. The probability of incorrectly producing a typical response on incongruent trials was greater in the nondistinctive than in the distinctive condition, $F(1, 30) = 5.5$, $MSE = 0.02$, demonstrating that memory slips were more likely to occur when the task materials were less distinctive. There was no significant interaction with the deadline condition ($F < 1$; see Table 3).

An analysis of estimates of recollection was carried out for both distinctiveness conditions and response deadlines (see Table 3). This investigation revealed that recollection estimates were greater in the distinctive condition than in the nondistinctive condition,

Table 3
Probabilities of Responding With a Typical Item and Mean Estimates of Recollection and Automatic Influences for Older Adults as a Function of Response Deadline and Distinctiveness Condition in Experiment 3

Response deadline and condition	Trial type				Estimates					
	Congruent		Incongruent		Recollection		Habit		Guessing	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Fast										
Nondistinctive	0.87	0.08	0.45	0.14	0.42	0.12	0.77	0.13	0.77	0.15
Distinctive	0.86	0.08	0.38	0.15	0.48	0.17	0.72	0.13	0.73	0.11
Slow										
Nondistinctive	0.84	0.09	0.41	0.12	0.42	0.16	0.72	0.12	0.75	0.13
Distinctive	0.89	0.07	0.31	0.12	0.58	0.15	0.73	0.13	0.74	0.10

$F(1, 30) = 5.84$, $MSE = 0.03$. Although the relevant interaction was not significant, $F(1, 30) = 2.22$, $MSE = 0.03$, further analyses of recollection estimates showed that participants recollected more in the distinctive than the nondistinctive condition when given an unlimited deadline, $F(1, 30) = 7.76$, $MSE = 0.024$, but performance did not differ between distinctiveness conditions at the faster response deadline, $F(1, 30) = 1.40$, $MSE = 0.022$. The lack of a significant difference in recollection estimates across distinctiveness conditions at the fast deadline was not caused by any insensitivity in our measure because the power to detect an effect as large as that observed between distinctiveness conditions for young adults in Experiment 1 was .90 ($\alpha = .05$, Cohen's $d = 1.07$). These results demonstrate that elderly adults were able to exploit distinctive associative information to assist recollection only when they (a) had an unlimited amount of time to respond at test, (b) had enough time to encode information at study, and (c) were instructed about how they should process and associate the information presented to them.

An analysis of habit and guessing estimates across the distinctiveness and deadline conditions was performed but did not reveal any significant effects for type of automatic measure ($F < 1$), response deadline ($F < 1$), or distinctiveness condition ($F < 1$). The interactions did not approach significance (see Table 3). Again, using a more conservative estimate of effect size than that found for habit estimates in previous studies using this paradigm (Hay & Jacoby, 1996), we found that the power to detect an effect of distinctiveness on habit or guessing estimates at each deadline was .59 ($\alpha = .05$, Cohen's $d = 0.80$). The results of power analyses across Experiments 1–3 support the findings of invariance in the automatic component. Furthermore, estimates of automatic influences again approximated the probability of having seen typical items during the training session.

In summary, the pattern of recollection performance for older adults in Experiment 3 replicated the performance of young adults in Experiment 1; recollection estimates were higher in the distinctive versus the nondistinctive condition. These results demonstrate that older adults are capable of exploiting distinctive associative information to the same extent as young adults but only under highly specific, supportive task conditions. That is, when memorial processing is guided and they respond within an unlimited deadline, older adults are able to exploit distinctive contextual information to benefit recollection. Although recollection estimates were influenced by instructional and deadline manipulations in Experiment 3, habit was unaffected by these variables and again reflected the probability with which typical items had been presented during the training phase.

General Discussion

Using Jacoby's (1991) process-dissociation procedure to separate recollection and habit in young and elderly adults, we found a significant disadvantage in recollection for older participants, but estimates of habit were not influenced by the effects of aging. Similarly, previous research using different versions of the process-dissociation procedure has found selective age-related impairments in recollection in the presence of preserved automatic responding (Hay, Nordlie, & Jacoby, 1998; Jacoby & Hay, 1993; Jacoby et al., 1996; Jennings & Jacoby, 1993, 1997). Some researchers have suggested that the proactive interference effects of habit stem from older adults' difficulties inhibiting irrelevant information in memory (e.g., Hasher & Zacks, 1988; Zacks & Hasher, 1997). This deficit-in-inhibition account of age-related deficits in memory is compared with a dual-process approach in which we propose that elderly adults have impairments in consciously controlled processing.

Dual Processes Versus Deficit in Inhibition

In our experiments, performance on incongruent trials measured the proportion of memory slips committed by participants when they failed to suppress typical responses, making this condition similar to tasks used by researchers investigating inhibitory mechanisms (e.g., Gernsbacher & Faust, 1991; Hasher & Zacks, 1988). Performance on incongruent trials in Experiment 1 could be taken as evidence to support an inhibition account of age-related differences in memory (e.g., Hasher & Zacks, 1988). That is, older adults mistakenly produced typical responses from training more often than did young adults, as would be expected if they were less able to inhibit habitual responding. However, if age-related memory deficits arise from impaired inhibitory mechanisms, older adults should not differ from young adults on congruent trials in which recollection and habit work together to produce the same outcome. The results of Experiment 1 revealed poorer performance for elderly participants on congruent trials. Our dual-process approach holds that an age-related deficit in recollection is responsible for both the lower probability of correct responding shown by older adults on congruent trials as well as their higher probability of memory slips on incongruent trials. We conclude that older adults are more susceptible to memory slips than are young adults because of a deficit in recollection in the presence of unchanged habit.

The difference between impaired inhibition and impaired recollection as explanations of age-related deficits in memory is important because these two views lead to very different approaches for memory rehabilitation. An inhibition account would encourage teaching older adults to resist interfering information (i.e., habit) by training them to suppress nontarget information. In contrast, the manipulations we used were not of the sort that we would expect to influence inhibition. Our strategy for rehabilitation was to manipulate the conditions of encoding and retrieval to enhance recollective abilities in elderly adults. Our experiments were guided by our view that age-related impairments in elaborative processing reflect deficits in consciously controlled uses of memory.

The results of Experiment 1 demonstrate that young adults elaborate distinctive semantic information to assist recollection, as evidenced by greater recollection in the distinctive than in the nondistinctive condition. In contrast, recollection estimates for older adults did not differ between distinctiveness conditions. These findings are consistent with research suggesting that older adults are less likely to process information as richly or deeply as young adults but instead encode items in a more general manner (e.g., Craik & Byrd, 1982; Craik & Simon, 1980; Rabinowitz et al., 1982). In Experiments 2 and 3, we attempted to repair deficits in recollection in older adults by focusing on their difficulties elaborating and integrating associative information. We found that they were able to exploit distinctive information to benefit recollection when supportive task conditions were provided in the form of additional time for study and test, along with instructions that directed processing. Manipulations that were effective in enhancing recollection seem better interpreted as removing a deficit in elaborative processing of a sort that can be used to aid later retrieval (e.g., Craik & Byrd, 1982) rather than removing a deficit in inhibition.

Aging, Frontal Lobe Functioning, and Control

It is widely recognized that the frontal lobes of the human brain perform a supervisory, "executive" role in controlling cognition and behavior, the importance of which has been established in the literature (e.g., Norman & Shallice, 1980; Stuss & Benson, 1986). Moscovitch (1992, 1994; Moscovitch & Winocur, 1992) has referred to the frontal lobes as a "working-with-memory structure" and has argued that they mediate the strategic, self-initiated aspects of memory that include organizing and coordinating information to and from the hippocampal system as well as performing activities such as inferencing, planning and elaborative processing. Although deficits in these cognitive abilities are most often cited in patients with frontal lobe damage, these characteristics have also been reported in normal older adults. Such observations are not surprising given that age-related memory decline is often linked to frontal system dysfunction (e.g., Craik, Morris, Morris, & Loewen, 1990; Moscovitch & Winocur, 1992; Parkin, 1997). Findings from Experiments 1 and 2 can be viewed as evidence supporting age-related deficits in strategic processing, in that older adults were not able to elaborate the experimental stimuli to take advantage of distinctive contextual information to improve their memory performance.

However, when task conditions were made more supportive to guide recollective processing in Experiment 3, older adults demonstrated they were able to elaborate distinctive information to enhance recollection in a manner similar to young adults. These findings suggest that young adults can initiate elaborative strategies on their own but that older adults may be less able to do so unless processing is guided by external sources and they are given generous amounts of time (e.g., Hulicka & Grossman, 1967; Treat & Reese, 1976). In studies that have not shown age differences in the processing of contextual information, the older adults have typically been supplied with mediational strategies and generous amounts of time to process information, or they have performed highly structured tasks (see Craik, 1986; Multhaup, 1995). Craik (1983, 1986) has argued that older adults have difficulties spontaneously initiating memorial processing, which is most apparent in situations lacking environmental support or structure. Our findings of age-related impairments in consciously controlled processing can be viewed more specifically as a deficit in self-initiated or strategic processing. We find it encouraging, however, that our older adults were able to engage in elaborative processing when guided to do so. That is, with additional support and structure, we were able to improve recollection in older adults to a level comparable to that of young adults. These findings suggest that age-related memory deficits are not absolute but instead can be restored under some conditions.

Recollection, Remembering, and Awareness

What is the relation between consciously controlled uses of memory and conscious awareness? Recollection, as defined by the process-dissociation procedure, is an objective measure of cognitive control that is measured as the difference in performance when one is trying to, as opposed to trying not to, engage in some act. In our experiments, the difference between remembering a specific episode when it was congruent versus incongruent with prior learning reflected the degree to which one was able to control responding. How might recollection of this sort relate to subjective awareness of an earlier experience? To investigate issues surrounding memory awareness, several researchers have used a remember–know paradigm (e.g., Gardiner, 1988; Gardiner & Java, 1991; Gardiner & Parkin, 1990; Parkin & Walter, 1992; Tulving, 1985) in which participants are asked to subjectively report on their memorial states. Using this procedure, participants classify whether they "remember" or "know" words from a previously presented study list. Participants are told to respond "remember" if they can recall some specific detail about an item's previous occurrence (e.g., if they can remember an image or association that came to mind during an earlier presentation of that item) or to respond "know" if an item is so familiar that they were certain it was studied earlier but they cannot reexperience any details of its prior presentation.

The process-dissociation and remember–know procedures are similar in that they both separate out two different bases of responding. Indeed, one might expect "remember" responses to map onto recollection and automatic responding to underlie "know" responses (however, see Donaldson, 1996, and Donaldson, MacKenzie, & Underhill, 1996, for a single-process view).

Although the interpretation of "know" responses has been controversial (see Jacoby et al., 1996; Jacoby, Yonelinas, & Jennings, 1997), researchers have found that aging reduces "remember" responses in tests of recognition memory (Parkin & Walter, 1992) and cued recall (Mantyla, 1993), paralleling age-related deficits in recollection that have been demonstrated using the process-dissociation procedure (Jennings & Jacoby, 1993, 1997). Using a habit-learning paradigm highly similar to the one described here, we have recently completed a study (reported in Jacoby et al., 1996) in which we measured objective memory performance and subjective awareness within the same task. Our results revealed that both types of measure produced highly comparable estimates of recollection and habit. Furthermore, the correlation between subjective "remember" responses and recollection estimates gained using the process-dissociation procedure was high for both young and elderly adults, suggesting that participants were aware that they were recollecting when they were doing so. On the basis of such findings, it is likely that participants in our experiments would say that they were "remembering," had they been asked, when they showed evidence of recollection in their objective performance.

Automatic Influences as Probability Matching

Researchers have distinguished between "knowing that" and "knowing how" (Cohen & Squire, 1980), suggesting that the type of memory that underlies conscious recollection of learned facts and information is different from that which reflects skills and habits (e.g., Squire, 1987). Dissociations between recollection (explicit or declarative memory) and habit (implicit or nondeclarative memory) have been demonstrated in adults who have normal memory functioning (for reviews, see Richardson-Klavehn & Bjork, 1988; Roediger & McDermott, 1993), in people with amnesia (e.g., for a review, see Moscovitch, Vriezen, & Gottstein, 1993), and in animals (e.g., Mishkin & Appenzeller, 1987).

Probability learning tasks are indirect tests that are assumed to reflect the development of automatic responding or habit (e.g., Knowlton, Squire, & Gluck, 1994; Reber, 1989). However, a weakness of these tasks is that they likely involve intentional responding and therefore suffer from the same contamination concerns associated with other indirect tests of memory. Previous researchers have tried to prevent participants from becoming aware of stimuli patterns by presenting information at rapid rates and in complex sequences, but there has been no method of determining the extent to which conscious processes are eliminated. Knowlton et al. (1994) argued that probability learning relies primarily on the form of memory preserved by patients with amnesia. However, they found that although patients with amnesia showed evidence of probability learning, they performed more poorly than healthy controls. Knowlton et al. suggested that patients with amnesia, unlike people with normal memory functioning, are disadvantaged because they are not able to supplement their automatic habit learning with conscious strategies. Our procedure avoids such contamination issues and offers a useful alternative to earlier probability learning paradigms because it allows us to examine the effects of habit separately from intentional responding. Using a process-dissociation approach, we demonstrate probability matching is evident only in the automatic component and therefore qualifies as implicit learning (e.g., Reber, 1989, 1993).

Although our habit estimates were uncontaminated, one could argue that performance on guessing trials reflected strategic processes in which participants became aware of the presentation probabilities from training and intentionally used that knowledge to guide responding. "Guessing items" were familiar from the training session but appeared at test without having been presented in the preceding study list. Similar to an indirect test of memory, participants were instructed to complete these items with the first response that came to mind. We do not argue that guessing trials provide a pure estimate of automatic influences, as guessing trials are open to the same contamination problems as indirect tests. However, there are several reasons why we believe the use of conscious strategies on guessing trials was minimized in our experiments. If participants were consciously using typical items from the training phase to respond on guessing trials, it is unlikely that guessing scores would reveal probability matching and converge with estimates of habit. However, probability matching and convergence were found for estimates of habit and guessing. Furthermore, if conscious strategies were used on guessing trials, one would expect guessing scores to be influenced by variables that affected conscious recollection. Our results show that guessing scores were not influenced by manipulations of distinctiveness, presentation rate, deadline, or aging, variables that had significant effects on recollection. These findings support our claim that conscious contamination was minimal on guessing trials.

Finally, there are some unique characteristics of the current paradigm that should be kept in mind when comparing our results to those from other studies. In our experiments, familiarity of typical items was saturated across multiple presentations to create a habit of 75%. The probability matching that emerged in the automatic component would make it difficult to reveal an influence of elaborative processing on habit, if any effect existed. However, if the automatic measure was not constrained by probability matching in this manner, one might expect to see the effects of elaborative processing on the automatic component in situations in which semantic or conceptual cues recruit prior episodes. Using a different procedure, Jacoby (1996) demonstrated effects of conceptual processing on both recollection and automatic influences of memory when study–test contexts were reinstated. Similarly, it would be expected that environmental support would produce both automatic and controlled effects on memory performance in some situations (see Craik & Jacoby, 1996; Jacoby, 1996; Jacoby & Hay, 1998).

Concluding Comments

Because of deficits in recollection, the effects of habit are sometimes left unopposed in older adults, increasing the likelihood that they will produce memory slips. However, we demonstrated that elderly adults also have memory impairments in a facilitation condition. We suggest that an understanding of age-related deficits in memory requires consideration of both an opposition condition, in which recollection and habit lead to conflicting outcomes, as well as a facilitation condition, in which both processes act in concert to produce the same outcome. By examining performance in both conditions, we found that older adults have deficits in recollection but that automatic influences, or habit, remain intact.

A dual-process view of memory differs from inhibition accounts of aging (e.g., Hasher & Zacks, 1988), which suggest that older adults have difficulties suppressing interfering information. In contrast, our focus has been on helping elderly adults process information in a more elaborate, integrative fashion to increase recollective abilities. Although older adults showed deficits in their abilities to exploit distinctive contextual information, performance improved to a level comparable to young adults when task conditions were made more supportive. That such abilities are not lost entirely and can actually be improved under some conditions should be encouraging to practitioners attempting to rehabilitate memory deficits associated with aging.

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