AGE-RELATED CHANGES IN AUTOMATIC AND CONSCIOUSLY-CONTROLLED MEMORY PROCESSES

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Abstract

Memory retrieval relies on automatic and consciously-controlled processes. However, it is not clear whether one or both of these influences are affected by age. The present experiments used Jacoby's (1991) process dissociation procedure to separately examine the effects of aging on each process. The results show that age impairs consciously-controlled memory but leaves automatic processing intact (Experiments 1, 2, 5 & 6). Moreover, age-related declines in conscious processes are severe. Elderly adults revealed marked deficits in conscious memory when only *three* words intervened between study and test (Experiments 3 - 5).

In these experiments (Experiments 1 - 5) impairments in conscious influences left automatic memory as the sole basis for retrieval, which led to "false" recognition errors. Although these errors suggest that older adults may be unaware of the process that underlies their performance (automatic versus conscious), they actually proved as aware as young adults and were highly capable of identifying which form of processing they used (Experiment 6). More importantly, the level of memory ability they demonstrated in the lab corresponded to their performance in the real world. Elderly subjects showed a high correlation between conscious memory failures on lab tasks and self-reported failures in everyday life (Experiment 7). This result suggests that the lab tests used were ecologically valid and predictive of real world functioning.

The implications of these seven experiments for memory assessment and rehabilitation are discussed.

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Table of Contents

List of Tables

Chapter 1

Introduction

Declines in memory with age have been documented since the time of Aristotle. He noted that the "old have inferior memories", a problem that he felt occurs because they "are in a state of rapid decay" (Aristotle, translated 1936). According to Aristotle, aging produces two distinct effects on memory. One, the elderly have difficulty *acquiring* memories because "the impression does not penetrate" and, two, they are poor at *retrieval* because their search attempts "do not keep their direction, but are scattered" (Aristotle, translated 1936).

Today, we would classify Aristotle's view as a processing model of memory, where memory is comprised of mental activities or operations. Acquisition of memory or encoding can be understood in terms of different degrees of processing (Craik & Lockhart, 1972) and by the influence of context on the way an event is processed (Tulving & Thomson, 1973). Memory retrieval can be seen as the recapitulation of encoding operations (Kolers, 1973) with different types of retrieval cues determining the success of recovery (Tulving & Thomson, 1973).

Not all cognitive aging researchers are interested in changes in memory processing. Instead, some have examined the mental structures that are hypothesized to support memory. One influential structural view envisions memory as composed of different stores. It can be divided into primary memory, which passively holds information temporarily (Waugh & Norman, 1965); working memory, which saves items temporarily but also works to manipulate and integrate information (Baddeley, 1986); and secondary memory, which retains information over the long term (Waugh & Norman, 1965). Trying to determine which stores are affected by age has occupied those working within this framework. The general consensus is that age has a minimal effect on primary memory, but disrupts both working memory and secondary memory (for reviews see Craik & Jennings, 1992; Smith & Earles, in press).

A second structural approach for exploring memory has focused on systems rather than stores. In this view, secondary memory can be separated into at least three distinct systems: episodic memory, which contains autobiographical or personal memories organized by time and place of occurrence; semantic memory, which is our general, encyclopedic knowledge of the world and language (Tulving, 1983); and procedural memory, which is knowledge that supports well-learned skills (Tulving, 1985). Similar to the memory store approach, research has been designed to establish which memory systems are altered by aging. Again, the effects are selective. Age has a small or negligible influence on semantic and procedural memory, but a pronounced negative impact on episodic memory (for reviews see Craik & Jennings, 1992; Anderson & Earles, in press; Mitchell, 1989).

Although these findings are useful for indicating where age deficits occur, it is not evident which aspects of secondary memory or episodic memory have been impaired to produce poor performance. That drawback has led some researchers to rediscover Aristotle's early view and probe memory for changes in encoding and retrieval.

When examining encoding the essential question is whether older adults encode events in ways that are less rich, meaningful or distinctive, making those events difficult to remember. One hypothesis is that older adults encode events in a general fashion, failing to elaborate and include specific details that would make them memorable (Craik & Simon, 1980; Mantyla & Backman, 1990; Rabinowitz & Ackerman, 1982). There is some evidence that this idea is true. For example, Rabinowitz, Craik and Ackerman (1982) presented subjects with a series of target words each paired with a weak associate. During the test phase, when cued with that same associate versus a strong associate that was not shown at study, young adults remembered more targets in the latter condition. Older adults, however, showed better performance with the strong associate, suggesting they had failed to encode the specific details during study (i.e., the weak associate).

A related theory of encoding deficits suggests that older adults acquire general information because they are unable to acquire the contextual detail that provides a more specific trace. The elderly do prove to be deficient at encoding source information, such as whether items are presented by a male or female voice (McIntyre & Craik, 1987) and whether actions are actually performed during study or only visualized (Hashtroudi, Johnson, & Chrosniak, 1990). Similarly, they are poor at remembering the spatial (e.g., Naveh-Benjamin, 1987, 1988) and temporal information (e.g., Kausler, Salthouse & Saults, 1987; McCormack, 1982) associated with an event. Although there is evidence suggesting that older adults encode in a more general fashion and acquire less contextual detail, others do not find the data compelling (for review see Light, 1991). Consequently, those individuals have looked towards the effects of aging on retrieval for answers (e.g., Burke & Light, 1981).

One of the most significant findings regarding retrieval in the elderly is that the level of impairment is dependent on the type of test used (e.g., Craik 1983, 1986). In a classic experiment, Schonfield and Robertson (1966) found a strong age difference in free recall performance but no significant deficit in recognition. Their results have been replicated several times, demonstrating that older adults sometimes have little or no difficulty with recognition performance (e.g., Craik & McDowd, 1987; Rabinowitz, 1984). Even more compelling task dissociations have been found with the introduction of indirect memory tests to research. The tasks that have been mentioned here so far, such as free recall and recognition, are *direct* memory tests. Subjects are asked to deliberately think back to a prior event and try to remember it. In contrast, *indirect* tests of memory do not ask people to report on a prior event but require them to engage in some task that indirectly reflects the occurrence of that event. For instance, a subject may be presented with a set of words, and later shown a list of three-letter word stems (e.g., gra__ for grass) with the request to complete each stem with the first word that comes to mind. Although many of the stems can be completed with study words, subjects are not told to think back to the prior list. However, they are very likely to use those words in their completions indicating memory for the prior presentation. When the results of these two types of tests are compared, there is a striking dissociation found in task performance with age. The elderly show deficits on direct tests but demonstrate relatively intact memory on indirect tests (for reviews see Craik & Jennings, 1992; Light, 1991) - a finding that will be examined and discussed in greater detail here.

Indirect versus Direct Tests of Memory

Direct tests of memory, which ask people to report on a past event, reveal pronounced declines in memory performance with age. The elderly are impaired, relative to the young, on tests of free recall, cued recall, and in some cases, recognition (e.g., Craik, 1986; Craik & McDowd, 1987; Light & Singh, 1987). In contrast, indirect tests of memory often do not reveal effects of aging. The elderly do not show significant memory deficits whether they complete word stems or fragments (Light, Singh, & Capps, 1986; Light & Singh, 1987), perform perceptual identification tasks (Light & Singh, 1987), or generate category exemplars in response to category names (Light & Albertson, 1989). As mentioned, these tasks are "indirect" because subjects are initially presented with items that serve as potential responses for the subsequent task, but are not asked to think back to the earlier presentation during task performance.

Dissociations in performance on indirect and direct tests shown by the elderly have been interpreted as evidence that indirect tests reflect a form of memory or processing that aging spares (e.g., Howard, 1983; Light & Singh, 1987). Although discussed in the literature under a variety of terms such as priming (Rose, Yesavage, Hill & Bower, 1986), procedural memory (Mitchell, 1989), and implicit memory (Light & Singh, 1987), the general notion is that performance on an indirect test does not entail deliberate recollection (Light & Albertson, 1989). Instead, the characteristics attributed to the processes underlying indirect test performance are similar to those ascribed to automaticity. Automatic processing has been described as a fast process that consumes no attentional capacity, is under the control of stimuli rather than intention, and occurs without awareness (e.g., Hasher & Zacks, 1979; Posner & Snyder, 1975; Schneider & Shiffrin, 1977). Performance on direct memory tests, however, is believed to rely on conscious, intentional processes (Jacoby, 1991; Klatzky, 1984; Logan, 1989).

Given the above, it might be concluded that results from experiments employing indirect tests indicate that aging does not influence automatic uses of memory (cf., Hasher & Zacks, 1979). However, there are problems for that conclusion. Although the aged do not show significant deficits in performance relative to young subjects on the indirect tests mentioned above, there are consistent age trends favouring the young. Failures to find significant effects may have stemmed from the use of experimental designs with insufficient power (Chiarello & Hoyer, 1988).

Moreover, other studies have revealed significant age differences using indirect tests identical to those used to show age constancy (Chiarello & Hoyer, 1988; Davis et al., 1990; Howard, Shaw, & Heisy, 1986; Rose et al., 1986). Consequently, some researchers conclude that the form of memory underlying indirect test performance is not invariant with age (Chiarello & Hoyer, 1988; Davis et al., 1990; Rose et al, 1986).

Conflicting interpretations of indirect test results stem from the assumption that each task taps only a particular form of memory. Indirect tests are said to primarily reflect automatic or unconscious uses of memory whereas direct tests primarily reflect consciously-controlled uses of memory. However, there is good reason to believe that assumption is false (e.g., Jacoby, 1991; Richardson-Klavehn & Bjork, 1988; Schacter, 1987). Intentional, consciously-controlled forms of processing may sometimes "contaminate" performance on indirect tests; consequently, finding an age-related effect cannot be taken as evidence that aging produces a deficit in automatic processing. Decrements may stem solely from use of conscious processes (Graf, 1990; Light & Albertson, 1989; Light & Singh, 1987; Russo & Parkin, 1993).

The same problem exists when interpreting results from direct tests. Automatic uses of memory may enhance performance, producing underestimations of age-related declines in consciously-controlled processing (e.g., Jacoby, 1991; Jacoby, Toth, & Yonelinas, 1993). Moreover, these processes are difficult to distinguish because most indirect and direct tests act as "facilitation" paradigms. Memory for a prior event may facilitate task performance by means of automatic processes, but conscious memory would produce the same result (e.g., Richardson-Klavehn & Bjork, 1988).

In addition to the problem of contamination, mapping processes onto test performance overlooks an essential aspect of any adequate definition of automatic and conscious processes, which is that these processes seldom operate in isolation. Automatic processes acting in isolation may be qualitatively different from those operating in the context of consciously-controlled memory, and vice versa. Because the indirect versus direct test distinction identifies processes with tasks, it provides no means of measuring automaticity in the presence of consciously-controlled memory, yet both types of processes likely operate concurrently in most real world tasks. For example, consider a common complaint about the elderly which is their propensity for repeatedly asking the same question or telling the same story to the same audience. This memory failure arises from the interaction of automatic and conscious processing. Automatic influences from an earlier recounting of a story, rather than producing recognition that it was previously told, are misattributed to the story being appropriate for the particular audience. If these influences of memory are not successfully opposed by recollection for the prior telling, the story is repeated. Relying on indirect tests to measure memory offers no means for investigating the role of automatic and conscious processes as they act together in this repetition example or in other real life situations.

To eliminate the concern of contaminated tests, and the "qualitative difference" problem created by process pure measures, one needs a technique that separately estimates the contribution of both consciously-controlled and automatic processes as they act together within a given task. The process dissociation procedure developed by Jacoby (1991) provides the means to determine such estimates.

The Process Dissociation Procedure

Unlike the indirect/direct test distinction described above, the process dissociation procedure requires two test conditions - a facilitation condition, where automatic and consciously-controlled processes produce the same effect on performance, and an opposition condition, such as the story telling example, where automatic and conscious processes have opposite influences on performance. By combining these conditions it is possible to tease apart the influence of each process (Jacoby, 1991). The task used in Experiment 1 will be described to illustrate the procedure. In the first phase of Experiment 1, elderly and young adults were asked to read a list of 60 nonfamous names for a pronunciation task. They were then given an opposition task, where they were shown 30 nonfamous names that they had seen at study, mixed with 60 famous and 30 new nonfamous names and asked to judge whether each name was famous. In this opposition condition, subjects were correctly informed that all of the names they read in the first list were nonfamous, so if they recognized a name on the fame test as one from the first list, they could be certain that the name was nonfamous.

The earlier reading of the nonfamous name was expected to increase its familiarity, making it possible that the name would mistakenly be called "famous".

That is, subjects would find a name familiar because of its prior presentation and misattribute that familiarity to fame. This effect of familiarity is an automatic influence of memory, subjects show memory for the prior presentation of the nonfamous names without conscious intention through their errors (responding "famous"). On the other hand, recollection can be seen as a consciously-controlled, intentional use of memory that prevents errors on this task (responding "nonfamous"). These two processes function independently; familiarity can occur without recollection and vice versa.

Telling subjects that the earlier-read names were nonfamous places the effects of familiarity and recollection in opposition. This condition can be referred to as an "exclusion" test (Exc) because recollection serves to exclude names that were earlier read. Formally, old nonfamous names would mistakenly be called famous only if the name was familiar (F) but subjects did not recollect (R) the name as being earlier presented: F(1-R). The probability of calling an old name "famous" on the exclusion task can be represented as:

$$\text{Exc} = F(1-R) \qquad (1)$$

A series of "false fame" studies illustrate successful use of this exclusion condition (Dywan & Jacoby, 1990; Jacoby, Kelley, Brown & Jasechko, 1989; Jacoby, Woloshyn, & Kelley, 1989). By placing automatic and conscious processes in opposition, one can examine differential influences of the aging process (Dywan and Jacoby, 1990). Dywan and Jacoby hypothesized that aging would decrease the probability of using the intentional recollection process, leaving familiarity unchecked. This proved to be true. Young adults were less likely to call old nonfamous names "famous" as compared to new nonfamous names. They were able to recollect that the old names had been read and therefore were nonfamous. On the other hand, the elderly adults called more old nonfamous names "famous" than new nonfamous names. They were less able to use conscious recollection to oppose the influence of familiarity.

Craik (e.g., Craik & Byrd, 1982; Rabinowitz et al., 1982) has argued that the memory effects of aging are similar to those produced by dividing attention of younger adults. In line with that possibility, Jacoby, Woloshyn and Kelley (1989) showed that dividing attention during the reading of nonfamous names or during the fame judgment test increased the probability of old nonfamous names being called "famous". Similar to aging, dividing attention makes it less likely that subjects will be able to recollect the prior presentation of old nonfamous names and, thereby, counter familiarity.

By placing familiarity and recollection in opposition, the false fame experiments showed that aging has the effect of reducing recollection, leaving effects of familiarity largely unopposed. However, from those results one cannot be certain that the elderly did not also show a deficit in automatic influences of memory (familiarity) as compared to younger subjects. The probability of calling an old name "famous" reflects a combination of automatic and intentional influences (F(1-R)).

Unless recollection is fully eliminated (R=0), the probability of calling old nonfamous names "famous" underestimates the influence of familiarity. In order to show that both aging and dividing attention influence recollection but have no influence on familiarity, effects on the two types of processes need to be estimated separately, which requires an additional test condition.

In that condition, labelled the inclusion test, subjects were misinformed that all of the earlier read names were actually "obscure" famous names. In this case, both recollection and familiarity would produce judgments of "famous". That is, in contrast to the exclusion condition, recollection would serve to include earlier-read names as "famous". For an inclusion test (Inc), an old name could be judged "famous" either because it was recollected as being on the earlier-read list (R) or, because, although recollection failed, the name was sufficiently familiar to be accepted as "famous" (F(1-R)). The probability of calling an old name "famous" on the inclusion test can be represented as:

$$Inc = R + F(1-R) \qquad (2)$$

Combining results from the inclusion and exclusion test conditions allows one to separately estimate the effects of consciously-controlled and automatic processes. Subtracting the probability of calling an old name "famous" on the exclusion test from that probability on the inclusion test provides an estimate of the probability of recollection:

$$R = Inc - Exc \qquad (3)$$

Given an estimate of recollection, an estimate of familiarity can be computed by means of simple algebra. One way of doing this is to divide the probability of calling an old name "famous" in the exclusion condition (Exc) by the estimated probability of a failure in recollection (1-R):

$$F = Exc/(1-R) \qquad (4)$$

The probability of recollection can be best understood as a measure of aware, consciously-controlled processing defined in terms of selective responding. For the inclusion test, people are to *select for* old names whereas for the exclusion test, people are to *select against* old names. Therefore, if the probability of recollection were 1.0, people would always call old names "famous" on the inclusion test and never call those names "famous" on the exclusion test. In contrast, if the probability of recollection were 0, people would be as likely to call an old name "famous" on the exclusion test as on the inclusion test.

Independence Assumption

One cannot distinguish between automatic and conscious processing without making an assumption about the relationship between the two types of processes. Thus, one of the strongest assumptions underlying the process dissociation procedure is that automatic and consciously-controlled uses of memory act independently. To justify that assumption, it is important to show dissociations between the two processes by finding factors that affect one process while leaving the other process unchanged. Jacoby and colleagues (e.g., Jacoby, 1991; Jacoby, Ste-Marie, & Toth, 1993; Jacoby, Toth, & Yonelinas, 1993, Jacoby, Yonelinas & Jennings, in press) have produced results that support this assumption. For example, Jacoby, et al. (in press) reviewed the results of 20 studies using the process dissociation procedure and found that variables traditionally associated with reduced cognitive control, such as dividing attention at study, rapid presentation rate of stimuli, and fast responding decrease estimates of consciously-controlled processes but leave automatic influences unchanged. Averaged across those 20 experiments, the effect of factors associated with reduced cognitive control on estimates of conscious memory processing was .24 whereas the effect on estimates of automatic influences was .002.

Invariance in automatic memory processes across those manipulations does not reflect a general insensitivity of that measure. Manipulations that influence automatic processing in a manner opposite to that found with consciously-controlled processing also exist. For example, Jacoby, Toth and Yonelinas (1993) showed that a read versus generate manipulation produced opposite effects on consciously- controlled and automatic processing. Generating, as compared to reading, a word at study enhanced conscious recollection but reduced automatic influences. Similarly, Jacoby and Hay (1993) found that repeated presentations of word-pairs (e.g., book - store) prior to the study and test phases of a memory task increased automatic processing but left conscious processing unaltered.

Because the process dissociation procedure allows separate estimation of the contributions of automatic (familiarity) and consciously-controlled (recollection) processes, the influence of age on each process can be examined separately to see if one or both processes are affected. Experiment 1 examined the effects of aging and dividing attention on familiarity and recollection using the fame-judgement paradigm. As mentioned, previous work using the process dissociation procedure found that divided attention subjects show a deficit in the ability to use recollection without any impairment in familiarity relative to full attention subjects (Jacoby, 1991; Jacoby, Toth, & Yonelinas, 1993; Jacoby et al., in press). I would expect the same result with the fame judgement paradigm used here. In addition, because dividing the attention of young adults produces results analogous to those found with the elderly (Craik & Byrd, 1982; Rabinowitz et al., 1982), it is possible that the elderly will also show impairment on recollection but not familiarity. However, if age deficits on indirect memory tasks do not stem solely from use of conscious processing, then the elderly may show deficits in both processes. Experiment 2 further examined the effects of age on automatic and consciously-controlled processing using a forced-choice recognition task.

Age-Related Deficits in Recollection

As mentioned earlier, indirect tests may not be alone in producing misleading results due to contamination - direct tests may also be affected. Automatic processes may enhance performance on direct tests leading researchers to underestimate deficits in conscious memory (Jacoby, Toth, & Yonelinas, 1993). For example, investigations of memory performance in amnesiacs have found that their memory is sometimes good or even comparable to that of normal subjects when tested with recognition tasks (Freed, Corkin, & Cohen, 1987; Hirst & Johnson, 1986; Hirst, Johnson, Kim, Phelps, Risse, & Volpe, 1986; Johnson & Kim, 1985). As reported above, similar findings have been obtained with older adults. The elderly show less memory impairment on tests of recognition than recall (Craik & McDowd, 1987; Rabinowitz, 1984; 1986). Because recognition tests are considered to be direct memory tests that reflect conscious processes, interpreting these results could erroneously suggest that older adults and amnesiacs are less impaired in conscious processing than is truly the case. In actuality, their intact recognition performance may arise from their use of automatic memory rather than conscious processing (e.g., Jacoby, Toth, & Yonelinas, 1993; Rabinowitz, 1984; Verfaillie & Treadwell, 1994).

One influential explanation of intact recognition performance in memory impaired subjects, put forth by Craik (Craik 1983; 1986), is in line with this view. Craik suggests that memory tasks can be ordered along a continuum from free recall to procedural learning according to the amount of environmental support they offer to aid retrieval. He argues that some types of tests, such as recognition, induce mental operations that are strongly driven by environmental cues and do not require self-initiated processing (demanding mental operations that involve conscious awareness). In short, recognition performance may rely heavily on automatic memory. However, as Craik's continuum suggests, recognition is not the only direct task where performance is boosted by automatic memory. Rather, conscious processes should always be examined separately from automatic influences, since no type of direct test provides a pure or accurate index. This issue is of particular concern when assessing the ability of memory-impaired populations, such as elderly adults or amnesiacs, because most neuropsychological assessments rely exclusively on direct tests.

For these reasons, I was not only interested in comparing the effects of aging on automatic and consciously-controlled processes, but in using the process dissociation procedure to examine age-related declines in conscious processing more carefully. Specifically, I wanted to investigate the magnitude of change in recollection with age by mimicking the repeated story-telling case described earlier. In that example, automatic influences of memory that push toward repeatedly telling a story to the same individuals are not successfully opposed by recollection for having previously told the story. Errors of this sort clearly signify a deficit in recollection, but more importantly, they can indicate the severity of that deficit. For instance, one would be far more concerned about an elderly relative who repeats a story or question after only five minutes than a relative who repeats herself after one week. Therefore, I wanted to devise a similar situation to determine the length of the interval between presentation and test necessary to show age differences in conscious memory. The length of this interval should provide an indication of the degree of age-related change; if this interval proved to be very short, age deficits could be considered very strong.

Experiments 3, 4 and 5 were designed to address this question. Subjects were asked to read aloud and learn a list of words. They were then given a recognition test where they were shown study words and new words with those new words repeated after a certain number of intervening items occurred (e.g., 4, 12, 24 or 48 intervening items). Subjects were asked to respond "yes" to study words, but "no" to the new items regardless of whether it was their first or second presentation in the test list. The second presentation of new words was crucial because earlier presentation in the test list would increase their familiarity, which may be misattributed to the prior study phase, leading subjects to mistakenly respond "yes". However, if subjects could recollect that the item was first encountered at test, they would correctly respond "no". This task is similar to the "false fame" task in producing misattributions of familiarity that can be countered by recollection. However, by varying the interval between the first and second presentation of a test item a finer-grained measure of deficits in recollection can be obtained.

Subjective Versus Objective Measures of Memory

The research described thus far was designed to examine age deficits in recollection based on task performance. The process dissociation procedure, as used in these experiments, presupposes aware remembering (recollection) for accurate responding, particularly in the exclusion condition. However, to completely understand the effects of aging on memory, older adults' awareness of their memory processing should be examined. Can elderly adults identify (self-report) when they are basing a decision on familiarity versus recollection?

Attempts to explore memory awareness or metamemory with the elderly have focused on the ability to assess the processes and contents of memory (Lovelace, 1990), and a number of tasks have been employed. Older adults' ability to predict memory performance prior to commencing a task, to recognize the encoding strategies necessary for a task, to adjust their study time according to task difficulty, and to evaluate their performance after completing a task have all been explored (for review see Bieman-Copland & Charness, 1994; Lovelace, 1990). The results of these studies though, have been mixed. Sometimes the elderly perform more poorly than young adults, but in many experiments there are no age differences. For example, when asked at study to evaluate the probability of successfully recalling items during test, young and elderly adults can sometimes show comparable accuracy in predicting performance (e.g., Bieman-Copland & Charness, 1994; Lovelace & Marsh, 1985; Shaw & Craik, 1989). Similarly, there are no deficits in the ability to monitor the correctness of a response at retrieval (e.g., see Lovelace, 1990 for review; Lovelace & Marsh, 1985; Perlmutter, 1978). In some circumstances, both young and elderly adults are equally aware of their memory performance. However, no one has investigated age differences in the awareness of *which* process is being used at retrieval, familiarity or recollection.

Tulving (1983), Gardiner and colleagues (Gardiner, 1988; Gardiner & Java, 1991; Gardiner & Parkin, 1990) have developed a remember/know procedure that elicits self-reports of familiarity and recollection. Subjects study a list of words, and are then given a recognition test, where they must indicate whether they "remember" a word from study, that is, recollect some specific detail of seeing the word, or if they just "know" on some other basis that the word occurred. Recollection appears to drive "remember" responses, whereas familiarity seems to underlie "know" responses. The remember/know technique relates well to the process dissociation procedure with one essential difference. It is assumed in the process dissociation procedure that familiarity and recollection are independent processes. In contrast, the remember/know procedure, assumes, at least implicitly, that the two processes are mutually exclusive. Subjects can only respond "remember" *or* "know" - both responses, and therefore the processes that underlie them, cannot act together. By adopting the independence assumption and applying it to the remember/know technique, one can estimate recollection and familiarity in a manner similar to that used with the process dissociation procedure. "Remember" responses map directly onto recollection, because a subject can only say "remember" if he/she recollects specific information about an item. Therefore recollection equals the proportion of "remember" responses:

$$R = \text{Remember} \qquad (5)$$

In contrast, "know" responses do not map directly onto familiarity. "Know" responses resemble the exclusion condition in the process dissociation procedure. In both cases, subjects give a response because an item is familiar but cannot be recollected (F(1-R)). Consequently, familiarity equals the proportion of "know" responses divided by a failure in recollection (1-R):

$$F = \text{Know}/(1\text{-}R) \qquad (6)$$

Experiments with young adults have applied the independence assumption to the remember/know technique (independence-remember/know) and produced estimates of recollection and familiarity that are identical to those found using the process dissociation procedure (Jacoby, et al., in press). These two methods provide converging data from objective and subjective measures of memory, making independence-remember/know a viable tool for studying aging and awareness of memory processing.

Using this procedure with elderly adults allows one to examine the correspondence between objective and subjective measures of memory. If the process dissociation procedure shows that aging produces a decline in recollection but leaves automatic influences intact, and if objective performance and subjective awareness are related, then the same pattern of results should be obtained using subjective report.

Lab Performance Versus Memory in the Real World

Investigating age-related deficits in automatic and conscious processing, and self-awareness of that processing is only useful if older adults' lab performance relates to real world functioning. That is, one hopes that the elderly will show a close correlation between performance on lab tasks and everyday memory, as measured by self-report questionnaires. However, this result has not been found. Many different questionnaires examining everyday memory failure have been reported in the literature (e.g., Broadbent, Cooper, Fitzgerald and Parkes, 1982; Crook & Larabee, 1992; Reason, 1993), yet responses on these instruments correlate weakly with laboratory and clinical memory tests (Cohen, 1993; Herrmann, 1982; Herrmann, 1990; Little, Williams, & Long, 1986). Moreover, in many cases, older adults report fewer everyday memory failures than the young (Cavanaugh, 1986-1987; Rabbitt & Abson, 1990; Reason, 1993), which conflicts directly with experimental and clinical findings.

Researchers have offered several explanations for the lack of convergence between memory performance in the lab and self-report questionnaires. One, the poorer memory associated with age may cause older adults to forget their own memory failures (Cohen, 1993; Herrmann, 1990; Rabbitt & Abson, 1990). Two, personality factors such as increased depression, reduced self-esteem and reduced self-efficacy, which occur in later life, may cloud subjects' evaluation of their performance (Rabbitt & Abson, 1990; 1991). Three, there may be systematic age differences in subjects' perception of the response scales used on questionnaires. Categories such as "quite often" and "frequently" may have a different interpretation for older adults (Reason, 1993). Four, older adults may be accurate in their self-evaluation, instead, they may have adopted a less demanding, routinized lifestyle that precludes frequent memory errors (Cohen, 1993). Fifth, laboratory measures may lack ecological validity, measuring performance in tightly controlled, artificial situations (Broadbent et al., 1982; Cohen, 1993; Rabbitt & Abson, 1991), far removed from everyday memory demands and performance (Broadbent et al., 1982; Rabbitt & Abson, 1991).

Although each of these reasons may account for some portion of discrepancy between objective lab performance and questionnaire results, one fundamental problem has been overlooked. Laboratory tasks have failed to separate out automatic and consciously-controlled influences. Given that age-related deficits are expected in recollection but not automatic influences, everyday memory problems may stem only from recollection failures. It follows then, that correlating self-reported memory errors, which may be recollection failures, with lab tasks where recollection and familiarity are combined would dilute any correlation between lab and real world performance.

Consequently, I wanted to determine whether subjects who showed poor recollection would report a high frequency of memory failures in daily life. To explore this issue (Experiment 7) I used a memory questionnaire designed by Janine Hay and me (Jennings & Hay, 1994) to focus on everyday situations that relied on recollection. Some questions were taken from existing questionnaires (Broadbent et al., 1982; Reason, 1993) while others were created specifically to tap recollection. Subjects were asked to rate the frequency of everyday memory errors, such as the likelihood of forgetting to take medication or turn off the stove. Their results were then compared with their performance on the independence-remember/know task used in Experiment 6, which provided an estimate of their ability to use recollection in the lab. If low correlations between lab and questionnaire performance are typical because lab tasks have confounded recollection and familiarity, then correlations between recollection and the questionnaire should be high.

Summary

To summarize, Experiments 1 and 2 were designed to compare the effects of aging on automatic and consciously-controlled memory processes. Experiments 3, 4 and 5 were employed to measure the severity of age-related declines in conscious memory. Experiment 6 was carried out to investigate subjects' awareness of their memory processing, and Experiment 7 was constructed to determine whether recollection on lab tasks can be predictive of real-world functioning.

Chapter 2

Automatic and Consciously-Controlled Memory Processing in Older Adults

Experiment 1 was designed to examine the effects of aging and dividing attention on automatic and consciously-controlled memory processes using a false-fame task. Previous research using the process dissociation procedure has shown that dividing attention affects conscious memory but leaves automatic processing intact (Jacoby, 1991; Jacoby, Toth, & Yonelinas, 1993; Jacoby et al., in press). It was expected that this finding would replicate using the fame paradigm. In fact, including divided attention subjects in Experiment 1 ensured that the process dissociation procedure/fame-judgement combination could produce the expected process dissociations. Moreover, given the analogous performance between divided attention subjects and elderly adults (Craik & Byrd, 1982; Rabinowitz et al., 1982), one would also expect older adults to show a deficit in conscious processing with unimpaired automatic processing.

Experiment 1

During the study phase in Experiment 1, a group of elderly and a group of young subjects devoted full attention to reading a list of nonfamous names. A second group of young subjects read the same list under a divided attention condition. For all three groups, an inclusion test followed by an exclusion test were given. Both tests were fame judgement tasks. For the inclusion test, subjects were misleadingly told that all old names appearing on the test were names of famous people and if they recollected reading a name in the earlier list, they should call the name "famous." For the exclusion test, subjects were correctly told that all old names appearing on the test were nonfamous, and if they recollected reading a name in the earlier list, they could be certain that the name should be called "nonfamous." Taking the results from these two test conditions, the equations described earlier were used to separately estimate the contributions of recollection and familiarity to fame judgments for each group of subjects.

One potential concern with using a fixed test order is that giving the inclusion test prior to the exclusion test may produce a bias in the estimation procedure. One assumption underlying the procedure is that the probabilities of recollection and familiarity are the same for both tests, and that assumption could be violated by forgetting across the two conditions. However, to examine the effects of aging and dividing attention it is not necessary that the estimates be totally unbiased, only that they are not differentially biased for the three groups. The constant test order was used to simplify the design, and because the results of earlier experiments showed that order effects were not problematic (Jacoby, 1991).

Method

Subjects. The subjects were 54 young adults, ranging in age from 18 to 23 (M age = 19.5), and 31 older adults, ranging in age from 66 to 90 (M age = 73.8). The young subjects were enrolled in an introductory psychology course and took part for course credit. They had an average of 12.9 mean years of education. Twenty-four of these subjects participated under a full attention condition, while the remaining subjects participated in a divided attention condition. Data from six subjects in this latter group were not used because those subjects were unable to perform at a level of 60% accuracy on the divided-attention task. Consequently, it is questionable whether their attention was truly divided.

The elderly adults were community-dwelling residents, who reported themselves to be in good health. They had, on average, 11.2 years of education. In addition, they had an average score of 77% on the Mill Hill Vocabulary test. This score is comparable or better than that typically achieved by young adults. For example, in Experiment 2, the young adults had an average score of 63%. Some of the elderly individuals came from a seniors' group at a local church, while the rest came from the Seniors' Centre at the YWCA. They offered their services voluntarily. Data for seven elderly adults had to be discarded. These individuals were unable to follow instructions as evidenced by their inability to discriminate between old and new non-famous names, or to discriminate between actual famous and new non-famous names at test. In summary, data was obtained from 48 young adults (24 individuals tested under a full attention condition; 24 individuals tested under a divided attention condition) and 24 elderly adults.

Materials. The stimuli consisted of 126 nonfamous names, and two sets of 120 famous names. The famous names were selected to be ones that subjects would likely recognize as famous without being able to identify what the named individual had done to achieve fame. This criterion was used to encourage subjects to base their fame judgements on the name's familiarity rather than its identifiability. Because names that were only familiar to the young subjects, such as Jack Benny or Betty Grable, were well-known to the elderly subjects, two sets of famous names were required. Each age group had its own set developed from surveys carried-out prior to the experiment.

The 126 nonfamous names were taken either from lists used in prior experiments (Dywan & Jacoby, 1990), or from the telephone book. These names matched the famous names on the following characteristics: gender as indicated by the first name, nationality of first and last names, the number of first and last names beginning with a given letter, and the length of the first and last names. Examples of nonfamous names are Sandra Baker and Wilson Love.

The non-famous names were divided into two sets of 60. One set represented the old non-famous names, presented at both study and test whereas the second set was used as new non-famous names, shown only at test. (The remaining six non-famous names were used as filler items presented at the beginning of the study list). Because there were two test phases, each set was further subdivided into two sets of 30; one for the inclusion test, and the other for the exclusion test. Each set of 30 names was balanced for gender, nationality, number of names beginning with a given letter, and name length. Four test formats were formed by rotating each set of 30 names through conditions (old versus new and inclusion versus exclusion) such that, across the four formats, every name represented each combination of study/test conditions. The famous names were presented only at test, and were divided into two sets of 60, one set for each test. These names were not rotated across conditions. For both study and test, the presentation order of names was random with the restriction that not more than three names representing the same study/test condition could be presented successively.

Procedure. An Apple IIE computer was interfaced with a monochrome green monitor to present the stimuli. The character size of the stimuli was approximately 5.7 x 6.6 mm. Names were presented in lower case letters, with the initial letter of each first and last name capitalized, in the centre of the screen. In the study phase each name was presented for two seconds and subjects were instructed to read the names aloud. They were told that their ability to pronounce the names quickly and accurately was of interest, and that their pronunciation of the names was being recorded. In reality, no recording took place. Moreover, the subjects were given no indication that their memory for the names would be tested later.

The divided attention subjects performed a listening task, previously used by

Craik and Byrd (1982), while reading names aloud. For that listening task, subjects monitored a tape-recorded list of digits to detect target sequences of three odd numbers in a row (e.g., 9,3,7). The digits were random with the exception that a minimum of one and a maximum of five numbers occurred between the end of one and the beginning of the next target sequence. The digits were presented at a rate of one digit every 1.5 sec. Subjects pressed a key to indicate when they detected a target sequence. When subjects missed more than two consecutive sequences, they were prompted by the experimenter with the word "miss".

Immediately after subjects read the list of nonfamous names, they were given an inclusion and then an exclusion fame-judgement test. For those tests, subjects indicated that a name was famous by pressing one key or nonfamous by pressing a different key. Subjects were instructed to respond as quickly and accurately as possible. For the inclusion test, subjects were *misinformed* that all names in the test list that had been read in the earlier phase of the experiment were famous and, so, if they recognized a name as earlier read, they should call it "famous". For the exclusion test, subjects were told that now all earlier-read names in the test list were names of nonfamous people, and if they recognized a name as earlier read, they should call it "nonfamous".

The significance level for all tests was set at $p < .05$. Tests revealing significant main effects will not be reported when variables producing those main effects entered into significant interactions.

Results and Discussion

In the study phase, the young, divided-attention subjects only missed an average of 5.3 out of 33 target sequences (16%) in the listening task, suggesting they were attending to the number sequences while pronouncing names.

In the test phase, the probability of calling a famous name "famous" proved comparable for the young, full-attention (.77), young, divided-attention (.75), and the elderly groups (.74), F (2, 69) = .189, MSe = .037, although different sets of famous names were presented to the young and elderly adults. The probability of correctly calling a famous name "famous" between the inclusion (.76) and exclusion (.74) conditions also did not differ significantly, F (1, 69) = 3.75, MSe = .004, despite the use of different sets of names across the two tasks.

Examining the probability of calling a new non-famous name "famous" (see Table 1) provides an indication of the baserate familiarity of names without any influence of prior presentation, and demonstrated each group's bias to accept familiar names as "famous". The young, full attention group appeared slightly less willing to call names "famous" than were subjects in the other two groups. There was also some evidence that the elderly subjects used a higher criterion for familiarity-based judgements on the exclusion test than on the inclusion test. However, these criterion differences for familiarity were small to almost non-existent. In an analysis of the probability of calling a new non-famous name "famous", there was no significant effect of group, F (2, 69) = 1.474, MSe = .040, test, F (2, 69) = 1.037, MSe = .010, nor a significant group x test interaction, F (2, 69) = 1.746, MSe = .010.

Table 1
Observed Probabilities of Calling Old and New Nonfamous Names Famous for the Inclusion and Exclusion Tests in Experiment 1

	Test condition			
	Inclusion names		Exclusion names	
Group	Old	New	Old	New
Young, full Attention	.73	.19	.13	.19
Young, divided Attention	.59	.22	.25	.22
Elderly Adults	.58	.29	.27	.23

Of greater interest, analysis of the probability of calling old nonfamous names "famous" (see Table 1) revealed a significant interaction of group x test, F (2, 69) = 16.71, MSe = .018. The form of that interaction suggests that young, full-attention subjects held an advantage in recollection over subjects in the other two groups. For the inclusion test, recollection served to increase the probability of an old name being called "famous". A post hoc Newman-Keuls comparison showed that the young, full-attention group was significantly more likely to call old names "famous" on the inclusion test than were the young, divided-attention group and the elderly adults. The latter two groups did not differ. For the exclusion test, recollection of a name as earlier read allowed subjects to be certain that the name was nonfamous and, so, decreased the probability of old names being called "famous". The young, full-attention subjects called fewer old names "famous" on the exclusion test than did the young, divided-attention group or the elderly adults. The latter two groups again performed similarly.

More conclusive evidence of a difference in recollection between the three groups of subjects was gained by using the process-dissociation procedure to separately examine effects on recollection and familiarity-based judgments. The probability of recollection was estimated as the difference between the probability of responding "famous" to old names in the inclusion and exclusion test conditions. As described by Equation 4, that estimated probability of recollection was then used to estimate the probability of calling a name "famous" on the basis of its familiarity (see Table 2). Analysis of these estimates revealed a significant difference between the groups in the probability of recollection, F (2, 69) = 16.85, MSe = .036. According to post hoc Newman-Keuls comparisons, the young, full-attention group differed significantly from the other two groups, who showed a comparable level of performance. The results of those analyses show that both aging and divided attention produced large decrements in the probability of recollection, a consciously-controlled form of processing.

In contrast to effects on recollection, the probability of calling an old name "famous" on the basis of its familiarity did not differ across the three groups, F (2, 69) = 1.52, MSe = .036. This estimate of familiarity consists of automatic influences from prior presentation of the names at study and the baseline probability that names are familiar without prior exposure (the probability of calling a new name "famous" across the two tests). Presentation increased the familiarity of old names relative to the familiarity of new ones for all three groups. The estimated probability of calling old names "famous" because of familiarity (Table 2) was significantly higher than the probability of calling new names "famous" (Table 1) for the young, full-attention group, t (23) = 4.84, the young, divided-attention group, t (23) = 8.37, and the elderly adults, t (23) = 3.85. That difference between old and new names reflects the influence of familiarity for earlier reading of the old names.

Table 2
Estimated Probabilities of Calling Old Names Famous on the Basis of Recollection and Familiarity in Experiment 1

Group	Recollection	Familiarity
Young, Full Attention	.60	.31
Young, Divided Attention	.34	.39
Elderly Adults	.31	.38

One can also examine differences in responding on the basis of familiarity by removing the baseline probability of calling a new name "famous" from the familiarity estimates. The simplest method of doing so, involves subtracting the baseline probability from each estimate of familiarity. When considering these new values, the means for the young, full-attention (.14), young, divided-attention (.16) and elderly (.13) groups are even more similar than when only the familiarity values for old names (Table 2) are examined. This is because, as mentioned earlier, the young, full-attention subjects called fewer new non-famous names "famous" on the basis of familiarity than subjects in the other two groups.

It should be noted that directly subtracting baseline responding from a familiarity estimate is a relatively unsophisticated correction procedure that does not reflect the non-linear relationship between the two measures. A more precise method for correction entails applying a signal detection procedure to the familiarity estimates to take baseline responding into account (Yonelinas, Regehr, & Jacoby, in press). However, for small differences in baserate, such as those found here, the corrected results are nearly identical (Yonelinas, Regehr, & Jacoby, in press). Familiarity estimates, as measured by d-prime, are 0.42 for the young, full-attention group, 0.46 for the young, divided-attention group and 0.39 for the elderly adults. Given that d-prime values typically range from 0 to 2.5, these d-prime differences across the groups are small.

In sum, the results of Experiment 1 showed that both aging and dividing attention produced large deficits in conscious recollection but left the use of familiarity as a basis for judgments unchanged. The effects of dividing attention on recollection are consistent with results from earlier experiments (Jacoby, et. al., 1989; Jacoby, 1991), and, in conjunction with the performance shown by older adults, provide support for claims that aging and dividing attention have their effects by limiting the possibility for consciously-controlled processing. These results also confirm findings that suggest declines in recollection with age produce an increased false fame effect for names (Dywan & Jacoby, 1990) and faces (Bartlett, Strater, & Fulton, 1991).

More importantly, the results of Experiment 1 provide evidence that the use of familiarity as a basis for judgments remained invariant across differences in both age and the manipulation of attention. The lack of an aging effect on familiarity-based judgments agrees with findings of age constancy on indirect tests of memory (for reviews, see Craik & Jennings, 1992; Light, 1991). However, because the process-dissociation procedure was used, the present conclusions are not based on the questionable assumption that tests are process pure. Lastly, the influence of aging and dividing attention on recollection and familiarity proved very similar. This finding corresponds to other results that show dividing attention in young adults produces effects in performance similar to those found with the elderly (e.g., Craik & Byrd, 1982; Rabinowitz et al., 1982). The results of Experiment 1 will be discussed further in the General Discussion section.

Experiment 2

The results of Experiment 1 showed that dividing attention and aging both reduced the probability of recollection but left invariant the use of familiarity as a basis for fame judgments. Experiment 2 used a recognition-memory task to further examine the effects of aging. Dual-process theories of recognition memory (e.g., Atkinson & Juola, 1974; Jacoby & Dallas, 1981; Mandler, 1980) hold that judgments of familiarity and memory search (recollection) serve as alternative bases for recognition-memory decisions. Similar to fame judgments, the use of familiarity for recognition-memory decisions may be an automatic influence of memory that is unaffected by aging. That is, deficits in recognition-memory performance for elderly, as compared to younger subjects (e.g., White & Cunningham, 1982; Light, Singh, & Capps, 1986; Light & Singh, 1987), may stem solely from a deficit in recollection, a consciously-controlled use of memory. To examine that possibility, the process-dissociation procedure was used to separately estimate the contributions of familiarity and recollection to recognition-memory judgments. Similar to the fame judgment results, aging should reduce recollection, but have no influence on the use of familiarity.

In the first part of the study phase, a group of young and elderly subjects were presented with a list of words that were to be read intermixed with anagrams that were to be solved. Following that presentation, subjects in both groups heard a list of words that they were told to remember for a later test. An exclusion test followed by an inclusion test were then given. Both tests used a two-alternative, forced-choice recognition test. One of the alternatives in each test pair was always an old word (one that was read, seen as an anagram, or heard) whereas the second alternative was always a new word, not presented earlier in the experiment.

For the exclusion test, subjects were *misinformed* that each test pair included a word that had been presented aurally in the study phase paired with either a new word, a word that had been read, or a word that had been presented as an anagram at study. They were told to select the word that had been aurally presented, and told that they could make a correct choice by exclusion if they recollected a member of a pair as one that was read or seen as an anagram during study. Because visually presented words (read/anagram items) were never presented aurally, subjects were told that if they recollected a word as one they had read or seen as an anagram, they should choose the *other* word in the test pair as the aurally presented word. Given those exclusion instructions, subjects should select read/anagram words only if those words were familiar (F) but not recollected (1-R) as earlier read or seen as anagrams.

For the inclusion test, subjects were informed that one member of each test pair was a new item and were instructed to choose the alternative that they recognized as occurring at study, either visually or aurally. For that test, a word that had been read or seen as an anagram could be selected because subjects were able to recollect its prior occurrence (R) or because the word was sufficiently familiar (F) to be selected, although recollection failed (1-R). As in Experiment 1, the equations presented earlier were used to separately estimate the contributions of recollection and familiarity to recognition-memory performance.

The use of a forced-choice procedure was meant to eliminate the slight age difference in criterion when responding to familiar items observed in Experiment 1. The recognition memory task used in Experiment 2 also places heavier demands on recollection than the fame-judgment task. For the recognition-memory task, it is necessary to recollect whether a word was presented aurally or visually. In contrast, for the fame-judgment task recollecting that a name was earlier presented, without reference to the details of that presentation was sufficient. The more difficult recollection demanded for recognition memory here might reveal larger effects of aging on recollection than were observed in Experiment 1. One further difference between the two experiments is the order of testing. In Experiment 1, the exclusion test followed the inclusion test, however, in Experiment 2, the exclusion phase was given prior to inclusion. If the results of Experiment 2 show the same pattern of performance as Experiment 1, one can be more certain that test order does not violate assumptions about recollection and familiarity across test conditions.

In other experiments, the procedures used in Experiment 2 have been employed to examine effects on the different bases for recognition memory. Jacoby (1991) found that dividing attention during study reduced the probability of recollection, but left invariant the use of familiarity as a basis for recognition-memory judgments. Jacoby (1991) also found effects of whether a word was read or seen as an anagram. Unlike the effects of dividing attention, solving anagrams versus reading words influenced both recollection and familiarity; solving anagrams produced a higher probability of recollection and greater familiarity of the solution words than did earlier reading those words. This issue will be discussed further after reporting the results of Experiment 2.

Method

Subjects. Two groups of subjects, a group of 20 elderly adults, ranging in age from 64 to 77 (M age = 70.2) and a group of 16 young adults, ranging in age from 17 to 20 (M age = 18.9) participated in the experiment. The young adults were enrolled in an introductory psychology course and participated for course credit. They had an average of 12.8 years of education, and an average score of 63% on the Mill Hill Vocabulary test. The elderly adults were community-dwelling residents with self-reported good health. They had an average of 11.6 years of education, and an average score of 70% on the Mill Hill Vocabulary test. These subjects came from the Seniors' Centre at the YWCA, and volunteered their help. Data for two of these subjects were lost due to problems with the computer program used for testing, while data for two other subjects could not be included because the subjects were unable to follow instructions on the exclusion test. In summary, data were obtained from 16 young and 16 elderly adults.

Materials. The stimuli consisted of 204 five-letter words. Sixty of those words were divided into two sets of 30 and used to construct study lists for the first study phase. One set of words was presented as anagrams to be solved, the second set was presented as words in their normal form to be read. These items were randomly intermixed for presentation. To construct the anagrams, words were presented with the second and fourth letters underlined and in their proper places, with the remaining letters randomly re-arranged (e.g., imsle/smile). Constraining the order of letters made the anagrams easier to solve and gave each anagram only one solution. Eight filler items (four anagrams, and four words in normal form) were shown at the beginning of the study list, creating a 68 item study list. A second set of 68 words was chosen from the stimulus pool for the second part of the study phase. These words were presented aurally. The first eight words in that list served as filler items. The remaining 68 words were used as distracters for the recognition tests. Each word was matched with one of the visual or auditory items from the study phase according to word frequency counts determined by Kucera and Francis (1967).

Two recognition test lists, one for each test condition, were constructed. Each list consisted of 30 visual items (15 from the anagram list, and 15 from the to-be-read list) and 30 heard items. Each study item was paired with a distracter. All sets of 15 words were balanced for frequency of occurrence in the language (Kucera & Francis, 1967), ease of anagram solution (Jacoby, 1991), and the first letter of the word. Each recognition list began with eight filler items (two anagram items, two read items, and four heard items). These were used for practice trials to ensure that subjects understood the instructions.

Four formats were formed by rotating the visual study items through each presentation and test condition (read versus anagram, and inclusion versus exclusion). The aurally presented items were also rotated across tests. Study items alternated between visual and aural presentation, creating eight possible formats in total. Filler items, however, remained constant across conditions. The presentation order of words for both the study and test conditions was random with the constraint that no more than three items representing the same condition (e.g., type of study or test item) could be presented successively.

Procedure. An Apple IIE computer was interfaced with a monochrome green monitor to present the stimuli. The character size of the stimuli was approximately 5.7 x 6.6 mm. Stimuli were presented in lower case letters in the centre of the screen. In the first part of the study phase, subjects were asked to solve anagrams and read words. They were told that the anagrams would be presented with the second and fourth letters underlined, and that those letters were in their correct positions; therefore only the remaining letters had to be re-arranged. If subjects correctly solved the anagram, the experimenter pressed a key initiating presentation of the next item; however, if subjects made an error, they were told to keep trying. A maximum of 30 seconds was allowed before subjects were told the solution and asked to ensure that it was correct. They were also informed that when words were presented in their normal form their task was to read those words aloud as quickly as possible. Subjects believed that the experiment focused on their ability to solve anagrams and read words; they were not told that a recognition test would follow. In the second part of the study phase, the remaining 68 study words were presented by an audio-cassette recorder. Words were presented one at a time at a rate of one word every two seconds and subjects were asked to repeat each word aloud and try to remember it for a recognition memory test.

The study phase was followed by the exclusion and inclusion tests. Both tests consisted of a two alternative forced-choice recognition task presented by computer. One of the two words was always an old word (i.e., one subjects had read, seen as an anagram, or heard), the second word in the pair was always a new word. In the exclusion test, subjects were *misinformed* that each pair always contained a heard word, and they were instructed to choose the word they had heard by indicating whether it was on the left or right of the pair by pressing the corresponding response key. They were also told that if they recognized a word as one they had read or seen as an anagram, they should avoid that word and select the opposite one. For the inclusion test, subjects again had to do a forced-choice, recognition test. This time they were correctly informed that each pair consisted of an old and new item, and they were instructed to select any word they recognized as old, whether they had heard, read, or seen it as an anagram. Words that had been presented visually were now to be included. Both tests began with eight practice trials combined with feedback to make certain that the instructions were clear. Subjects were asked to make their decisions as quickly as possible.

The significance level for all tests was set at $p < .05$. Tests revealing significant main effects will not be reported when variables producing those main effects entered into significant interactions.

Results and Discussion

The elderly adults solved 75% of the anagrams presented at study, while the young adults solved 86%. Although this difference was statistically significant, *F* (1, 30) = 4.66, *MSe* = .026, one would not expect it to have a great impact on the recognition-memory results. Both groups solved the majority of the anagrams, and when subjects could not solve an anagram the solution was provided.

The probability of choosing an old word for each study and test condition is shown in Table 3. The probabilities of choosing read/anagram words are of primary interest. For those words, there was a significant interaction of study and test condition, *F* (1, 30) = 83.11, *MSe* = .015, as well as a significant interaction of age group and test condition, *F* (1, 30) = 7.99, *MSe* = .008. Those interactions show that young subjects held an advantage in recollection over elderly subjects, and that the prior presentation of words as anagrams was more likely to be recollected than was that of words that were read.

Table 3
Observed Probabilities of Choosing Old Words for each Study and Test Condition in Experiment 2

	Inclusion			Exclusion		
Group	Read	Anag	Heard	Read	Anag	Heard
Young	.70	.87	.77	.51	.23	.72
Elderly	.60	.80	.68	.53	.37	.62

For the inclusion test, recollection serves to increase the probabilities of read and anagram words being selected. Post hoc Newman Keuls tests showed that for that test, young subjects were more likely to select study words than were elderly subjects, and words earlier presented as anagrams were more likely to be selected than were words that were earlier read for both groups. For the exclusion test, recollection serves to exclude words that were earlier read and words that were earlier presented as anagrams. For that test, post hoc Newman Keuls tests showed that younger subjects were less likely to select study words across the two study conditions than were elderly subjects, and words that were earlier read were more likely to be selected than were words that were earlier presented as anagrams for both groups. In addition, there was a significant group (young versus elderly) by study item (read versus anagram) interaction, F (1, 30) = 4.93, MSe = .008. However, that interaction is not readily interpretable because it is collapsed across the inclusion and exclusion test conditions, which make very different demands on subjects.

Further evidence of differences in recollection was gained by using the equations presented earlier to separately estimate the contributions of recollection and familiarity to recognition-memory decisions (Table 4). The probability of recollection was higher for words earlier presented as anagrams than for words that were earlier read, F (1, 30) = 8.30, MSe = .030. In addition, the probability of recollection was significantly higher for young than for elderly adults, F (1, 30) = 86.77, MSe = .051. There was no significant group by study item interaction, F (1, 30) = 1.11, MSe = .030.

To examine differences in familiarity, the individual score for one young subject had to be replaced with the group mean. That subject performed perfectly on the inclusion test, choosing all the anagram/read words, and made no errors in exclusion. Consequently, recollection equalled 1.0, and familiarity was undefined because its computations involved division by 0 (see Equation 4). In contrast to the difference in recollection, the estimated probability of selecting a word on the basis of its familiarity was identical (.62) for young and elderly subjects. Neither the main effect of study item (read versus anagram) nor the interaction of study item with age approached significance in the analysis of effects on familiarity, F (1, 30) = 1.54, MSe = .024, and F (1, 30) = 1.79, MSe = .19, respectively. The probability of selecting read/anagram words on the basis of their familiarity was significantly above chance (.50), for both the elderly, t (15) = 4.8, and the young adults, t (15) = 4.8.

Table 4
Estimated Probabilities of Choosing Old Words on the Basis of Recollection and Familiarity for each Study Condition in Experiment 2

	Recollection		Familiarity		
Group	Read	Anag	Read	Anag	Mean
Young	.19	.64	.62	.62	.62
Elderly	.07	.43	.58	.66	.62

The results of Experiment 2 replicated those of Experiment 1 in showing that the effects of aging produced a large deficit in the probability of recollection, but left invariant the use of familiarity as a basis for judgments. The advantage in recollection of words earlier presented as anagrams over words that were earlier read was expected (Jacoby, 1991). However, Jacoby also found that words presented as anagrams held an advantage in familiarity over read words, whereas here there was no effect on familiarity. Jacoby argued that the effect of reading versus solving anagrams on familiarity was important because the effect is opposite to the prediction made by theories that hold that familiarity relies on the match in perceptual characteristics between the study and test versions of an item (e.g., Jacoby & Dallas, 1981; Mandler, 1980). Because words were presented in their normal form to be read on the recognition test, words that were earlier read should have held an advantage in familiarity over words that were earlier presented as anagrams.

Jacoby interpreted his finding as evidence that familiarity is not totally reliant on the match in perceptual characteristics between the study and test versions. It is unclear why his result was not replicated here, but it may be because Jacoby used a "yes/no" test of recognition memory, rather than a forced-choice test. Regardless, finding no difference in familiarity between anagram and read words is damaging enough to theories that emphasize perceptual similarity for recognition, since read words showed no advantage in familiarity.

Another analysis examined recognition differences for words that had been presented aurally (Table 3). There was an age difference in the probability of choosing those earlier-heard words, F (1, 30) = 14.66, MSe = .010. The young adults were more likely to select earlier-heard words than were elderly adults. That result is understandable as further evidence that the elderly subjects suffered a deficit in their ability to recollect the prior presentation of a word as compared to younger subjects.

Because subjects were instructed to choose earlier-heard words for both tests, one would not expect any effect of type of test on the probability of those words being selected. However, subjects were more likely to select earlier-heard words on the inclusion, as compared to, the exclusion test, F (1, 30) = 5.52, MSe = .008.

The effect of type of test on the probability of selecting earlier-heard words may be taken as evidence for false recollection. On the exclusion test, subjects may falsely recollect an item they have heard as an item they have read or seen as an anagram, and consequently, exclude that item rather than select it. For the inclusion test, however, such errors in recollection would not reduce the probability of choosing heard items since subjects were to select all study items. The effect of test type for earlier-heard words was the same for elderly and young subjects ($F < 1$ for the interaction), so any bias in the estimation procedure produced by false recollection was the same for both groups. Because the conclusions concern differences between the elderly and young rather than *absolute* values of estimated probabilities, the absence of a differential effect is all that is required.

In summary, despite the different testing procedures used in Experiments 1 and 2, there is a striking similarity in the results; both experiments show the same pattern of performance with age. Aging impairs consciously-controlled memory processing but spares automatic memory.

Chapter 3

The Severity of Age-Related Deficits in Consciously-Controlled Memory

After establishing that age deficits occur only in consciously-controlled memory, I became interested in using the process dissociation procedure to examine the severity of this age-related decline. As discussed in the introduction, automatic memory may enhance direct test performance such that age deficits in consciously-controlled processes are more dramatic than suspected. For instance, consider the inclusion test results from the anagram condition in Experiment 2. The inclusion task is a direct test of memory, subjects are asked to try to recognize words shown as anagrams, and automatic and consciously-controlled processes act together to produce the same effect. Examining the results of this condition shows an age difference in performance of only 7%. However, the difference in recollection for anagrams between young and elderly adults proved to be 21%. Relying solely on a direct test (the inclusion condition) to measure the age-related difference in conscious memory would have led to an underestimation of three times less than its actual magnitude! In short, determining the severity of age deficits in conscious memory requires that recollection be examined separately from the influence of automatic processing.

Experiment 3

Experiment 3 was designed to investigate changes in recollection more precisely by drawing on the commonplace error of repeating a story to the same audience. Reasoning from that example that short intervals between each re-telling are indicative of serious age-related impairment, I wished to establish the length of the interval between presentation and test necessary to show age deficits in consciously-controlled processing. If this interval proved to be brief, declines in recollection could be considered severe. Young and elderly adults studied a list of words, followed by a recognition test where they were shown old and new words with each new word repeated once, after 4, 12, 24, or 48 intervening items (lag intervals) occurred. The second presentation of new words are labelled "catch items". For this experiment only an exclusion test was used. As usual, that test set automatic and consciously-controlled processes in opposition. Subjects were asked to identify study words; they were to respond "yes" to old words, but to respond "no" to new and catch items.

The catch words are critical. The first presentation of catch items should increase their familiarity (Fischler & Juola, 1971; Underwood & Freund, 1970), and subjects may misattribute this familiarity to the prior study phase, confuse catch words with old ones, and mistakenly respond "yes". However, if subjects can recollect the source of a word's initial presentation (study versus test), or recollect that they have already responded to a word, then any influence of familiarity is opposed, and subjects will correctly respond "no". Again, familiarity is an automatic influence of memory -

subjects reveal memory for the catch items without conscious intention through their errors whereas recollection can be seen as a controlled, intentional use of memory that prevents errors.

Telling subjects to respond "no" to catch words places familiarity and recollection in opposition. thus, failures of recollection can be inferred from the probability of mistakenly responding "yes" to catch items in comparison with the probability of mistakenly responding "yes" to new items. Responding "yes" to new items indicates the baserate familiarity level associated with words without prior exposure during study. If subjects respond "yes" to significantly more catch items than new items, one can conclude that they were unable to recollect the catch items, but found them more familiar than new items from their first presentation at test. No age difference in recollection was expected at the shortest lag, but recollection should become more difficult with increasing intervals. Consequently, the elderly should answer "yes" to more catch words than new words as lags increase, and should answer "yes" to more catch words than the young adults at longer lags.

Method

Subjects. The subjects were 16 young adults, ranging in age from 18 to 23, (M age = 19.9), and 17 older adults, ranging in age from 63 to 88 (M age = 72.4). The young subjects were enrolled in an introductory psychology course and participated for course credit. They had 14.1 mean years of education, and an average score of 73% on the Mill Hill Vocabulary test. The elderly adults were McMaster Alumni, who volunteered their services. They were all community-dwelling residents in self-reported good health. They had an average of 17.4 years of education, and an average score of 81% on the Mill Hill Vocabulary test. Data from one of these subjects were lost due to computer failure.

Materials. The stimuli consisted of 120 words. Sixty words were presented at study, and comprised the old items for the recognition test. The remaining 60 words were presented only at test and acted as new items. Two study formats were devised so that words presented at study in one condition, occurred only at test in the second condition. In addition, the 60 new words were divided into four sub-groups of 15 items. Items in these groups were balanced for frequency of occurrence in the language, imagibility, and concreteness according to normative values obtained from the Toronto Word Pool (Friendly et al., 1982). They were also balanced for the number of letters, and the first letter of the word.

Each group of 15 test words was used for a different lag condition. Items in one group were presented, then repeated after four intervening items had occurred; the second group of items was repeated after 12 intervening items and so on. Four test formats were developed by rotating these groups through each lag condition, so that every group of words was tested as a catch word after 4, 12, 24, and 48 intervening items across the experiment. In short, eight formats of the experiment were devised so that each word was presented as an old or new item, and every new item was repeated at each test interval. The study and test list orders were random with the restriction that no more than three items of a given type (study word or test item type) could occur consecutively.

Procedure. An Apple IIE computer was interfaced with a monochrome green monitor to present the stimuli. The character size of the stimuli was approximately 5.7 x 6.6 mm. Words were presented in lower case letters in the centre of the screen. In the study phase each word was presented for two seconds, and subjects were asked to read each word aloud and try to remember it for the recognition test that would follow.

Immediately after the study phase, subjects were given the exclusion test. The test consisted of the 60 old words from study, and 60 new words. In addition, these 60 new words were repeated at one of four different lags. Words were repeated after 4, 12, 24, or 48 intervening items had occurred between the first and second presentation of the word. Words were shown one at a time, and subjects had to decide if a word was one they had read aloud. They were to respond yes if a word was one they had read aloud and no if a word was new or repeated (catch item). They were informed that study words would not be repeated, and if they recognized a word as one they had already seen in the test list then they should respond "no". Subjects responded by pressing one of two keys.

The significance level for all statistical tests was set at $p < .05$. Tests revealing significant main effects will not be reported when variables producing those main effects entered into significant interactions.

Results and Discussion

There was no significant effect of age on the probability of correctly identifying old or new items (Table 5), F (1, 30) = 2.38, MSe = .015. The elderly and young adults did not differ significantly in their ability to recognize words they had read aloud, although the young adults did tend to recognize slightly more words. More importantly, the two groups were equally capable of identifying new words they had not read aloud. Both groups made few "yes" responses to those items.

As mentioned earlier, the probability of responding "yes" to new items is significant because it is a measure of the baserate familiarity for items that have not been shown during the experiment. Therefore, any increase in the probability of responding "yes" to catch items from their first to second presentation can be taken as evidence for an increase in familiarity due to prior presentation. Moreover, finding no age difference in the probability of responding "yes" to new items shows that there is no age difference in bias or willingness to accept familiar words as "old".

Table 5
Observed Probabilities of Responding "Yes" to Old, New, and Catch Items at each Lag Interval in Experiment 3

	Old Items	New Items	Catch Items Lags			
Group			4	12	24	48
Young	.63	.08	.05	.06	.06	.13
Elderly	.54	.09	.23	.25	.27	.25

The most important effect, however, involves comparing performance between new versus catch words for young and elderly adults. Mistakenly responding "yes" to more catch words than new ones signifies that subjects failed to recollect those items yet found them familiar, and catch words provided evidence for an age-related decline in recollection. Analysis of the probability of responding "yes" to new versus catch items at each lag revealed a significant interaction of age x item, F (4, 120) = 5.90, MSe = .009. A post hoc Newman Keuls test showed that young adults were equally likely to respond "yes" to new and catch items at any one of the four lag conditions (Table 5). They were able to recollect the catch words, making as few errors for those items as new ones. That is, they did not tend to confuse catch items with old items. In addition, confusion did not increase significantly across the four lags; the young made few errors regardless of the number of intervening items between the first and second presentation, although errors did rise slightly at Lag 48.

In contrast, the elderly adults responded "yes" to significantly more catch items than new items at all four lags. Although they were as capable as the young adults in discriminating new from old words, they were less able to discern catch items from old words. They responded "yes" to far more catch items than the young adults, suggesting poorer recollection for initial presentation of the catch words. Furthermore, their recollection was equally weak across all four lag conditions. The ability of the elderly to discriminate between catch words and old words seemed to have reached its maximum decline after only four intervening items.

These results were startling. A difference between the age groups at the shortest lag condition was unexpected, since it was thought that age differences would gradually increase as lags increased. Instead, there was a large difference in performance between the two groups after only four interfering items, and this difference did not change. The elderly seemed to show a very rapid decline in recollective processing. However, one other explanation is plausible. The elderly may have performed poorly in the shortest lag condition because they misunderstood or had difficulty complying with the task instructions. In order to rule out this potential confound, a similar experiment was carried out using a Lag 0 condition. For this test interval, a word was repeated immediately after its initial presentation, so subjects could not fail to recollect the word. If the elderly showed low performance in this condition, it would suggest that they were unable to comprehend the instructions. However, if performance did not deteriorate until some intervening items had occurred between repetitions, one could be more certain that their deficit truly lay with recollection.

Experiment 4

Experiment 4 was conducted to establish whether elderly adults had difficulty in the previous experiment because of failures in recollection or because of task confusion. The design of Experiment 3 was repeated using shorter lag intervals. During the test phase, catch words were repeated after zero, one, three or seven intervening items occurred between the first and second presentation. As described, the Lag 0 condition was included to determine if older subjects were capable of following the task instructions. The other short intervals were used to trace the decline in performance found in the previous experiment across gradually increasing delays. Because Experiment 4 was designed to test older adults' ability to follow task instructions, and to pinpoint the interval where recollection first began to decline, there was no need to test young adults. Consequently, only older subjects were asked to participate.

Method

Subjects. Seventeen elderly adults, ranging in age from 60 to 84 (M age = 73.2) took part. The subjects were all McMaster Alumni, who volunteered their services. They lived in the community and reported themselves to be in good health. The subjects had an average of 17.5 years of education, and an average score of 85% on the Mill Hill Vocabulary test. Data from one of these subjects could not be included because the subject admitted to being confused with the instructions.

Materials and Procedure. Experiment 4 used the same materials and procedures as Experiment 3 with one exception. The lag intervals were shortened so that zero, one, three, or seven intervening items occurred between the first and second presentation of a catch word. For the Lag 0 condition, the target word was repeated immediately after subjects responded to the first presentation. The screen remained clear for 200 msecs before the word re-appeared; so there was an obvious separation between repetitions.

Results and Discussion

The probabilities of correctly identifying old items (.60) and new items (.11) were in keeping with the results obtained in Experiment 3. A one-way analysis of variance comparing the probability of mistakenly responding "yes" to new versus catch items at each lag produced a significant effect, F (4, 60) = 15.75, MSe = .01. A post hoc Newman Keuls test indicated that older adults responded "yes" to significantly fewer catch items than new items at Lag 0. They were also inclined to respond "yes" to fewer catch items than new items at Lag 1, although this difference was not significant. However, more catch words than new words invoked a "yes" response at Lags 3 and 7. This difference was significant only at Lag 7. Results are displayed in Table 6.

Table 6
Observed Probabilities of Responding "Yes" to Old, New, and Catch Items at each Lag Interval in Experiment 4

	Old Items	New Items	Catch Items Lags			
			0	1	3	7
Elderly	.60	.11	0	.07	.17	.27

These findings suggest that the age-related decline in recollection seen in Experiment 3 cannot be attributed to instructional confusion. The elderly adults chose fewer catch items at Lag 0 than new items, suggesting they were able to follow instructions. In addition, they demonstrated a deficit at Lag 7 comparable to the deficit shown at Lag 4 in Experiment 3. Although performance for catch items at Lag 3 did not differ from that obtained with new items, there was a significant drop in performance between Lags 1 and 3. Recollection appears to begin showing an age-related decline when one to four items interfere between presentation and test. Moreover, these declines seem to asymptote after four intervening items have occurred and remain constant for up to at least 48 intervening words.

Experiment 5

The results of Experiments 3 and 4 were intriguing. Recollective performance in the elderly declined rapidly after only a few intervening items between presentation and test. Because deficits in recollection had only been inferred from an exclusion condition, it was not possible to obtain actual estimates of recollection. However, the rapid change in performance shown by the elderly suggested that observing declines in the estimated probability of recollection would be interesting. Experiment 5 combined the exclusion test used in Experiments 3 and 4 with an inclusion condition, allowing the comparison of estimated recollection across lags for young and elderly adults. In addition, any decrease in familiarity with an increase in test interval could also be observed.

Young and elderly adults were asked to study a list of 90 words followed by an inclusion and exclusion test. Both tests consisted of old and new words with each new word repeated once (catch items), after 0, 3 or 12 intervening items (lag conditions) occurred. Instructions for the exclusion test were the same as the previous two experiments. Recall that telling subjects to respond "no" to catch words placed familiarity and recollection in opposition, a catch word would elicit a "yes" only if it was sufficiently familiar (F) and not recollected as presented at test (1 - R).

In contrast, on the inclusion task, subjects were told to respond "yes" to *any* words they had seen before (words they had read aloud at study and catch words presented at test). In this case, both recollection and familiarity would lead subjects to correctly respond "yes" to catch words. For an inclusion test, they could respond "yes" to a catch word either because they recollected it was on the test list (R) or, because, although recollection failed, they found the word sufficiently familiar (F(1-R)).

Combining results from the inclusion and exclusion test conditions allows one to separately estimate the effects of consciously-controlled and automatic processes using the equations described in the introduction. Estimates can be calculated for both age groups at each lag condition allowing one to look for age differences in both processes, and determine how rapidly the recollective process declines across test intervals with age. In addition, one can establish whether familiarity changes as test intervals increase. Because familiarity remains impervious to age while recollection deteriorates, familiarity may not decline across lags as rapidly as recollection.

Method

Subjects. Twenty-five young adults, ranging in age from 18 to 21, (M age = 19.1), and 30 older adults, ranging in age from 63 to 80 (M age = 71.5) took part.

The young subjects were enrolled in an introductory psychology course and participated for course credit. They had 13.3 mean years of education, and an average score of 69% on the Mill Hill Vocabulary test. The elderly adults were McMaster Alumni, who volunteered their services. They were all community-dwelling residents, who reported good health. They had an average of 17.0 years of education, and an average score of 87% on the Mill Hill Vocabulary test. Data from one young adult and five elderly adults were discarded because these subjects could not follow task instructions. In addition, data from one elderly adult were lost due to computer failure.

Materials. The stimuli consisted of 180 words. Ninety words were shown at study, and comprised the old items for the two recognition tests. The remaining 90 words were presented only at test and acted as new items. Two study formats were devised by rotating the old/new items so that words presented at study in one condition, occurred only at test in the second condition.

Two recognition test lists were constructed (inclusion and exclusion). Each list consisted of 45 old and 45 new items. In addition, the new words were divided into three groups of 15 items. These groups of items were balanced for frequency of occurrence in the language, imagibility, and concreteness according to normative values obtained from the Toronto Word Pool (Friendly et al., 1982). They were also balanced for the number of letters, and the first letter of the word.

Each group of 15 words was tested in a different lag condition. One group was presented and repeated after zero intervening items; the second group was presented after three intervening items and so on. Three test formats were developed by rotating every group through each lag condition, so that items repeated after zero intervening items in one format, were repeated after three intervening items in a second format etc. In addition, these lists were rotated so that each item was tested in both the inclusion and exclusion conditions across the experiment. In brief, 12 formats of the experiment were devised so that each word was presented as an old or new item, every new item was repeated at each test lag interval, and all items occurred in both the inclusion and exclusion tests. Each test list order was random with the restriction that no more than three items of a given type (study word or test item type) could occur consecutively.

Procedure. An Apple IIE computer was interfaced with a monochrome green monitor to present the stimuli. The character size of the stimuli was approximately 5.7 x 6.6 mm. Words were presented in lower case letters in the centre of the screen. For the study phase, each word was presented for two seconds, and subjects were asked to read the words aloud and remember them for a recognition memory test.

Following the study presentation, subjects were given the inclusion and exclusion tests. Testing order was counterbalanced across the experiment. Each test consisted of 45 old words from study, and 45 new words. In addition, the new words were repeated at one of three different lags. Words were repeated after zero, three, or 12 intervening items had occurred between the first and second presentation of the catch word. For the inclusion test, subjects were to respond "yes" to any word they had seen before (from study or test), and "no" if a word was a new word they had not yet viewed. For the exclusion test, subjects were again to respond "yes" if a word was one they had read aloud, and "no" if a word was new or a catch item. Subjects responded by pressing one of two keys.

The significance level for all statistical tests was set at $p < .05$. Tests revealing significant main effects will not be reported when variables producing those main effects entered into significant interactions.

Results and Discussion

As in Experiment 3, there was no effect of age on the probability of correctly identifying old and new items (Table 7), F (1, 46) = 1.16, MSe = .0498, no significant age x item interaction, F (1, 46) = 1.81, MSe =.017, nor an age x test x item interaction F (1, 46) = 1.60, MSe = .0109. Elderly and young adults did not differ significantly in their abilities to recognize words they had read aloud or identify new words, although older adults were inclined to mistakenly respond "yes" to slightly more new words than the young. Moreover, the capability of both age groups remained the same for both the inclusion and exclusion tests. Finding no significant age effect in the probability of responding "yes" to new items suggests there is no significant group bias in accepting familiar words as "old". There was also no change in bias across the two test conditions for either age group.

The probability of correctly identifying new versus catch items, however, revealed a significant interaction of age x test x item, $F(4, 184) = 12.51$, MSe = .0098. For the inclusion task, a post hoc Newman Keuls test found that the young adults were proficient at correctly answering "yes" to catch words. Moreover, this ability did not diminish significantly across the three lags. The elderly adults were as capable as the young at including catch words at Lags 0 and 3. However, performance declined at Lag 12, producing a significant difference between the age groups.

Table 7
Observed Probabilities of Responding "Yes" to Old, New, and Catch Items at each Lag Interval for both Test Conditions in Experiment 5

		Old Items	New Items	Catch Items Lags		
Group	Test			0	3	12
Young	Inc	.63	.09	.98	.96	.94
	Exc	.63	.10	.02	.06	.12
Elderly	Inc	.61	.17	.96	.91	.88
	Exc	.66	.15	.02	.21	.36

There was also a distinct pattern of performance with age on the exclusion test. Both groups responded "yes" to fewer catch items than new items in the Lag 0 condition, indicating that both groups were following instruction.·. In addition, there was no significant difference in the probability of responding "yes" to new and catch items at Lag 3 for either group. However, there was a significant age difference in the probability of saying "yes" at Lag 3. The elderly adults responded "yes" to slightly more catch items than new items, whereas the young responded "yes" to slightly fewer catch items than new items. This discrepancy between the groups increased at Lag 12. The young adults continued to answer "yes" to a comparable number of new and catch items, but the elderly said "yes" far more frequently to catch items than the young adults.

Given failures in recollection are manifest in the probability of responding "yes" to catch items, the above pattern of results suggest that young adults demonstrated better recollection than the elderly at Lags 3 and 12 in the inclusion and exclusion tests. This interpretation is confirmed when one calculates estimates for recollection using the equations described in the introduction. The probability of recollection was estimated as the difference between the probability of responding "yes" to catch words in the inclusion and exclusion test conditions (Table 8).

A two way analysis of variance testing the influence of age x lag on recollection revealed a significant interaction, F (2, 92) = 13.5, MSe = .02. Examination of this interaction using a post hoc Newman-Keuls test revealed no significant age difference in the probability of basing a decision on recollection at Lag 0, but significant age differences in recollection at Lags 3 and 12. Moreover, there was a significant difference in the probability of basing a decision on recollection across Lags 0, 3, and 12 for the elderly; they showed a significant decrease across all three lags. Performance for the young, however, dropped only slightly from Lag 0 to Lag 12.

Table 8
Estimated Probabilities of Basing a Decision on Recollection and Familiarity at each Lag Interval in Experiment 5

	Recollection			Familiarity		
	Lags			Lags		
Group	0	3	12	0	3	12
Young	.96	.90	.83	-	.64	.66
Elderly	.94	.71	.51	-	.67	.74

The probability of responding on the basis of familiarity was also calculated from the inclusion and exclusion data (Table 8). However, estimates at Lag 0 were incalculable, because most subjects had a probability of correctly responding "yes" in inclusion of 1.0, and a probability of mistakenly responding "yes" in exclusion of 0. This makes recollection equal to 1.0, which makes the estimate of familiarity undefined. Consequently, only estimates of familiarity at Lags 3 and 12 were analyzed. In addition, scores for two elderly subjects and six young adults had to be dropped from these analyses for the same reason. Those eight subjects all had at least one familiarity estimate at Lag 3 or 12 that was indeterminable. Analyzing the probability of basing a decision on familiarity revealed no effect of age, lag, nor a significant age x lag interaction (all $F < 1$).

Estimates of familiarity consist of automatic influences from a catch word's first presentation and the baseline probability that words are familiar without prior exposure (responding "yes" to a new word). Presenting catch words at test increased their familiarity above baseline for both young and elderly adults. The estimated probability of responding "yes" to catch words because of familiarity (Table 8) was significantly higher than the probability of responding "yes" to new words (Table 7) for young adults at Lags 3 and 12, t (17) = 5.74 and t (17) = 6.76, respectively. The elderly adults showed the same effect, t (21) = 9.24 and t (21) = 12.36.

As discussed for Experiment 1, differences in responding on the basis of familiarity can also be examined by simply subtracting the baseline probability of responding "yes" to a new word from the familiarity estimates. After doing so, the means for the young adults at Lag 3 (.55) and Lag 12 (.56), and the elderly adults at Lag 3 (.51) and Lag 12 (.58) are even more similar than when the familiarity values (Table 8) are examined. This change stems from the tendency for young subjects to respond "yes" to fewer new words on the basis of familiarity than the older subjects. Applying the more sophisticated signal detection correction procedure (Yonelinas et al., in press) to the original familiarity estimates produces the same result. There are small differences in a d-prime measure of familiarity for young (1.64) and elderly (1.43) adults at Lags 3 and 12 (1.69 and 1.63 respectively).

The results .f the lag task replicated the finding in Experiments 1 and 2 that automatic processing does not change with age. The ability of the elderly to use familiarity also remained constant across test intervals, despite large deficits in recollection, suggesting that familiarity is robust to both age and interference. However, elderly adults showed a sharp decline in recollection when only a few intervening items occurred between presentation and test, whereas young adults did not show a significant change.

In summary, Experiments 1 to 5 suggest that aging impairs consciously-controlled memory processing but leaves automatic memory processing intact. Moreover, age deficits in conscious processing are quite severe. Older adults are impaired relative to young when only three items have occurred between presentation and test.

Chapter 4

Self-Reported Awareness of Memory Processing in Older Adults

Age-related declines in conscious memory proved to be quite marked in Experiments 3 to 5. Moreover, when failures in recollection occurred automatic processing was left as the sole basis for performance leading to "false" recognition errors. Older subjects were inclined to "recognize" catch words as ones they had seen in the study list. These errors raise the question of whether older adults are aware of their memory processing. After all, if familiarity combined with a lack of recollection can produce errors (mistaking catch words for study words) then subjects' awareness that they are responding to an item on the basis of familiarity could make them cautious about calling it a study item. That is, awareness that familiarity is driving a response could preclude errors. Are older subjects aware of which form of processing underlies their memory decisions?

Conscious memory, by definition, implies that subjects are aware of remembering information, however, in Experiments 1 to 5 conscious recollection was measured through performance on objective tasks. Older adults' subjective reports may not match their objective performance. For example, when subjects find a "catch" item familiar on the test list and misattribute that familiarity to the study presentation, they may feel as though they have "recollected" the item. They may not know that they are reacting due to familiarity. Awareness of which type of memory process underlies responding can be considered an aspect of metamemory. As discussed in the introduction, in many cases, elderly adults show accuate metamemory (e.g., see Lovelace, 1990 for review; Lovelace & Marsh, 1985; Perlmutter, 1978). Therefore, they may also be quite capable of identifying which process they are using during recognition; their subjective reports may parallel their objective performance.

Experiment 6

As described earlier, Tulving's remember/know procedure (Gardiner, 1988; Gardiner & Java, 1991; Gardiner & Parkin, 1990; Tulving, 1983) provides a means for measuring subjective report when individuals are recollecting information or merely find it familiar. Subjects are asked to respond "remember" when they are using recollection, and "know" when they are relying on familiarity. By combining the independence assumption with this procedure we can estimate the probability of using recollection (R=Remember) and familiarity (F=Know/1-R). Applying this independence-remember/know procedure with young adults has produced results identical to those found using the process dissociation procedure (Jacoby, et al., in press). Young adults are clearly aware when they are recognizing information due to recollection versus familiarity. The important question then is whether older adults are equally aware. If older adults are conscious of their memory processing, then the subjective report technique should produce the same pattern of results found in Experiments 1 through 5; recollection should decline with age but familiarity should remain unchanged.

Research with the original remember/know procedure has been conducted with elderly adults. Parkin and Walter (1992) found that "remember" responses declined with age, whereas "know" responses increased. These results are expected. Older adults should show poorer recollection, and therefore fewer "remember" responses than young adults. Further, given the assumption that "know" responses and exclusion are comparable, the proportion of "know" responses should increase with age, similar to errors in an exclusion condition. However, if one estimates familiarity from these "know" responses, one should not find age differences. Calculating familiarity estimates from Parkin and Walter's (1992) mean data produced conflicting results. In Experiment 1, elderly subjects showed a higher proportion of "know" responses and higher familiarity than the young. In contrast, Experiment 2 revealed small group differences for both "know" responses and familiarity. It is difficult to draw conclusions from these discrepant results, particularly since the design and materials of Parkin and Walter's experiments are identical. Consequently, I wanted to conduct an experiment to investigate independence-remember/know with elderly adults and determine which results were replicable.

In contrast to my previous five experiments, Parkin and Walter (1992) tested three groups of subjects - young adults, young-elderly adults, and old-elderly adults.

In an effort to replicate their study, three groups of subjects were tested in Experiment 6. The young adults had a mean age of 20.7 years, which is comparable to Experiments 1 through 5, while the other two groups had mean ages of 65 and 75.3 respectively. The old-elderly adults are slightly older on average than the older subjects in the previous five experiments whereas the young-elderly group, on average, is slightly younger. As discussed, it is possible that the two groups of older subjects may not show the correspondence in results between independence-remember/know and the process dissociation procedure that we have found with young adults (Jacoby, et al., in press). The elderly may not be aware of their memory processing in the same way as the young, and those differences may be revealed with independence-remember/know. However, if the elderly do show the same pattern of results between independence-remember/know and the process dissociation procedure, then one can conclude that there is a correspondence between objective and subjective memory measures.

Method

Subjects. Twenty young adults and 46 older adults took part. The young subjects, ranging in age from 19 to 24 (M age = 20.7), were enrolled in an introductory psychology course and participated for course credit. They had 14.8 mean years of education, and an average score of 67% on the Mill Hill Vocabulary test. The elderly adults were McMaster Alumni, who volunteered their services. They were all community-dwelling residents, in self-reported good health. Data for six elderly and one young adult were discarded from the experiment because they failed to follow instructions. The remaining 40 elderly adults were divided into two groups of 20, a group of young-elderly and a group of old-elderly. The young-elderly group, ranging in age from 61 to 69 (M age = 65.0), had an average of 18.7 years of education, and an average score of 85% on the Mill Hill Vocabulary test. The old-elderly group, ranged in age from 70 to 82 (M age = 75.3), with an average of 17.6 years of education, and 80% on the Mill Hill test.

Materials. The stimuli consisted of 120 nouns. Sixty words were presented at study, and comprised the old items for the recognition test. The remaining 60 words were presented only at test and acted as new items. Two study formats were devised so that words presented at study in one condition, occurred only at test in the second condition. Items in these groups were balanced for frequency of occurrence in the language, imagibility, and concreteness according to normative values obtained from the Toronto Word Pool (Friendly et al., 1982). These were also balanced for the number of letters, and the first letter of the word. The test list order was random with the restriction that no more than three items of a given type (study word or new item) could occur consecutively.

Procedure. An Apple IIE computer was interfaced with a monochrome green monitor to present the words. The character size of the stimuli was approximately 5.7 x 6.6 mm. Words were presented in lower case letters in the centre of the screen. In the study phase each word was presented for two seconds, and subjects were asked to read each word aloud, and try to learn it for a recognition task. Following the study phase, subjects were given the recognition test, which consisted of the 60 old words from study and 60 new words. Words were shown one at a time, and subjects had to decide if a word was one they had read aloud. If subjects recognized a word from study, they were to respond "remember" if they were "consciously aware of some aspect or aspects of what happened or what was experienced at the time the word was presented" or if "the word should bring back to mind a particular association, image, or something more personal from the time of study". If subjects could not "remember" the word, but could recognize it from study, they were to respond "know" to indicate that they recognized the word, "but could not remember any details about the word's prior presentation". These instructions were taken directly from work carried out by Gardiner (Gardiner, 1988; Gardiner & Java, 1991; Gardiner & Parkin, 1990). If subjects did not recognize a word from study, they were to respond "new" to indicate that they had not seen the word before.

The significance level for all statistical tests was set at $p < .05$. Tests revealing significant main effects will not be reported when variables producing those main effects entered into significant interactions.

Results and Discussion

There was no significant difference in the probability of correctly identifying old and new items, $F\ (2, 57) = 3.01$, $MSe = .019$, that is, correctly responding "remember" or "know" to old items and "new" to new items. All three age groups recognized a comparable number of old items as "old" and new items as "new" (see Table 9). These results are in line with those studies described in the introduction that find that recognition performance can remain relatively intact with age (Craik & McDowd, 1987; Rabinowitz, 1984; 1986).

Table 9

Observed Probabilities of Correctly Recognizing Old Items as "Old" and New Items as "New" in Experiment 6

Group	Old Items	New Items
Young	.78	.88
Young-Elderly	.77	.85
Old-Elderly	.68	.86

However, when responses to items were separated into "know" and "remember" categories, the results were somewhat different. A two-way analysis of variance examining the probability of responding "know" to old and new items for all three groups showed no significant group difference in the probability of responding "know" to old or new items, F (2, 57) = 1.23, MSe = .03. All three groups made an equal number of errors in mistakenly responding "know" to new items. Responding "know" to new items indicates the baserate familiarity for items that have not been shown during the study, thus there was no age difference in willingness to respond "know" to familiar words. Each age group also correctly labelled a statistically comparable number of old items "know", although in keeping with Parkin and Walter's data, the old elderly group called slightly more items "know" than the other two groups (see

Table 10).

Table 10
Observed Probabilities of Responding "Remember", "Know" or "New" to Old and New Items in Experiment 6

	Old Items			New Items		
Group	Rem	Know	New	Rem	Know	New
Young	.56	.22	.22	.02	.10	.88
Yng-Elderly	.51	.26	.22	.05	.11	.85
Old-Elderly	.35	.33	.32	.03	.11	.86

In contrast, there was a significant group by item interaction evident in the probability of responding "remember" to old and new items, F (2, 57) = 4.68, MSe = .025. A post hoc Newman Keuls test showed that the three groups mistakenly indicated that an equal number of new items were "remembered". Responding "remember" to new items also indicates the baserate familiarity for items without prior exposure, and the similarity across the three groups indicates no age difference in false recollections or bias to respond "remember" to familiar words. There was, however, an age difference in the probability of responding "remember" to old items, old-elderly subjects said "remember" less frequently than the other two groups, who did not differ significantly (see Table 10). These results suggest that there is a significant effect of age on recollection in the old-elderly group.

Age differences in recollection support an argument made earlier regarding intact recognition performance in older adults. It was pointed out that relying on a recognition task as a pure test of conscious processing could mask true differences in conscious memory. Elderly adults may show equivalent performance to young adults due to spared automatic processing, not because of preserved recollection. The findings here bear out that assertion. There was no significant age difference in overall recognition, yet, examining conscious processing separately from automatic memory revealed an age-related change.

In contrast, when we calculated estimates of familiarity, we found no significant difference between the three groups, $F\ (2, 57) < 1$, $MSe = .04$. The young and elderly groups showed a similar likelihood of basing a decision on familiarity (see Table 11).

Table 11
Estimated Probabilities of Basing a Decision on Recollection and Familiarity in Experiment 6

Group	Recollection	Familiarity
Young	.56	.50
Young-Elderly	.51	.52
Old-Elderly	.35	.47

The familiarity estimates consist of the baseline probability that words are familiar without prior exposure (responding "know" or "remember" to a new word) and automatic influences from the study presentation. The estimated probability of responding to study words because of familiarity (Table 11) was significantly higher than the combined probability of responding "remember" or "know" to new words

(Table 10) for the young, t (19) = 11.84, young-elderly, t (19) = 8.22, and old-elderly adults, t (19) = 6.27. That difference between old and new words reflects the influence of familiarity from the study presentation.

The results from Experiment 6 were encouraging. Elderly adults seem able to accurately identify when they are recollecting an item, and when they are recognizing it as familiar. That is, when estimates of familiarity and recollection are calculated from their self-reports, they show the same pattern of results obtained with the more objective process dissociation procedure.

Unfortunately, this study does not shed much light on the inconsistencies between Parkin and Walter's (1992) first and second experiments. The data obtained in this experiment agree with their second experiment. However, there is no explanation for the difference between their experiments. One possibility is that their young and elderly adults may have used a different criterion for considering study items to be "remembered" or "known" across the two experiments. This explanation seems plausible because when the "remember" and "know" responses are combined to measure overall recognition in Experiment 1, the elderly are recognizing 10% more old items than the young! These results do not make much sense nor are they replicated in the second experiment; consequently, it is easy to dismiss Parkin and Walter's first experiment.[1]

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[1] Note that the discussion of Parkin and Walter's data here and on page 71 were based on an "in press" manuscript received by Larry Jacoby.

In conclusion, Experiment 6 indicates that elderly adults can show awareness of retrieval processing. Their metamemory for which memory process they use for a recognition decision appears intact. Older adults show the same pattern of results with a subjective memory test (independence-remember/know) as they do with a more objective measure (process dissociation procedure).

Chapter 5

Everyday Memory Failures in the Elderly

The results of Experiments 1 through 6 all reveal the same profile of age-related deficits. On lab tasks, older adults clearly demonstrate pronounced declines in recollection with spared familiarity, which raises the question, what role does this impairment play in their daily lives? Is there a relationship between the level of performance shown by older adults in the lab and their everyday memory failures? As described in the introduction, previous attempts to establish a relationship between lab and real world performance have been unsuccessful (Cohen, 1993; Herrmann, 1982; Herrmann, 1990; Little, Williams, & Long, 1986). However, these efforts have failed to separate out the effects of automatic and conscious processing on the lab measures.

If everyday memory errors are produced by faulty recollection in older adults, which seems likely since it is that process that changes with age, then correlating these errors with tasks where recollection and familiarity are confounded are bound to produce low correlations. Moreover, there is a second potential problem with previous studies. Memory questionnaires rely on subjective report whereas lab performance is usually evaluated through objective memory tests. Although Experiment 6 shows that objective and subjective memory measures can correspond, this result may not always hold true. Consequently, the difference between the subjectiveness of a questionnaire and the objectiveness of a lab task may introduce extraneous noise into the correlations.

Experiment 7

To address these issues, I wanted to use a memory questionnaire that asked about everyday situations that specifically reflect recollection, and compare that score with recollection estimated from the subjective report task used in Experiment 6. This approach offers two advantages. Firstly, estimates of recollection are compared for both the questionnaire and lab task. Secondly, self-report is relied upon for both measures. As mentioned in the introduction, I chose to use a memory questionnaire that was designed by myself and Janine Hay to measure recollection in daily life. This questionnaire was mailed to subjects who participated in Experiment 6, and their questionnaire results were compared with their "remember" score from the independence-remember/know task.

If associations between self-report measures and lab performance are low because recollection and familiarity are not correlated separately with questionnaire scores, then three predictions can be made. One, correlating questionnaire results with the estimate of recollection obtained in Experiment 6 should produce larger correlations than has been found in previous studies. Two, correlating questionnaire scores with estimates of familiarity from Experiment 6 should produce very low to non-existent correlations. Three, correlating questionnaire results with recognition performance (recollection and familiarity combined) should produce a lower correlation than that found using recollection. Moreover, this latter correlation should be comparable to those found in previous research.

Method

Subjects. The 40 older subjects who participated successfully in Experiment 6 were asked to participate in the questionnaire study about 2 to 6 months later. They were asked to complete the questionnaire as honestly as possible and return it in the self-addressed stamped envelope. Twenty-eight subjects returned the questionnaire in the allotted amount of time (one month). Their ages ranged from 61 to 88 (M age = 70.9), and they had an average of 17.9 years of education, with an average score of 82% on the Mill Hill Vocabulary Test.

Materials and Procedure. Subjects were sent a questionnaire that asked about everyday memory failures. Some questions were taken from existing questionnaires (Broadbent et al., 1982; Reason, 1993) while others were newly created. The questionnaire consisted of 38 questions that asked about situations that indicated some aspect of recollection. For example, subjects were asked "how often do you repeatedly tell the same story to the same group of people", and "how often do you forget whether you took your medicine or turned off a light" (see Appendix 1 for questionnaire). Subjects had to rate the frequency of their memory errors on a 5-point scale, where "1" represented "almost never" and "5" signified "almost always". The scores for each question were then summed together to produce an overall everyday memory score, and that score was divided by the highest possible score (5 x 38 = 190) to produce a proportional value. Janine Hay and I tested the reliability of this questionnaire by mailing it to a number of subjects who had participated in previous experiments in the lab, having them complete it on two occasions separated by one month. Thirty-three subjects returned the questionnaire to us both times. The test-retest reliability of the questionnaire proved to be .85. The internal consistency or reliability of the questions themselves was .88, which suggests that the questions were measuring the same process (i.e., recollection).

This questionnaire was mailed to all the subjects who participated in Experiment 6. For each subject who returned the questionnaire, their overall memory score on the questionnaire was calculated and then correlated with three measures from the previous experiment. Their score was correlated with their overall recognition performance as indexed by d', and their familiarity and recollection estimates.

Results and Discussion

The average recognition score as measured by d-prime was 1.75, the average recollection score was .42, the average familiarity estimate was .46, and the average proportional score on the memory questionnaire was .45.

The correlation between the questionnaire and overall recognition performance as indexed by d' was -.33, (p = .09). This value is negative because a high score on the memory questionnaire indicates poor everyday memory - as the questionnaire score increases, it means memory performance is declining. This value of .33 is similar to the range of correlations found in other questionnaire studies. The correlation between the questionnaire and recollection, however, was much higher ($r = -.56$, $p = .001$) than has usually been found. In contrast, the correlation with familiarity was non-existent ($r = .08$, $p = .68$).

These results suggest that it is possible to find a relationship between everyday memory questionnaires and lab performance when one specifically examines the relationship between recollection and everyday memory complaints. The correlation between the questionnaire data and recollection was much higher than typical, and was much higher than that obtained when looking at recognition, supporting the predictions made earlier. Therefore, prior findings of low correlations between memory complaints measured by questionnaires and lab performance may not stem entirely from poor ecological validity, forgotten memory failures, or reduced feelings of self-efficacy. Instead, low correlations can occur because the lab tasks consist of both consciously-controlled and automatic influences. Given that recollection alone correlates with everyday memory complaints and familiarity was uncorrelated, failing to examine the effects of recollection separately from automatic influences will weaken the latter relationship. In summary, attempts to measure recollection in the lab appear to correspond to performance in real life.

Chapter 6

General Discussion of Results

The experiments described here were designed to examine the effects of aging on memory retrieval. Following the assumption that retrieval is dependent on two types of processing, automatic and consciously-controlled, seven experiments were designed to determine whether one or both processes were impaired by age. As discussed, previous research has attempted to address this question by comparing performance on indirect versus direct memory tests yielding inconclusive results. Although direct tests consistently show age differences, indirect tests produce mixed data, sometimes revealing deficits and, in other cases, demonstrating intact performance. However, it is not clear whether indirect tests are measuring only automatic processes or if consciously-controlled processes are contaminating performance. In order to avoid the problem of contamination, I chose to use the process dissociation procedure to separately examine the effects of age on each process.

Effects of Aging on Automatic and Conscious Memory

The results of all the experiments described here concur in showing that aging produces a substantial decrement in the probability of consciously-controlled memory processing but leaves invariant the use of automatic memory as a basis for judgments. The lack of an age effect on familiarity-based responding is consistent with the results of indirect tests that reveal non-significant age differences in performance (Howard, 1983; Howard, 1988; Light & Albertson, 1989; Light & Singh, 1987; Light, Singh, & Capps, 1986; Mitchell, 1989). Moreover, the findings obtained here suggest that discrepant results on indirect tests, which reveal age deficits (Chiarello & Hoyer, 1988; Davis et al., 1990; Howard, Shaw, & Heisy, 1986; Rose et al., 1986), arise from contamination by conscious memory. It is this process that is responsible for age effects. In short, tests cannot be considered process pure, and determining the impact of age on a specific process by relying on a single test may not produce valid results.

Concluding that aging spares automatic memory but produces a deficit in consciously-controlled processes is in agreement with arguments made by Hasher and Zacks (1979). However, by use of the process dissociation procedure the terms "consciously-controlled" and "automatic" have been somewhat re-defined. Jacoby, Ste-Marie, and Toth (1993) argue that traditional definitions of automaticity are based on the assumption that tests are process pure, just as has been the interpretation of performance on indirect memory tests. For example, Hasher and Zacks (1979) argued that if memory for a particular attribute of an event, such as frequency of occurrence, is uninfluenced by instructions to remember, then processing of that attribute can be considered automatic. The interpretation of memory effects that are "uninfluenced by instructions to remember" suffers similar problems as interpretations of performance on an indirect test (cf., Begg, Maxwell, Mitterer & Harris, 1986). That is, it is not certain that conscious processes are not contaminating performance. Instead, the process dissociation procedure defines automaticity in relation to a measure of consciously-controlled processing. If a person is as likely to engage in a given act when trying not to (i.e., exclusion condition) as when trying to (i.e., inclusion condition) then the person has no conscious control. Essentially, conscious control supports selective responding. This intuitively appealing definition of control serves as the foundation for measuring consciously-controlled processing. In contrast, automatic processes do not support selective responding, but, rather, produce the same effect regardless of one's intentions.

Interpretation of an Interference View of Aging

Defining automatic processing in the manner described above integrates different historical "phases" in theorizing about the memory deficit suffered by the aged. In the 1970s, it was commonly held that the elderly were less resistant to effects of interference than younger adults. During that period, experiments presenting multiple lists to examine age differences in retroactive and proactive interference were common (for a review, see Winocur, 1982). Fragment-completion tasks, now popular as indirect tests of memory, were originally used by Warrington and Weiskrantz to preclude interference and, thereby, show savings in the performance of amnesiacs (see Weiskrantz & Warrington, 1975, for a description of that early work). The shift from the presentation of multiple lists to the use of fragments as retrieval cues was a change from an interference paradigm, where automatic and consciously-controlled processes operated in opposition, to a facilitation paradigm, where the two processes acted in concert. Therefore, recent emphasis on preserved memory revealed by indirect tests is really "the other side of the coin" for the greater interference effects demonstrated by older subjects. In both cases, age-related performance is produced by a deficit in consciously-controlled processing in conjunction with intact automatic memory. In contrast, the process dissociation procedure combines a facilitation paradigm (inclusion test) with an interference paradigm (exclusion test) to separately examine effects on the two types of processing.

Implications for Recognition Memory

In worrying about the significance of drawing conclusions from a contaminated task, most researchers have focused on the problem with indirect tests. Few have considered the repercussions when interpreting direct test performance. However, the necessity of using the process dissociation procedure over a "process-pure" task to examine conscious memory is highlighted by the results of Experiment 6. It is obvious from that experiment that depending on a direct task to measure consciously-controlled processing can lead to inaccurate conclusions. The recognition data obtained in Experiment 6 reveal a non-significant age difference in performance. Evaluating that result as a measure of recollection could lead one to believe that consciously-controlled processing remains relatively intact with age on some tests. However, by removing the influence of automatic processing from the recognition test and measuring recollection alone, one finds a large (21%) difference in the ability to use conscious memory. Thus, a true-age related change in recollection was masked by the influence of familiarity.

This finding also sheds some light on discussions of recognition memory in older adults. Similar to indirect test performance, recognition tests produce diverse results with elderly subjects. Under some circumstances, there are small to non-existent age deficits in recognition (Craik & McDowd, 1987; Schonfield and Robertson, 1966; Rabinowitz, 1984). However, in other conditions performance is impaired (e.g., White & Cunningham, 1982; Light, Singh, & Capps, 1986; Light & Singh, 1987). Given that recognition is a function of both automatic and conscious processing, the extent to which conscious memory is enlisted on a particular recognition task could determine the pattern of results. Rabinowitz (1984) indicated that recognition tasks can consist of varying degrees of automatic and effortful processes, and that age deficits in recollection are due entirely to defective conscious processing. The latter part of his hypothesis was confirmed in my experiments. Further, it seems plausible that recognition tests where automatic processing is sufficient for performance will not show age differences, whereas tests where recollection is crucial will be affected.

Severity of Age-Related Changes in Recollection

Separately examining the effects of recollection and familiarity provided a clear picture of the negative impact of age on recollection in Experiment 6. Moreover, it provided a method for assessing that deficit with greater precision than has traditionally been the case. As shown in Experiments 3 through 5, asking subjects to recollect the second occurrence of an item in the test list (catch words) and varying the interval between the item's first and second presentation revealed a marked decrease in recollection. In fact, age-related declines in conscious memory proved to be surprisingly pronounced. Older adults revealed significantly worse recollection than young adults when only *three* items had intervened between the first and second presentation of a catch word, a time interval of less than 10 seconds! Moreover, performance continued to decline as the lag intervals increased. In contrast, automatic influences were unaffected by both age and delay.

The pattern of dissociations found here with the lag paradigm has also been obtained with a group of moderate to severe closed-head injured patients using a similar technique. They, too, show deficits in recollection but preserved automatic processing (Ste-Marie, Jennings, & Finlayson, in press). More importantly, their level of recollection is identical to that found with older adults. The brain-injured patients show the same probability of using recollection when three items have intervened between presentation and test. Finding that head trauma produces an equivalent degree of impairment as aging makes the decline in recollection seen in Experiments 3 to 5 even more remarkable. Further, it suggests that the lag paradigm is a sensitive index of memory deficits, which can produce consistent results across a variety of populations. This technique may have the potential to be adapted and utilized as a diagnostic memory tool, a point that will be discussed further below.

Awareness of Memory Processing in Older Adults

Despite the elderly's pronounced deficit in recollection, they demonstrated relatively accurate metamemory. Older adults appeared quite capable of identifying when recognition was based on familiarity or recollection. In Experiment 6, young and elderly subjects were asked to respond "remember" when they were relying on recollection and "know" when they were responding due to familiarity. Calculating the probability of recollection and familiarity from their reports showed the same pattern of performance as Experiments 1, 2, and 5. Recollection showed a decline with increasing age but familiarity remained constant. In short, older adults' subjective responding matched their objective performance, suggesting they were aware of their memory processing.

The profile of results found with self-report indicates a degree of correspondence between objective and subjective memory measures for both young and elderly adults. However, evidence to support the similarity between objective and subjective measures would be more compelling if both procedures yielded identical values when compared across the same subjects for a common task. Jacoby and Hay (1993) investigated this possibility. They asked young and elderly subjects to complete word fragments with items seen in a preceding study list under facilitation and opposition conditions, and to respond "recall" if they could recollect that their response came from study. A "recall" response resembles the "remember" response from Experiment 6. The probability of saying "recall" served as a subjective measure of conscious memory that was compared to an estimate of recollection calculated from fragment completion performance.

Jacoby and Hay (1993) found that comparing subjective and objective measures of recollection produced nearly equivalent results for both the young (.44 versus .44) and the older adults (.24 versus .29). In addition, these estimates were significantly correlated for both groups, with coefficients of .71 and .81 for young and old, respectively. Clearly, the agreement between subjective and objective measures of memory did not differ with age. Both young and elderly subjects were accurate in their ability to determine when they were recollecting.

The results of Experiment 6 and Jacoby and Hay's (1993) data support studies of aging and metamemory that suggest elderly adults are comparable to young subjects in assessing memory accuracy at retrieval (e.g., see Lovelace, 1990 for review; Lovelace & Marsh, 1985; Perlmutter, 1978). If young and older adults are aware they are recollecting information, then they should be capable of realizing that their memory is accurate. Similarly, if they are conscious that information only feels familiar then they will likely be cautious about believing their memory's veracity. Since there appears to be no age difference in awareness of memory processing, it is not surprising that there is no deficit in evaluating the accuracy of one's memory.

Everyday Memory Failures in the Elderly

Older adults' awareness of their memory performance seems to extend to their daily lives. Their self-reports of everyday memory failures corresponded closely to lab estimates of recollection based on subjective report (Experiment 7). When older adults were asked to indicate the frequency of everyday memory failures, such as forgetting where they learned a piece of information, their results correlated highly with self-reported recollection measured in Experiment 6. Despite other findings that suggest lab performance is not predictive of everyday functioning (Cohen, 1993; Herrmann, 1982; Herrmann, 1990; Little, Williams, & Long, 1986), Experiment 7 shows that specific lab tests of recollection can correlate with questionnaire responding. However, these questionnaire results were compared with a subjective measure of recollection when most studies that have failed to find significant correlations have relied on objective lab tasks. Although it seems likely that the high correlations found in Experiment 7 occur because recollection was measured separately from familiarity, it is possible that the use of self-report for both questionnaire and lab task played some role. One important follow-up to Experiment 7 would be to take an objective lab measure of recollection, which does not utilize self-report, and determine its association with questionnaire data.

Future Directions for the Process Dissociation Procedure

The process dissociation procedure provided an invaluable technique for investigating age-related changes in memory performance. Its use allowed me to demonstrate that aging impairs consciously-controlled processing but spares automatic processing, that age deficits in conscious memory are severe, that older adults are aware of their memory processes and that performance in everyday life can be predicted from lab measures of recollection. Being able to separately examine different processes within the same task provided a means for resolving two long-standing puzzles in the cognitive-aging literature, namely whether aging affects automatic memory and why cognitive questionnaires do not correspond to lab performance. However, the procedure also has great promise for practical applications that are vital for those with memory deficits. The process dissociation procedure can easily be refined to produce a diagnostic memory tool, and offers new directions for the development of memory remediation programs.

Diagnosis of Memory Deficits

One of the principal objectives of neuropsychological assessment is the evaluation of memory performance. Yet, an examination of reviews on clinical memory testing (e.g., Erickson & Scott, 1977; Loring & Papinacolaou, 1987) reveals that memory tests are weakly grounded in cognitive theory. In particular, the theory that multiple processes are involved in memory decisions (e.g. Atkinson & Juola, 1974; Jacoby, 1991; Mandler, 1980) has yet to be integrated into the assessment battery. As seen with Experiment 6, this omission calls into question conclusions drawn about a person's recollective abilities because the estimates of memory gained by typical neuropsychological tests do not distinguish recollection from familiarity. The process dissociation procedure, however, could be adapted to produce standardized tests that diagnose deficits in consciously-controlled memory while taking automatic processes into account.

Specifically, the recognition-lag task used in Experiments 3 to 5 can be modified for memory assessment. By gradually increasing or decreasing the lag intervals between the first and second presentation of a catch item, a person's level of recollection can be evaluated on an individual basis. For example, deficits in recollection after only one or two intervening items, or performance levels below the mean (i.e., greater than 25% errors) at longer intervals, may act as warning signals for dementia in older adults or memory impairment in closed-head injured patients. In addition, including the Lag 0 condition provides a means of verifying that subjects understand the task instructions and are able to perform accordingly. This check is important because one wants to ensure that any deficits in clinical performance are due to memory processes rather than other cognitive problems.

Memory Rehabilitation in Older Adults

Diagnosing memory deficits in older adults, demented patients and the head-injured meets only one practical need. Having some means of treating those problems is also essential. The process dissociation procedure has the potential to act as a unique memory training technique. Typically, efforts to improve memory in the aged have focused on elaborate encoding schemes (for review see Kotler-Cope & Camp, 1990), such as pegword mnemonics (Wood & Pratt, 1987) and method of loci (Kliegl, Smith & Baltes, 1989; Robertson-Tchabo, Hausman, & Arenberg, 1976). Although some improvement has been demonstrated, these effects are usually task specific and short-lived (Scogin & Bienias, 1988; Wood & Pratt, 1987). More recently, rehabilitation has focused on training automatic retrieval processes. The spaced retrieval technique (Camp & Schaller, 1989; Landauer & Bjork, 1978; Schacter, Rich & Stampp, 1985) and method of vanishing cues (Schacter & Glisky, 1986) are designed to create habits or automatic responses through repeated rehearsal, allowing memory disordered subjects to acquire a limited amount of new information. Unfortunately, these techniques are open to error. If the strongest automatic response that comes to mind during training is erroneous, then the wrong habit may be strengthened (Baddeley & Wilson, 1994). One means for avoiding this drawback involves training consciously-controlled uses of memory.

Training recollection may be possible with memory impaired individuals who retain some conscious processing, such as the elderly and patients with mild to moderate memory deficits. In all the experiments described above, elderly adults showed some degree of spared recollective processing. It may be possible to train that ability by placing the elderly in a situation where recollection is easy, then gradually increasing the difficulty to shape recollective processing. Slowly moving the elderly from a situation where they can perform competently may allow them to adapt their recollective process to more demanding situations.

Preliminary research exploring this idea has been carried out (Jennings & Jacoby, 1993). Seven elderly subjects received four training sessions a day for seven days. For each session, subjects studied 30 words, followed by a training phase where they were shown the 30 study words, 30 new words, and those new words were repeated at one of two lags. Using the exclusion instructions described for Experiments 3 to 5, subjects were given positive feedback whenever they responded correctly. The shaping procedure was implemented by gradually increasing the lag intervals. In Session 1, words were repeated after one or two intervening items. If subjects performed to criterion (the level of performance shown by young adults), then in Session 2, the lag conditions increased to one and three items, then two and four, and so on to eight and forty. Thus, subjects were always working at one easy lag interval, and one that was new and more difficult. If subjects did not achieve criterion at both lags, they continued at those intervals till criterion was met. Improvements were gauged by comparing the length of the interval where subjects reached criterion on the first and last training day.

Results suggested a significant improvement in recollection. On the first day of training, subjects could only perform to criterion when one item intervened between the first and second presentation of a new word. However, after training, these subjects performed to criterion with 28 intervening items. In addition, the effects of training appear to last at least three months (Jennings & Jacoby, 1993). Although this line of training research still requires a substantial amount of work, these early results encourage the notion that conscious memory can be rehabilitated in older adults.

Conclusions

In conclusion, I have adopted a new approach for examining memory processing in older adults. This approach goes beyond the "process-pure" assumption underlying the interpretation of dissociations between indirect and direct tests because one does not need to equate processes with tasks. Instead, automatic and consciously-controlled processes are recognized as combining independently to determine performance, and the contributions of each process are measured with the process dissociation procedure. Doing so, shows that consciously-controlled memory processes are affected by aging, and that these deficits can arise when only a small number of intervening items occur between presentation and test. In contrast, automatic uses of memory are spared. These findings help support the theoretical assumption that automatic and consciously-controlled memory processes act independently (see Jacoby et al., in press) and, thus, the validity of the process dissociation procedure itself. However, the real value of the technique lies in its practical applications, providing a measure that is predictive of performance in everyday life, and offering the promise of a new approach for memory diagnosis and rehabilitation.

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Appendix A

Memory Questionnaire

The following questions are about minor mistakes which everyone makes from time to time, but some of which happen more often than others. We want to know how often these things have happened to you in the last 6 months. Please indicate by entering the number that corresponds to your response (see below). Answer as honestly as possible.

5 - almost always, 4 - quite often, 3 - sometimes, 2 - hardly ever, 1 - almost never

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1) How often do you have the feeling you should be doing something, either now or later, but you can't remember what it is?

2) How often do you forget phone numbers that you use frequently?

3) When someone says that he/she has told you something already, how often do you find that you have no recollection of his/her telling you?

4) If you go to the store to buy a few things (without a list), how often do you remember all of them?

5) How often do you discover when you have just gone out that you must return for something you had intended to bring but accidentally left behind?

6) Suppose that someone has given you directions to get to some unfamiliar place, and you are unable to write them down. How often would your remember the directions?

7) How often do you forget that you have just done something, and start to do it over again (e.g., go to set your alarm clock and find that you had already done so) ?

8) Think of times when you have wanted to tell a friend about a conversation that you had. How often do you find that you have forgotten part of what you wanted to tell?

9) When you need to know what the date is, how often do you find you remember it without needing to look it up or ask someone?

10) How often do you forget whether you've turned off a light, locked a door, or taken necessary medication?

11) How often do you forget personal information, such as your phone number or street address?

12) When you see someone you know casually, how often do you have difficulty remembering their name?

13) How often do you forget where you read or heard about a particular piece of information (e.g., news event)?

14) After leaving your parked car for a few hours, how often do you remember where you left it?

15) How often do you find yourself carrying out some unnecessary action (e.g., clicking on the light when you're leaving the room in daylight)?

16) When you put something away and then look for it a day or two later, how often do you remember where you put it?

17) How often do you find you can't quite remember something although it's on the tip of your tongue?

18) How often when you are out, do you forget how to get home?

19) When you want to remember an experience, or a story, how often do you find you cannot do so?

20) How often do you remember appointments when or if you don't write them down?

21) How often do you leave some necessary step out of a task (e.g., forgetting to put tea in the teapot)?

22) How often do you find yourself needing directions when returning to some place you have only been to once (several months before)?

23) How often do you forget to take necessary medication?

24) When someone asks you to pass on a message, how often do you remember to do so?

25) How often are you unable to find something that you put down only a few moments before?

26) How often do you remember important dates like birthdays or anniversaries (other than your own)?

27) When meeting many new people at a social gathering, how often can you remember all their names?

28) How often do you find you cannot immediately recall the name of a familiar person, place or object?

29) How often do you forget to turn something off, such as a light or the stove?

30) How often do you find at the end of a conversation that you forget to bring up something that you intended to mention?

31) When you go out to run a few errands (and don't have them written down), how often do you forget to do at least one of them?

32) How often do you forget why you went from one part of the house to the other?

33) When you hear a phone number for the first time and do not write it down, how often can you remember it an hour later?

34) Think of the times when you have ru.. into someone who you haven't seen in awhile. How often do you find, although they may seem familiar, that you can't remember where you met him/her before?

35) How often do you start to tell someone something (e.g., a story) only to discover that you have told that item to the same person before?

36) How often do you remember to pay your bills on time?

37) How often do you forget to do something you were going to do after dealing with an unexpectea interruption?

38) How often do you remember where you left your keys?

39) How often do you find you have forgotten to do something you intended to do?

40) How often do you see members of your immediate family and are not able to recognize them?

41) After your first reading of a poem, song, or another piece of literature, how often are you able to remember most of the lines?