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5 Age-related Deficits in Memory: Theory and Application

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Over the last few years there has been a proliferation of demonstrations that memory can affect performance in the absence of awareness of the past. Even amnesiacs who, by definition, cannot remember an earlier presentation of a word when given a test of recognition memory or recall (direct tests), show evidence of memory by using a word more often as a completion for a word stem or word fragment (indirect tests) than they would had the word not been presented earlier (for a review, see Moscovitch, Vriezen, & Gottstein, 1993). Dissociations between performance on these two types of test are also shown by people with normal memory functioning (e.g. Roediger & McDermott, 1993).

Findings of dissociations are important for applied purposes as well as for theorising about memory. Much of our recent research has been aimed at investigating age-related deficits in memory. We believe the distinction between automatic and consciously controlled influences of memory is important for understanding memory dissociations and is critical to the assessment and treatment of memory deficits. Failure to distinguish between these different bases of responding can create interpretation difficulties because there is evidence that elderly adults possess preserved automatic influences of memory in the presence of significant recollection deficits (see Jacoby, Jennings, & Hay, 1996). Our goals have been to devise better methods for diagnosing such deficits along with treatment programmes to remedy or diminish age-related differences.

Automatic processing has been described as a fast, unaware process that is under the control of stimuli rather than intention (e.g. Hasher & Zacks, 1979; Posner & Snyder, 1975; Schneider & Shiffrin, 1977) whereas consciously controlled memory is aware and intentional (Jacoby, 1991; Klatzky, 1984; Logan, 1989). Indirect tests might be more reliant on automatic forms of processing than are direct tests of memory. However, equating tasks with underlying processes as done by the direct/indirect test distinction can be problematic because consciously controlled, intentional processes (recollection) might contaminate performance on indirect tests (Reingold & Merikle, 1990; Toth, Reingold, & Jacoby, 1994) and, less obviously, automatic influences (familiarity) might contaminate performance on direct tests (Jacoby, Toth, & Yonelinas, 1993). More important, the indirect/direct test distinction does not provide a means of measuring the separate contributions of automatic and consciously controlled processing when the two types of processing both contribute to performance.

There is a growing consensus that it is important to separate the contributions of processes within a task; however, there is still disagreement about how this should be done. As will be described later, our process-dissociation procedure is based on the assumption that automatic and consciously controlled processes serve as *independent* bases for responding. In contrast, Gardiner and his colleagues (Gardiner, 1988; Gardiner & Java, 1991; Gardiner & Parkin, 1990) have used a Remember/Know procedure to reveal differences in the phenomenology that accompanies memory use, and have been critical of our independence assumption, as others have been (e.g. Curran & Hintzman, 1995; Joordens & Merikle, 1993). Later, we address the question of independence of processes along with the relation between the Remember/Know and process-dissociation procedures. We emphasise similarities between results from the two procedures because convergence in results is mutually supportive of the validity of the procedures.

There is good reason to search for support. Both the Remember/Know and process-dissociation procedures have been controversial and some critics have questioned the utility of postulating a dual-process model of memory. We begin by describing experiments that placed automatic and consciously controlled processing in opposition so as to reveal deficits in recollection in combination with preserved automatic influences of memory. The "opposition" procedures used in those experiments provide results that show the necessity of distinguishing between different uses of memory and highlight the importance of doing so for purposes of diagnosis and treatment of memory disorders.

PROCESSES IN OPPOSITION: IRONIC EFFECTS OF MEMORY

Our "false fame" experiments (Jacoby, Kelley, Brown, & Jasechko, 1989; Jacoby, Woloshyn, & Kelley, 1989) illustrate the use of opposition procedures to infer recollection deficits through the errors that people commit. In these experiments, automatic influences of memory (familiarity) were placed in opposition to recollection. Participants read a list of nonfamous names followed by a fame-judgement test consisting of old nonfamous names mixed with new famous and new nonfamous names. At test, participants were instructed to identify famous names and were told if they could remember a name from the earlier presentation list, then they could be certain that the name was nonfamous. However, the prior presentation of nonfamous names increased their familiarity, making it more likely that the nonfamous names would later be mistakenly identified as being famous. If participants could recollect reading the name earlier in the experimental setting, then any automatic influence of familiarity would be opposed, allowing them to be certain that the name was nonfamous.

A goal of our false fame experiments was to find manipulations that reduce the probability of recollection and, thereby, leave automatic influences of memory unopposed. For example, results revealed a "false fame" effect after nonfamous names were read under conditions of divided attention by showing that old nonfamous names were *more* likely to be mistakenly called famous than were new nonfamous names. In contrast, when participants gave full attention to the reading of nonfamous names, the results were the opposite—old nonfamous names were *less* likely to be called famous than were new nonfamous names. After full attention to reading nonfamous names, participants were able to escape misleading effects of automatic influences of memory by recollecting the earlier reading of the names. However, when recollection was reduced by dividing attention at study or test, or by extending the retention interval, then the false fame effect was observed.

Because of a deficit in their ability to recollect, those suffering a memory impairment might show a false fame effect even after full attention to reading names. Indeed, elderly adults do show a pronounced false fame effect (Bartlett, Strater, & Fulton, 1991; Dywan & Jacoby, 1990; Jennings & Jacoby, 1993), as do amnesiacs (Cermak, Verfaellie, Butler, & Jacoby, 1993; Squire & McKee, 1992) and patients who have sustained a closed-head injury (Dywan, Segalowitz, Henderson, & Jacoby, 1993). We have made use of such misleading effects of automatic influences of memory to diagnose age-related deficits in recollection.

We refer to the false fame effect and to other misleading effects of repetition as "ironic effects" to highlight their similarity to the ironic effects described by Wegner (1994). Wegner has shown that attempts to avoid mental states can have the ironic effect of increasing the probability of their occurrence. In all these cases, the result is a strengthened automatic influence which can produce an outcome opposite to that which is desired if left unopposed by cognitive control.

Two Effects of Repetition

A friend whose mother is suffering symptoms of Alzheimer's disease tells the story of taking her mother to visit a nursing home, preliminary to her mother moving there. During an orientation meeting at the nursing home, the rules and regulations were explained, one of which regarded the dining room. The dining room was described as similar to a fine restaurant, except that tipping was not required. The absence of tipping was a central theme in the orientation lecture, mentioned frequently to emphasise the quality of care along with the advantages of having paid in advance. At the end of the meeting, the friend's mother was asked whether she had any questions. She replied that she only had one question: "Should I tip?"

Similar to that unwanted effect of repetition, repeated asking of questions is one of the most striking and frustrating symptoms of Alzheimer's disease (AD). Earlier asking of a question seems to "strengthen" and increase the probability of later asking the same question for the AD patient, whereas those with normally functioning memory would not repeat the question because of the ability to recollect asking it earlier, as well as the ability to recollect the answer. Repetition may well have two effects, serving both to increase the strength of questioning, an automatic influence, and to increase the probability of recollecting the earlier asking. Because of a deficit in recollection, the AD patient is left only with the increase in strength and so repeatedly asks the same question. The result is similar to the false fame effect in showing automatic influences of memory that are unopposed by recollection.

An opposition procedure was used to examine age-related differences in memory and to show that repetition does have two effects (Jacoby, submitted). Elderly participants were community-dwelling and aged 60 years and older, whereas young participants were volunteers from an Introductory Psychology course. Young and elderly adults read a list of words, with each word being read either one, two, or three times. Next, they listened to a list of words that they were told to remember for a later test. At test, participants were instructed to identify words that they had *heard* and were warned that the test list would also include words that they had read. They were further told that the earlier-read words were to be excluded because none of those words was in the list of words that they heard. Repeatedly reading a word was expected to increase its familiarity and consequently, participants might misattribute the word's familiarity to its having been heard. However, recollection of having read the word should oppose its familiarity, allowing the word to be correctly excluded, similar to the logic used in the fame experiments.

Due to their deficits in recollection, the performance of elderly participants revealed the strengthening effect of repetition. For elderly participants, repeatedly reading a word *increased* the probability of mistakenly accepting that word as one that had been heard (Table 5.1). The strengthening effect of repetition, unopposed by recollection, is the same as that responsible for AD patients' repeated asking of questions. Younger participants, in contrast, were better able to use recollection to oppose familiarity. For younger participants, repeatedly reading a word made it more likely that they would later recollect that the word had been read, allowing them to be certain it had not been heard. For them, repeated reading of a word *decreased* the probability of mistakenly accepting the word as one that had been heard.

However, under some conditions, young participants produced a pattern of results that was the same as that produced by the elderly participants. When forced to respond rapidly, young participants showed that repeatedly reading a word made it more likely that the word would later be mistakenly accepted as having been heard (Table 5.1). In the rapid responding condition, a test word was exposed for 750ms and participants were required to respond during that interval. In contrast, for the condition that required slower responding, a word was exposed for 1250ms before participants were allowed to respond and then they too were required to respond within a 750ms interval. Just as in the fame experiments, we found that dividing attention while presenting the words to be read also led to a lower probability of later recollection, and produced the pattern for young participants whereby repeatedly reading a word made it more likely that the word was later misclassified as earlier-heard.

The effect of shortening the response deadline for younger participants suggests that the problem for elderly participants may have been that they simply did not have enough time to engage in recollection. The use of recollection is generally slower and more effortful than the use of familiarity to make decisions. As suggested by general slowing hypotheses (e.g Salthouse, 1994), elderly participants might require more processing time than younger participants. However, allowing elderly participants a greater amount of time to respond was not sufficient to eliminate the ironic effect of repetition. Elderly participants given extra time were told to respond "as soon as possible" rather than being required to respond within the 750ms response interval. Even when allowed

TABLE 5.1
Probability of Accepting Items as Heard

	False Alarms				*Hits*
	Repetitions				
Condition	*1×*	*2×*	*3×*	*New*	*Heard*
Young–Long (1250/750)	.32	.28	.20	.18	.56
Young–Short (750)	.24	.35	.38	.16	.37
Elderly–Long (1250/750)	.27	.34	.38	.13	.35
Elderly–Extra long (1250/ASAP)	.35	.42	.44	.14	.52

more time, repeated reading of a word still increased the probability of its being mistakenly categorised as a heard word. From these results, we suggest the ironic repetition effect found for the elderly reflects an age-related deficit in recollection rather than a general slowing of processes.

The retention test in these experiments incorporated a standard test of recognition memory by including words that were earlier-heard to which participants should respond "yes". Also included in the test list were new words to which participants should respond "no". Performance on new test words can be used to detect any difference between young and elderly participants in the criterion used for responding "yes". Increasing the amount of time allowed for responding resulted in elderly participants correctly accepting words that were earlier-heard with a probability that was nearly the same as that for younger participants who were required to respond at a somewhat faster rate. The probability of false recognition of new words was slightly less for elderly than for younger participants. Thus, as measured by this standard test of recognition memory, performance of the elderly participants who were given extra time to respond did not differ from that of the younger participants.

The opposition procedure, implemented by having participants respond "no" to earlier-read words if they could recollect having read them, was a more sensitive measure of age-related differences in memory than was the standard test of recognition memory just described. Tests of recognition memory sometimes show nonsignificant age differences in performance (e.g. Craik & McDowd, 1987; Dywan & Jacoby, 1990; Rabinowitz, 1984). In our study, allowing elderly participants more time to respond eliminated age differences on the standard test of recognition; however, the elderly still made many more errors on words that were earlier-read than did younger participants. Why was the opposition procedure a more sensitive measure of memory deficits? In the opposition paradigm, familiarity leads to errors. In contrast, familiarity is a basis for correct responding on standard tests of recognition memory, producing effects that are the same as those produced by recollection (e.g. Jacoby & Dallas, 1981; Mandler, 1980). Consequently, for recognition-memory performance, correct responding due to familiarity may mask a deficit in recollection (e.g. Jacoby et al., 1993). By placing automatic and consciously controlled processes in opposition, errors in performance allow us to examine age-related declines in recollection that cannot be offset by relying on familiarity.

Jennings and Jacoby (1997) investigated age-related declines in memory by using an opposition procedure meant to mimic the repeated telling of a story. Repeatedly telling a story to the same audience can be a sign of automatic influences of memory that are not successfully opposed by recollection. Unwanted repetition provides clear evidence of a failure in recollection and so can be used to measure severity of memory deficits. For example, one would be much more concerned if an elderly relative repeated a story immediately after telling it than if he or she repeated it a week later. Results of experiments by

Jennings and Jacoby showed that elderly participants were likely to make an error akin to the repeated telling of a story after a much shorter delay than were younger participants. As in the experiment just described, the opposition procedure used by Jennings and Jacoby provided a more sensitive measure of age-related decline in memory than did a standard test of recognition memory. Such findings again highlight the utility of an opposition procedure as an effective diagnostic tool.

Two Effects of Context: Environmental Support

Reinstating study context can also produce an ironic effect of memory. Note that in the "tipping" example, the question about tipping was asked in the same context and of the same person who had earlier said that tipping was not allowed. The error is striking because one might expect the context and person to provide very powerful cues for recollection. However, reinstating context has two effects just as does repetition: it produces automatic influences of memory and it enhances recollection.

In an experiment similar to the one described earlier, words were read at study paired with context words. Re-presenting the context words at test increased the probability of the word mistakenly being accepted as having been heard compared to when the context word was not presented. This result emerged for both elderly participants and young participants forced to respond rapidly. When given more time to respond, young participants showed an opposite effect of reinstating context: the context word increased the likelihood that they could recollect the earlier-read words, and therefore allowed them to reject read words as heard words. Manipulating full versus divided attention during study along with reinstatement of associative context produces a similar pattern of results in cued-recall performance. Reinstating associative context *decreases* the probability of excluding read words after divided attention during study but has the opposite effect after full attention during study (Jacoby, 1994, 1996).

The finding of two effects of reinstating context is important for the possibility of using environmental support to remediate age-related differences in memory. Craik (1983, 1986) proposed an environmental support hypothesis to account for variations across situations in the magnitude of age-related differences in memory performance. He suggested that age-related differences are partially due to deficiencies in self-initiated processing that can be compensated for by increasing environmental support at the time of test. Reinstating associative context is an example of providing environmental support. The prediction is that age-related differences in memory performance should decrease as the amount of environmental support is increased. Craik and Jennings (1992) reviewed the relevant literature and concluded that the results of some experiments agree with the environmental support hypothesis, whereas results of other studies conflict with the hypothesis by showing that age-related differences are constant across different levels of environmental support or even larger when the amount of environmental support is increased. Such mixed results are understandable if providing environmental support has separate effects on recollection and automatic influences of memory. The aged may suffer a deficit in self-initiated processing and, consequently, show smaller effects of environmental support (e.g. associative context) on recollection. That deficit in recollection leaves the elderly open to ironic effects of memory produced by the automatic influences of increasing environmental support.

Age differences in repetition errors observed using opposition procedures are closely related to deficits in source or context memory (for reviews, see Johnson, Lindsay, & Hashtroudi, 1993; Spencer & Raz, 1995). However, opposition paradigms differ in an important way from the form of tests traditionally used to measure memory for source. Standard tests of source memory explicitly instruct participants to report the source of information, rather than examine the monitoring of source as part of some ongoing task as done by opposition paradigms. To appreciate the difference, consider the discrepancy between the task of avoiding repeatedly telling a story while engaging in conversation and the task of listing all the people to whom one has told the story. This difference and its importance is illustrated by results from a fame study by Multhaup (1995).

Multhaup did not find a "false fame" effect with older adults when participants were explicitly asked to specify whether a test name was one they had read earlier, one that was actually famous, or one that was new. Increasing the structure or support of a task by directly asking participants about source benefits older adults' performance by allowing them to avoid errors produced by automatic influences of memory. However, increased structure also limits the role of self-initiated processing. An inability to monitor in unstructured situations may be a critical aspect of memory problems experienced by older adults. Suggestions that age-related differences in memory performance reflect a decline in frontal-lobe functioning (e.g. Parkin, in press; West, 1996) are consistent with this possibility.

Remembering, Knowing, and Excluding

The experiments just described used opposition procedures to show errors produced by automatic influences of memory unaccompanied by recollection. Familiarity without recollection is also central to the Remember/Know procedure. That procedure, introduced by Tulving (1985), asks participants to report on the subjective experience of memory. As an example, after judging a word on a test of recognition memory as being "old", participants are required to report whether they "remember" or only "know" that the word was studied earlier. A "remember" response is to be made only when participants are able to recollect the details of the study presentation of a word, such as its appearance or associations that came to mind during its presentation. Participants are to say

"know" if the word is so familiar that they are certain the word was studied but they are unable to recollect any details of its prior presentation.

Gardiner and his associates (e.g. Gardiner, 1988; Gardiner & Java, 1991; Gardiner & Parkin, 1990) as well as others (e.g. Conway & Dewhurst, 1995; Rajaram, 1993) have shown that a number of variables produce dissociations between "remember" and "know" responses. Our opposition experiments described earlier demonstrated that elderly participants suffer a deficit in recollection, as do young participants responding under a deadline or under conditions of divided attention. Because "remember" responses necessitate recollecting specific information about an item, it is not surprising that parallel effects on the probability of a "remember" response have been found. That is, it has been demonstrated that elderly participants are less likely to "remember" a word they called old in a test of recognition memory or gave as a correct response in a test of cued recall than are younger participants (Mäntylä, 1993; Parkin & Walter, 1992). The correspondence in definitions and results using these different procedures encourages the identification of "remember" responses with recollection.

Although "remember" responses may closely map onto recollection, there are problems for identifying familiarity with the probability of a "know" response. Such problems arise because manipulations that would be expected to influence familiarity have been shown to leave "know" responses invariant. For example, repetition and factors such as similarity are usually treated as fundamental to familiarity yet Gardiner, Kaminska, Dixon, and Java (1996) found repetition of Polish melodies increased both "remember" and "know" responses, but repetition of obscure classical melodies increased only "remember" responses, leaving "know" responses unchanged. It seems counter-intuitive that the familiarity of obscure classical melodies is not influenced by repetition, especially when Polish melodies are affected by the same manipulation. These findings suggest that it may be very problematic to equate "know" responses with familiarity. We will now describe a refinement of the Remember/Know procedure in which we make very different assumptions about the nature of the underlying relationship between recollection and familiarity.

We examined the effects of repetition in an experiment using a procedure similar to that described in conjunction with the "tipping" example. Words were presented one, two, or three times for study and then intermixed with new words for a test of recognition memory. Participants were required to respond "remember" or "know" to recognised items. Results (see Table 5.2) showed that the probability of a "remember" response increased with number of repetitions but "know" responses were unchanged. The pattern of results is the same as found by Gardiner et al. (1996) for obscure classical melodies.

One could claim that common words are similar to obscure classical melodies in that neither becomes more familiar with repetition. However, interpretation of the results depends on the assumption adopted regarding the relationship

TABLE 5.2
Probability of Responding "Remember", "Know", and Estimates of Familiarity across Repetitions

	Repetitions		
Response	*1×*	*2×*	*3×*
"Remember"	.40	.52	.59
"Know"	.35	.36	.35
Familiarity	.58	.74	.83

Estimates of familiarity, based on an independence assumption, were computed as: "Know"/(1–"Remember")

between recollection and familiarity. If the two bases for responding are assumed to be independent, familiarity should be computed as the probability of a "know" response conditionalised on the opportunity for such a response. Specifically, familiarity should be calculated as the probability of a "know" response divided by 1 minus the probability of a "remember" response [familiarity = "know"/(1–"remember")]. As shown in the bottom row of Table 5.2, familiarity computed in this way increases with the number of repetitions, as does recollection, indexed by the probability of a "remember" response. In contrast, Gardiner and other investigators analyse the straight proportion of "know" responses as a measure of familiarity. That calculation implicitly assumes an exclusivity relation between the process that gives rise to instances of "remember' and the process that gives rise to instances of "know". If a variable powerfully increases the likelihood of "remembering", there is little opportunity for a person to express familiarity in the absence of remembering. Consequently, the probability of "knowing" is highly constrained by the probability of "remembering".

The conclusion that both familiarity and recollection increase with repetition is consistent with results of experiments that used the opposition procedure. In contrast, identifying familiarity with the probability of a "know" response, as done using the exclusivity assumption, would not allow one to explain the ironic effects described earlier. Yonelinas and Jacoby (1995) described other cases in which apparent anomalies are resolved by combining the Remember/Know procedure with the assumption that recollection and familiarity serve as independent bases for responding. For example, increasing visual similarity between a study and a test item increases familiarity as computed using the independence assumption but not when the straight proportion of "know" responses is analysed.

Donaldson and his colleagues (Donaldson, 1996; Donaldson, MacKenzie, & Underhill, 1996) have noted that dissociations between "remember" and "know" responses do not require that two processes be involved. They use signal-detection theory to show that apparent dissociations might simply reflect differences in criteria for responding applied to a single memory process—participants might use a higher criterion for "remember" responses than for "know" responses. In contrast, findings from the use of opposition procedures provide stronger evidence for dual processes. For example, repeatedly reading a word either increases or decreases the probability of the word later being mistakenly accepted as earlier-heard, depending on factors such as the age of participants and the required speed of responding. Results such as these are easily understood by distinguishing between recollection and familiarity, but it is not obvious how they can be explained by postulating a single process even if multiple criteria are allowed.

THE PROCESS-DISSOCIATION PROCEDURE

Results from experiments using opposition procedures are sufficient to show the necessity of adopting a dual-process model, and to reveal age-related deficits in recollection. However, the results do not allow one to measure the severity of such deficits. To produce what we call an exclusion error (i.e. accepting an earlier-read word as heard), automatic influences must be sufficiently strong to produce a response *and* recollection must fail. Suppose that elderly participants suffer diminished automatic influences of memory as well as a deficit in recollection. If this is the case, then the difference in exclusion performance between young and elderly would be diminished. Errors in exclusion performance would *underestimate* the difference in recollection because although elderly participants would more often be unable to recollect, they would also be less likely than young adults to make a familiarity-based error when recollection failed. To distinguish between these possibilities one needs some means of separating the contributions of automatic and consciously controlled uses of memory. We now describe the process-dissociation procedure which was designed to accomplish that goal and then discuss its relation to the Remember/Know procedure.

The process-dissociation procedure (Jacoby, 1991) defines conscious control as the difference in performance between conditions where one is trying to, versus trying not to, do something. In the exclusion procedure outlined earlier, one can try not to call a name famous when one can remember that it was presented in a list of nonfamous names. We can also arrange an inclusion test condition, where one tries to call a name famous when one can consciously recollect that it was on the study list (by telling participants that all the names were famous), or when it simply seems famous. If we assume that conscious recollection and the familiarity that can be misattributed to fame are independent, then calling an old item "famous" in the inclusion condition is either due to conscious recollection or familiarity, or both: Prob(famous) Inclusion =

Recollection + Familiarity, minus the overlap of the two processes, RF, or R + (1–R)F.

In the exclusion condition, an old name will be called famous if it fails to be recollected (1–R), but it nonetheless has gained sufficient familiarity (F) from prior study to pass the criterion the participant sets for the fame decision: Prob(famous) Exclusion = (1–R)F.

To obtain estimates of recollection, or R, one subtracts the probability of calling a name famous in the exclusion condition from the probability of calling a name famous in the inclusion condition. Once an estimate of R is obtained, the equations can be used to solve for an estimate of F.

If it is true that two processes make independent contributions to a particular task, then one should be able to find manipulations that affect one estimate derived with the process-dissociation procedure without affecting the other estimate. In the fame task as well as other procedures, elderly adults show decrements in the conscious component but the automatic component remains unchanged (Jennings & Jacoby, 1993, 1997).

The process-dissociation procedure has been used in a variety of memory paradigms to separate out processes that afford conscious control from those that do not. Such paradigms have included stem cued recall, word cued recall, and recognition (for a review, see Jacoby, Yonelinas, & Jennings, 1997.) In each of those cases, divided versus full attention at study disrupted the processing necessary for conscious recollection, but had no effect on the remaining component, the automatic influence. The minimal processing of reading the name or word aloud in these memory paradigms appears to be enough to produce an unconscious or automatic influence of memory. Similarly, a short deadline for retrieval reduces conscious recollection but does not affect the automatic memory component (Yonelinas & Jacoby, 1994). Other manipulations produce an opposite pattern of results. Training can have the effect of increasing automatic influences of memory in the form of habit while leaving recollection relatively invariant (Hay & Jacoby, 1996).

Experiments reported by Jacoby et al. (1993) illustrate use of the process-dissociation procedure to examine recall cued with word stems. Participants studied words under conditions of full or divided attention and then were tested with word stems. For an *inclusion test,* participants were told to use the stem as a cue to recall an old word or, if they could not do so, to complete the stem with the first word that came to mind. An inclusion test is similar to a standard test of cued recall with instructions to guess when recollection fails. Participants could complete a stem with an old word either because they recollected the old word, with a probability of R, or because the old word came automatically to mind, with a probability of A. If these two bases for responding are independent, then performance equals R + A – RA. For an *exclusion test*, participants were instructed to use the stem as a cue to recall an old word, but then they were told *not* to use recalled words to complete stems. That is, participants were instructed

to exclude old words and complete stems only with new words. Following these instructions, participants would mistakenly complete a stem with an old word only if the word came automatically to mind without recollection of its prior presentation: A(1–R) = A–RA. As in the fame example, the difference between inclusion and exclusion tests provides a measure of recollection that can then be used to compute an estimate of automatic influences. Computing estimates this way, Jacoby et al. (1993, Experiment lb) found that dividing attention significantly reduced estimates of recollection (.25 vs .00) but left automatic influences essentially invariant (.47 vs .46).

In addition to the independence assumption, the estimation procedure rests on the assumption that R is equal for the inclusion and exclusion tests and furthermore, it is assumed that A is equal for the two types of test. To assess automatic influences of memory, Jacoby et al. compared A (.46) to completion rates for stems corresponding to new words (.35) and found a significant difference. Base rates did not differ significantly across the inclusion and exclusion tests nor across the manipulation of full vs divided attention. These results provide support for the assumption that A was equivalent across types of test and conditions created by manipulating full vs divided attention at study.

Base-rate performance reflects guessing based on pre-experimental knowledge, which is a third basis for correct performance on a test of recall cued with word stems. Our estimation procedure (e.g. Jacoby et al., 1993) treats A as reflecting the sum of automatic influences of memory and guessing based on pre-experimental knowledge. Others have proposed alternative procedures that they favour for taking guessing into account (Roediger & McDermott, 1994). Buchner, Erdfelder, and Vaterrodt-Plünnecke (1995) proposed a multinomial model that treats guessing as independent of automatic influences of memory. Their model uses performance on new items to estimate the probability of correct responding on the basis of guessing. We have compared results produced by various procedures, and have described the advantages of using a model based on signal-detection theory for examining automatic influences of memory in recognition performance (Yonelinas & Jacoby, 1996; Yonelinas, Regehr, & Jacoby, 1995).

Controversy Surrounding Assumptions: Boundary Conditions

The most controversial assumption underlying the process-dissociation procedure is the assumption that recollection and automatic influences of memory serve as independent bases for responding. Our findings of process dissociations provide support for the independence assumption. However, some attempts to conceptually replicate our results have failed. Most prominent has been work by Curran and Hintzman (1995). We briefly describe their work and then consider boundary conditions for the independence assumption.

Curran and Hintzman (1995) examined recall performance cued with word stems, and found results that they interpret as invalidating the independence assumption underlying the process-dissociation procedure. They manipulated study duration and found what they term a "paradoxical dissociation" between R and A. More specifically, they showed that lengthening study time produced an increase in R but a decrease in A. The dissociation is paradoxical because experiments using stem completion as an indirect test of memory have shown that manipulating study time leaves stem-completion performance unchanged (e.g. Greene, 1986). Similarly, increasing study time would be expected to increase R and leave A relatively invariant—the same form of process dissociation produced by manipulating full vs divided attention during study.

Significant correlations between R and A were found by Curran and Hintzman and were interpreted as direct evidence against independence. Due to a violation of the independence assumption, A was said to be underestimated by an amount that increased with the magnitude of R, explaining the paradoxical dissociation produced by manipulating study time. However, as discussed in later papers (Curran & Hintzman, 1997; Hintzman & Curran, 1997; Jacoby, Begg, & Toth, 1997; Jacoby & Shrout, 1997), interpretation of correlations involves a number of complexities. We believe the correlations between R and A found by Curran and Hintzman do not speak to the independence assumption underlying the process-dissociation procedure.

One reason for the general reluctance to accept the independence assumption is because it seems likely that participants sometimes use a generate/recognise strategy to accomplish recall cued with word stems. Using that strategy, participants would first generate a completion for a stem and then output the generated word only if a recognition-memory check revealed that the generated completion word was earlier-studied (Jacoby & Hollingshead, 1990). The generation strategy might rely on an automatic process of memory, and the recognition check might rely on a mixture of recollection and familiarity. If such a strategy was employed, then the independence equations would not capture the processes involved, as Jacoby et al. (1993) noted. Indeed, we argue that the test instructions in Curran and Hintzman's (1995) experiments encouraged participants to engage in a generate/recognise strategy rather than rely on direct retrieval.

The possibility that participants sometimes use a generate/recognise strategy raises the general issue of participants' understanding of exclusion instructions. Critics of the process-dissociation procedure (e.g. Graf & Komatsu, 1994) have argued that participants fail to understand instructions for exclusion tests. A high probability of failure to exclude old words on an exclusion test might be interpreted as a failure to understand instructions, and it is results of this sort that have received most attention. However, the total absence of exclusion errors can also reflect a failure to understand instructions. The goal of our instructions is to satisfy assumptions underlying the process-dissociation procedure, and doing so

requires that participants exclude old words *only on the basis of recollection*. If participants exclude words based on familiarity, or by using a generate/ recognise strategy, assumptions underlying our equations are violated and estimates are invalid. We see these as important caveats for how to set up experiments using the process-dissociation procedure, rather than as a basis for rejecting the use of process dissociation as a tool. Studies that aim to estimate the processes people use in the generate/recognise strategy will require different techniques.

Next we show how paradoxical dissociations can be produced in experiments using a Remember/Know procedure. We then return to the inclusion/exclusion procedure and describe an experiment that shows a corresponding paradoxical dissociation produced by instructing participants to use a generate/recognise strategy.

Process Dissociation and Remember/Know

To link the process-dissociation procedure to the Remember/ Know procedure, one must move from phenomenological reports of "remember" and "know" to effects on control of responding. For "remember" responses to serve as a valid measure of recollection, participants must be aware of recollecting old words that come to mind as completions for word stems. Such awareness is also required to use recollection as a means to avoid mistakenly producing old words on an exclusion test. The inclusion/exclusion procedure differs from the Remember/ Know procedure in that it requires participants to use awareness as a basis for conscious control of responding, rather than simply to report on awareness.

When examining the effects of repetition using the Remember/Know procedure combined with the independence assumption (which we have named "IRK"), results appear to be consistent with those found using opposition procedures. An experiment done to examine the effects of dividing attention during study illustrates the relation between the process-dissociation and Remember/Know procedures, and also illustrates how use of a generate/ recognise strategy can produce paradoxical dissociations. In that experiment, as for an inclusion test, participants were told to use stems as a cue for recall of an earlier-studied word or, if they could not do so, to complete stems with the first word that came to mind. After completing each stem, participants were to classify their completion word as one that they "remember" having studied, one that they "know" was earlier-studied, or one that was "new" (not earlier-studied).

Results (Table 5.3) showed that dividing attention during study reduced the probability of "remembering" and also slightly reduced the probability of a "know" response. The probability of remembering serves as a measure of recollection. Further, participants should classify an old word as "know" or "new" only if the word came automatically to mind but was not recollected as earlier-studied: A (1–R). That combination is the same as for mistakenly producing an old word on an exclusion test. Consequently, the independence

TABLE 5.3
Mean Probability of Completion with Study Word with "Remember"/"Know"/"New" Responses across Full/Divided Attention and New Items

	Study Condition		
Response	*Full Attention*	*Divided Attention*	*New*
"Remember"	.25	.09	.02
"Know"	.23	.20	.11
"New"	.24	.36	.33
Pr(completion)	.72	.65	.46

assumption can be used to estimate A as: [P(Know) + P(New)]/[1−P(Remember)].

Use of the IRK procedure to obtain estimates produced results (top row, Table 5.4) that were the same as found by Jacoby et al. (1993, Experiment 1) using inclusion/exclusion tests along with direct-retrieval instructions. Dividing attention during study reduced recollection but left automatic influences of memory unchanged.

However, suppose that instead of relying on direct retrieval, participants used a generate/recognise strategy. That strategy would result in participants excluding words that came to mind automatically and were recognised, as well as words that were recollected. Recognition without recollection describes words judged as "know" in the IRK procedure. When using a generate/recognise strategy for an exclusion test, failure to exclude will result only when old words are mistakenly judged as "new".

To mimic effects of a generate/recognise strategy, words that participants "know" were earlier-studied can be grouped with old words judged as "remember" rather than with those judged as "new". Therefore, estimating A using a generate/recognise strategy becomes: P(New)/[1−(P[Remember] + P[Know)]. Estimates computed in this way (bottom row, Table 5.4) show a paradoxical dissociation of the form found by Curran and Hintzman (1995)—dividing attention decreases R but increases A. Although the effects on A were fairly modest in this case, we have obtained more striking "paradoxical" dissociations in other experiments (Jacoby, in press).

Using the Remember/Know results to simulate performance on inclusion and exclusion tests shows that reliance on a generate/recognise strategy would produce base-rate differences. New words that gave rise to either a false "remember" or a false "know" response would be withheld as completions on an exclusion test but would be used for completions on an inclusion test. Because of the relatively high probability of false knowing, the result would be to produce a lower base rate for the exclusion than for the inclusion test. As discussed later, such base-rate differences should alert experimenters that a generate/recognise strategy is likely being employed and therefore signal a violation of independence as assumed by the process-dissociation procedure.

TABLE 5.4
Estimates of Recollection and Automatic Influences Across Conditions of Full and Divided Attention, Using IRK and Generate/Recognise Assumptions

	Estimates			
	Recollection		Automatic Influences	
Assumption	*Full Attn*	*Div Attn*	*Full Attn*	*Div Attn*
IRK	.25	.09	.61	.61
G/R	.48	.29	.44	.48

The IRK procedure is a refinement of a procedure that Curran and Hintzman (1995, Experiments 2 & 3) used to produce a paradoxical dissociation by manipulating study time. For their "recollect and exclude" procedure, participants were required to try to write down two completions for each stem, a recalled word in one column and a new word in another column. The probability of recalling a studied word served as a measure of recollection that was used to estimate automatic influences of memory. A weakness of the "recollect and exclude" procedure is that it does not discriminate between words that participants "remember" and those that they "know" were studied earlier. It seems likely that participants at least sometimes "recalled" words that would have been called "know" had they been given the option. Their doing so would result in an overestimate of recollection along with a paradoxical dissociation, just as did the generate/recognise version of our IRK procedure.

Similarly, not requiring participants to make the Remember/Know distinction is likely responsible for Richardson-Klavehn and Gardiner's (1996) finding of a paradoxical dissociation produced by manipulating level of processing. They investigated effects in stem cued recall using a procedure that is very similar to Curran and Hintzman's (1995) "recollect and exclude" procedure. Deeper processing increased the probability that words used as a completion were recognised as old, but produced a decrease in A estimated using the independence assumption. Again, this paradoxical dissociation likely occurred because the procedure used did not discriminate between remembering and knowing but, rather, grouped the two together as in the aforementioned generate/recognise version of the IRK procedure. In contrast, Toth et al. (1994) used inclusion and exclusion tests with direct-retrieval instructions and found that manipulating levels influenced R but left A unchanged.

Effects of Instructions on Inclusion/Exclusion

Results that are the same as those shown for the generate/recognise variant of the IRK procedure can be produced using generate/recognise instructions with inclusion and exclusion tests. Jacoby (in press) varied instructions for tests and examined the effects of dividing attention. For a direct-retrieval condition, instructions were the same as used in our earlier experiments. Participants were told to use stems as cues for recalling earlier-studied words. Recalled words were to be used as completions for inclusion tests but to be withheld on exclusion tests. In contrast, for the generate/recognise condition, instructions for inclusion tests were the same as for an indirect test of memory—participants were told to complete stems with the first word that came to mind. For exclusion tests in that condition, participants were instructed to generate a completion and then to do a recognition-memory check. If a generated word seemed at all familiar from study, it was not to be used as a completion.

Results for the direct-retrieval condition (Table 5.5) showed that full attention, as compared with divided attention, to the study presentation of words made it more likely that the words could later be recollected and included or excluded, whichever was required by the test. However, for the generate/recognise condition, the advantage of full attention for performance on the inclusion test was slightly diminished. This result was expected because instructions for that condition did not ask participants to intentionally use memory. More impressive was the difference in exclusion performance. Participants in the generate/ recognise condition were much more successful at

TABLE 5.5
Probability of Stem Completion in Inclusion/Exclusion Conditions across Full/Divided Attention at Study Using Direct-Retrieval and Generate/Recognise Instructions

	Inclusion			*Exclusion*		
Instructions	*Full*	*Divided*	*New*	*Full*	*Divided*	*New*
D/R	.70	.62	.45	.40	.48	.43
G/R	.63	.59	.45	.16	.29	.29

excluding earlier-studied words than were those in the direct-retrieval condition, as would be expected if the former used familiarity as well as recollection as a basis for exclusion.

Estimates of R and A computed for the direct-retrieval condition (Table 5.6) showed a process dissociation that was the same as found by Jacoby et al. (1993, Experiment 1). Dividing attention during study reduced the probability of recollection but left automatic influences of memory unchanged. In contrast, the probability of recollection was estimated as being much higher in the generate/recognise condition than in the direct-retrieval condition. Further, results for the generate/recognise condition showed a paradoxical dissociation. Dividing attention reduced recollection but *increased* estimated automatic influences of memory.

The cause of the paradoxical dissociation observed in the generate/recognise condition is likely the same as in our Remember/ Know experiment. Generate/recognise instructions lead participants to exclude words they only "know" are old. This strategy inflates the probability of recollection and results in an underestimation of automatic influences.

Base rates (Table 5.5) signal the differences between the two strategies. For the direct-retrieval condition, base-rate performance did not differ for the inclusion and exclusion tests (.45 vs .43, respectively). For the generate/recognise condition, in contrast, the base rate was lower for the exclusion test than for the inclusion test (.29 vs .45, respectively). This lower base rate likely occurred because some new words were falsely recognised as old, and consequently were not used as completions for the exclusion test.

Reading a word makes it more likely that the word will later come readily to mind as a completion for a word stem. When participants use a generate/recognise strategy or are asked to make Remember/Know judgements, the increase in the likelihood of a word coming to mind can be correctly attributed to

TABLE 5.6
Estimates of Recollection and Automatic Influences Across Full/Divided Attention at Study for Direct-Retrieval and Generate/Recognise Instructions

	Estimates			
	Recollection		*Automatic Influences*	
Assumption	*Full Attn*	*Div Attn*	*Full Attn*	*Div Attn*
D/R	.29	.14	.54	.55
G/R	.46	.30	.30	.40

its source and experienced as familiarity or "knowing". However, the same fluent generation of the word can be ignored or misattributed to differences among items and so not experienced as memory when direct-retrieval instructions are given (cf. Jacoby, Kelley, & Dywan, 1989). Fluency of completing a stem is ambiguous in that it does not specify its source. Because of its ambiguity, reliance on fluency as a basis for recognition or "knowing" results in the exclusion of fluently generated new words as well as old words, creating a difference in base rate between inclusion and exclusion tests. Exclusion on the basis of "knowing" or familiarity violates the assumption of independence along with the assumption that R is equal for inclusion and exclusion tests, and thereby invalidates the equations used to gain estimates. The process-dissociation equations model performance when people use the stems as cues for retrieval. They were not written to model the generate/recognise strategy.

Other experiments reported by Jacoby (in press) paralleled those described earlier but manipulated study time rather than full vs divided attention during study. Results were the same as those found for the effects of dividing attention. Grouping "know" and "new" responses together to obtain estimates of A using the IRK procedure showed that increasing study time produced an increase in recollection but left automatic influences unchanged. A corresponding dissociation was found when direct-retrieval instructions were used for inclusion and exclusion tests. In contrast, generate/recognise instructions produced a paradoxical dissociation as did the generate/recognise version of the IRK procedure. Base rates for inclusion and exclusion tests did not differ in the direct-retrieval condition but in the generate/recognise condition, base rate was lower for the exclusion than for the inclusion test. The paradoxical dissociation and base-rate differences parallel those reported by Curran and Hintzman (1995).

Jacoby et. al. (1997) showed other similarities between results from the process-dissociation procedure and results from the IRK procedure. Such convergence between the procedures is encouraging. However, because the process-dissociation procedure measures R as that which affords control over responding and the Remember/ Know procedure measures phenomenological experience, we expect that the two need not always coincide.

SUMMARY AND CONCLUSIONS

Many anomalies of memory and, in particular, of ageing and memory can be resolved by distinguishing between the consciously controlled process of recollection and the relatively automatic process of familiarity. However, the conceptual distinction must be accompanied by new tools to measure those processes. We have developed paradigms that place familiarity and recollection in opposition to reveal that recollection is reduced in ageing, and also in the young who encode material under conditions of divided attention, or who must respond under a short deadline. One consequence of impaired recollection is that the elderly are susceptible to ironic effects such as repeatedly asking the same question.

However, some ambiguity remains in results obtained with the opposition procedure because, for example, ageing could lead to deficits in both recollection and familiarity. We developed the process-dissociation procedure and the accompanying independence equations that describe performance to estimate familiarity and recollection when participants are attempting direct retrieval. These estimates confirm that familiarity is intact in the elderly, and that familiarity increases with repetitions. Reinstatement of study context affects both recollection and familiarity.

The process-dissociation procedure is a tool that can only be used when certain conditions are met. The equations only apply to situations in which people are attempting to use cues to retrieve, and therefore, care must be taken that participants do not shift to a completely different strategy, such as the generate/recognise strategy. One can use particular patterns of different base rates in the inclusion versus exclusion conditions to detect whether participants have adopted a generate/recognise strategy.

The Remember/Know procedure gives important insights into the phenomenology of memory, but additional assumptions are required to use those reports to study the underlying processes of recollection and familiarity. We argue that the underlying processes are independent, and so the process of familiarity can co-occur with the process of recollection, even though the phenomenology of "Remember" will dominate. Using the IRK calculations to estimate familiarity leads to striking parallels with results from the process-dissociation procedure. However, the process-dissociation procedure emphasises the use of recollection for controlled responding (differentially including vs excluding items), whereas the Remember/Know distinction emphasises phenomenology, and so parallel results will not always be found.

For purposes of theory, it is important to establish boundary conditions for the assumptions underlying the process-dissociation procedure and to consider alternative accounts of results. The same can be said for the Remember/Know procedure. However, for applied purposes, it is important to emphasise commonalities of approaches towards the goal of developing better techniques for diagnosis and treatment of memory disorders.

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