2.16 Retrieval Processes in Memory

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2.16.1 Retrieval Processes in Memory

A dominant framework during the past four decades has postulated three critical components to understanding memory – encoding, storage, and retrieval. But the relative importance that researchers have attributed to each of these components has varied over the course of history. In his 2000 chapter for the Tallinn Conference, Roediger traced this history by taking as his departure point Endel Tulving's remark, "the key process in memory is retrieval." Roediger noted that, despite the fact that the role of retrieval had been emphasized since the writings of Wolfgang Kohler (1947) and Richard Semon (1921; see Schacter, 1982, 2001; Schacter et al., 1978), the belief that encoding and storage processes are the key components of memory has persisted through recent history. Roediger then elaborated both the logical and empirical arguments to demonstrate why retrieval is the key process for understanding human memory (Roediger and Guynn, 1996; Roediger, 2000). The purpose of the current chapter is to reinforce and expand upon this argument.

It is reasonable to assume that without encoding and storage of information there can be no retrieval. But the converse is truer – without retrieval there is no evidence that either encoding or storage ever occurred. Furthermore, retrieval can occur even in the absence of encoding, as in the case of false memories. Retrieval processes thus provide a measure of not only what was encoded and stored but also of what constitutes memory from the perspective of the rememberer – regardless of the reality of that memory. In essence, retrieval then is the measure of memory.

In emphasizing the importance of retrieval processes, Tulving and Pearlstone (1966) proposed a critical distinction between the availability and the accessibility of information. Importantly, they proposed that what is available in memory cannot be known unless that information is accessed. If accessibility is the key to determining the availability of memory, then how can we determine what is accessible? The answer to this question depends on our understanding of the retrieval conditions that can successfully detect encoding and storage. In other words, our measure of what is available in memory is contingent on being able to arrange retrieval conditions that can elicit available memories. It follows then that an understanding of retrieval processes is crucial for understanding the nature of memory.

In this chapter, we have organized the discussion of retrieval processes into six sections: (1) task differences – the role of retrieval cues, (2) encoding and retrieval interactions, (3) retrieval mode, (4) repeated retrieval, (5) retrieval in a social context, and (6) retrieval errors and other retrieval effects. Many of these sections are the very topics of some of the other chapters in this volume and are covered comprehensively in those chapters. We bring together these topics here to evaluate their significance specifically in the context of retrieval and to determine how these phenomena and processes reveal something about the nature of retrieval process *per se*.

2.16.2 Task Differences – The Role of Retrieval Cues

Numerous studies have now amply demonstrated the critical role retrieval cues play in revealing availability of memory. These studies were inspired by a wide variety of theoretical frameworks, and as such they can be organized under a number of different subtopics. Regardless of the theoretical perspectives that inspired these studies – and we will discuss some of these perspectives in the course of this chapter – we include them here because they also underscore the importance of retrieval cues.

Some retrieval cues are internal, as in the case of the most quintessential of all memory tasks, free recall. In this task, participants are given no cues and are asked to write down all the studied information that they were presented earlier. As such, participants rely on their own internal resources – strategies, organization, and cues – to report studied information while performing the free recall task. Retrieval cues can also be external, and in this case the variety of retrieval tasks designed with different cues can span a wide realm, depending on the experimenter's theoretical needs. The most common of such tasks are cued recall and recognition, and we will discuss some findings that show the efficacy of these tasks in improving accessibility to learned information.

In their seminal study, Tulving and Pearlstone (1966) reported the extent to which accessibility can differ just between free-recall (where the cues are internal) and cued-recall (where the cues are external) tasks. In this experiment, participants studied categorized word lists, which consisted of a category name followed by a list of words (of varying length – 12, 24, or 48 words per list) that represented instances of that category. Later the participants were given either a free-recall test or a cued-recall test, the difference between these two tests being that the cued-recall test provided participants with the category names of each word list. Results indicated that participants were able to recall many more words under cued-recall conditions than under free-recall conditions. Furthermore, the benefit of cued recall over free recall increased as the number of words on the to-be-remembered list increased. These results have been interpreted as evidence that not all information that is available is also accessible. Accessibility depends upon the type of cues provided at test.

This demonstration can be expanded by adding tasks that provide even more external cues than those used in the category/cued-recall task. Under such conditions, we would expect memory output to increase as the information provided by the retrieval cues increases – as long as the encoding conditions across these memory tasks remain the same. This scenario can be found in another landmark paper by Tulving (1985), where he introduced the remember–know paradigm. We will discuss this paradigm in a later section on 'Retrieval mode,' but for now, we focus on the inclusion of a third task in Tulving's study. Subjects first studied category names and exemplars (musical instrument–viola) and later completed three successive memory tasks – free recall, category-cued recall (where the category name served as the retrieval cue, e.g., musical instrument–__________), and category plus letter recall (where, in addition to the category name, the first letter of the exemplar was also presented as the retrieval cue, e.g., musical instrument–v________). As the retrieval cues increased, so did the memory output. A recent study in our lab (Hamilton and Rajaram, 2003) replicated and extended this pattern by adding a fourth memory task to the mix – the recognition-memory task. In this task, the test cues completely recapitulate the study cues and by so doing provide maximal assistance for retrieval. We changed the design further by conducting these tests in a between-subjects design such that successive retrieval was not required and the efficacy of different cues could be assessed without contamination from the other retrieval tasks. Our aim in expanding and changing the design concerned issues of memory experience that we do not discuss here. Instead, we focus here on the overall memory performance across the four tasks. With our design, we replicated and expanded on Tulving's (1985) results such that memory output increased as retrieval cues increased, with the highest level of performance occurring in the recognition task (mean proportions of total items correctly retrieved: free recall = .21; category-cued recall = .40; category plus letter-cued recall = .56; recognition = .87 (Hamilton and Rajaram, 2003, Experiment 2), collapsed across the levels of processing manipulation discussed in the next section). Our results further illustrate how retrieval cues can change accessibility. We will return to role of retrieval cues in a later section on retrieval modes.

To summarize, as the number of cues available at retrieval increases, so does the memory output. This fact is important in distinguishing between memories that are available but simply inaccessible. Information that cannot be recalled during a free-recall task may be available, but currently inaccessible. That same information may be recalled during a recognition task.

2.16.3 Encoding and Retrieval Interactions

Studies discussed in the previous section show how increased retrieval cues can improve memory performance. This conclusion rests on the assumption that, when retrieval cues are varied, the encoding conditions are held constant. This assumption is the converse of a popular approach where encoding conditions are varied while the retrieval task is held constant. One of the most robust and enduring examples of the latter approach is the levels-of-processing paradigm. In their classic paper, Craik and Lockhart (1972) presented the levels-of-processing framework in which information encoded for its meaning is predicted to be more memorable than information processed at more 'shallow' levels such as focusing on the sound of the word or the letter patterns. This pattern of performance has now been replicated hundreds of times and is routinely observed in the standard memory tasks (Lockhart and Craik, 1990). For example, in the second experiment of our study described in the previous section (Hamilton and Rajaram, 2003), we observed the levels-of-processing effect within each of the four retrieval tasks – free recall, category-cued recall, category-plus-letter recall, and recognition. That is, within each task the level of memory output was consistently higher for items encoded for meaning than for items encoded at a shallow level. Even so, as we noted before, memory output increased as retrieval cues increased, and this pattern was true both for items that were encoded at a deep level and for items encoded at a shallow level.

Yet task differences can change memory accessibility in another way – different retrieval cues can interact differently with the encoded information when the encoding is also varied. Such encoding–retrieval interactions change memory performance in specific ways in contrast to the general effects illustrated in the empirical example above. The idea of encoding–retrieval interactions is embodied in the encoding specificity principle (Tulving and Osler, 1968; Tulving and Thomson, 1973; Tulving, 1974) and the transfer-appropriate processing framework (Morris et al., 1977; Roediger et al., 1989) – two theoretical approaches that inspired extensive research and have unraveled yet another layer of mystery about memory functions.

2.16.3.1 The Encoding Specificity Principle

Studies inspired by the encoding specificity principle have shown findings that seem counterintuitive in the context of the memory effects we discussed in the previous section. It turns out that, contrary to general expectations, an increase in retrieval cues or the provision of strong retrieval cues does not always produce the best memory performance. This is because strong cues are not always the best match for the study material. In a now classic study, Thomson and Tulving (1970) reported the highly counterintuitive finding that even the absence of retrieval cues can sometimes produce better memory than the presence of retrieval cues. Furthermore, strong retrieval cues can be sometimes *less* effective than weak retrieval cues. The design of this study went like this. During encoding, participants studied a list of words that were presented either alone (e.g., BLACK), with a weak associate (e.g., train – BLACK), or with a strong associate (e.g., white – BLACK). Later participants were given one of three types of recall tests – a free-recall test, a cued-recall test with weak associates serving as the recall cues, or a cued-recall test with strong associates serving as the recall cues. Results of this study indicated that it was the degree of match between cues at study and test (rather than the strength of preexisting associations between the cue and test word) that determined recall (**Table 1**). Strong associates aided recall if they were also given at encoding. However, if weak associates were given at encoding, strong associates as test cues hurt recall. In other words, a retrieval cue is effective if and only if it reinstates the original encoding (see also Tulving and Thomson, 1973).

Table 1 Mean number of words recalled across various encoding and retrieval conditions

	Retrieval condition		
Encoding condition	*Free recall*	*Cued recall with weak associate*	*Cued recall with strong associate*
Word only	14.1	11.1	19.0
Word with weak associate	10.7	15.7	13.9
Word with strong associate	12.2	9.2	20.2

Adapted from Experiment 1 in Thomson DM and Tulving E (1970) Associative encoding and retrieval: Weak and strong cues. *J. Exp. Psychol.* 86(2): 255–262.

As Tulving (1983) pointed out, the locus of the memory effect then is neither at encoding nor at retrieval *per se* but in the interaction between the two. It is reasonable to wonder at this point whether such an interaction undermines the case that retrieval is the key process for understanding memory. To the contrary, such findings underscore the importance of arranging the retrieval conditions that maximally exploit the features of the encoding conditions. This requirement becomes increasingly important as researchers explore the effects of increasingly complex variables – both at encoding and at retrieval – such as place and the internal state of the individual. We review a selection of studies here to illustrate this point and refer the reader to a comprehensive review by Roediger and Guynn (1996) on this subject.

A number of these studies have used the encoding–retrieval paradigm that Tulving (1983) proposed, where both encoding and retrieval conditions are experimentally manipulated. In its most basic form, it involves an encoding experiment with two (or more) encoding conditions (e.g., A and B) and a retrieval experiment with two (or more) retrieval conditions (e.g., X and Y) being conducted simultaneously. By examining only how A differs from B we are able to determine the influence of encoding. Similarly, by examining only how X differs from Y we are able to determine the influence of retrieval. By manipulating both encoding and retrieval conditions simultaneously we are able to examine the interaction between encoding and retrieval conditions. For example, in the study by Thomson and Tulving (1970) just described, encoding conditions were manipulated such that the words were studied under one of three circumstances (word alone, word paired with a weak associate, or word with a strong associate). Similarly, retrieval conditions were also manipulated. Participants were given either a free-recall test, a cued-recall test with the weak associates as cues, or a cued-recall test with the strong associates as cues. It is only by examining the interaction between encoding and retrieval conditions that Thomson and Tulving (1970) were able to observe support for the encoding specificity principle.

2.16.3.1.1 Place-dependent memory

The introduction of the encoding–retrieval paradigm inspired several studies that focused on two sets of variables – place and internal state – to test the encoding specificity principle. These variables carry wide appeal because they are complex and close to real life. In a frequently cited study, Godden and Baddeley (1975) examined the effects of matching or mismatching the place – including the environment – on memory in a rather interesting way. In their study, subjects studied a list of 36 words either on dry land or under water (**Table 2**). These encoding conditions were later crossed with two retrieval conditions in a 2 × 2 factorial design such that subjects performed a free recall task either in the same place/environment as the encoding condition (dry land–dry land or underwater–underwater) or in a different place/environment (dry land–underwater or underwater–dry land). The findings revealed what is known as place-dependent memory and were consistent with the encoding specificity principle; recall was best when the place/environment matched across study and test regardless of whether the place was on land or underwater.

Researchers have also examined place-dependent memory using more common places such as classrooms

Table 2 Mean number of words recalled in Expt. 1 as a function of learning and recall environment

	Recall environment	
Learning environment	*Dry*	*Wet*
Dry	13.5	8.6
Wet	8.4	11.4

Adapted from Experiment 1 in Godden DR and Baddeley AD (1975) Context-dependent memory in two natural environments: On land and underwater. *Br. J. Psychol.* 66(3): 325–331.

(Smith et al., 1978). In a series of experiments, Smith et al. showed that the environmental context effects (manipulated in their study by changing or keeping constant the classroom in which study and test took place) occur reliably. Furthermore, these context effects emerged even if the subjects did not perform the retrieval task in the same room as long as they imagined being in the same room while taking the test. This finding is intriguing because it suggests a strong role of the internal resources in mediating effects related to the external environment.

This implication – that internal resources play an important role in encoding–retrieval interactions – is consistent with the observations that the effects of the encoding–retrieval match are often task dependent. It turns out that place- and context-match effects occur more reliably in free recall but rarely in recognition (see Smith, 1988). This pattern makes sense if internal resources are critical for the encoding–retrieval interactions to occur, because free recall requires internal generation of context, associations, and thoughts, whereas recognition is driven at least in part by the external cues provided to the subject. A number of studies have since reinforced the importance of internal resources in mediating the place-dependent memory effects (Eich, 1985; Fernandez and Glenberg, 1985; McDaniel et al., 1989). As we will see shortly, task selection at retrieval seems to play a significant role in mood-dependent memory as well. Once again, this pattern points to the role of internal origins in mediating the encoding–retrieval interaction effects.

2.16.3.1.2 State-dependent memory

The impact of two interrelated factors we have just discussed – type of retrieval tasks and the involvement of internal resources – has also emerged in two other domains of encoding–retrieval interactions, both of which can be subsumed under the construct of internal states. One concerns state-dependent memory and the other concerns mood-dependent memory. The effects of state-dependent memory have been reported in studies that involved the administration of drugs such as alcohol (e.g., Lowe, 1982) or marijuana. For example, in a study that administered marijuana (e.g., Eich et al., 1975; Eich, 1980), participants encoded information either in a drug state (20 minutes after smoking a marijuana cigarette) or in a sober state (20 minutes after smoking a cigarette that only tasted like a marijuana cigarette). Later, there were four possible recall conditions such that type of test (either free-recall or a category-name cued-recall test) and physiological state (either same as encoding or different from encoding) were crossed with one another. The results indicated that a change of pharmacological state from encoding to retrieval impaired performance on a free-recall test but not on a cued-recall test. Further, even with free recall, it is important to note that drug states, even when matched across study and test, are not the best for improving memory because the best recall was observed when information was both encoded and retrieved in a sober state. Returning to the comparison between free- and cued-recall tasks, the general conclusion of these results was that internal state can sometimes serve as a memory cue (as is the case with the free-recall results of this experiment). However, when there are more effective external cues (such as category names) people do not use the less-effective internal cues (as in the case with the cued-recall results of this experiment).

2.16.3.1.3 Mood-dependent memory

We now turn to mood-dependent effects on memory. These effects are especially intriguing because people have an intuitive sense that memory must be sensitive to how we feel when we learn and when we retrieve the learned information. As we discussed earlier, internal context seems to be quite important for understanding encoding–retrieval interactions, and mood certainly provides a prototypical example of internal context (see Eich, 1985). Yet it turns out that findings in this area of research reveal a complex relationship between mood and memory.

Mood is usually manipulated in studies by using hypnotic suggestion, happy/sad music, or comic/sad video clips, and rating scales are often used to measure the attainment of mood. Early studies reported promising results in that mood match across study and test produced better memory performance. For instance, one study reported such effects in endogenously occurring mood states where psychiatric subjects reproduced more free associations if their mood (manic or normal) matched across the first and second attempts than if it mismatched (Weingartner et al., 1977). In another study, Bower et al. (1978) manipulated happy or sad mood through hypnotic suggestion and observed substantially higher recall of common words had they been studied and tested in the same mood than in different moods. But the empirical story got murky thereafter and led researchers to question mood-dependent memory effects (see Blaney, 1986). In fact, in a later study, Bower and Mayer (1989) failed to replicate the mood-dependent memory effect, and similar failures to replicate started to accumulate in the literature (see Eich, 1995b, for a review).

Two phenomena subsequently clarified when the mood-dependent memory effect is likely to occur, and both of these phenomena are consistent with the notion that internal context (or internal state) is important for observing the expected encoding–retrieval interaction in mood studies. In one study, Eich and Metcalfe (1989) asked subjects to either read the to-be-recalled targets (cold) or generate them from semantically related cues (hot-???). Subjects performed this task in either pleasant or unpleasant moods induced through different types of music. Subjects were later induced to experience the same mood or a different mood before recalling the word pairs under conditions of free recall. Mood-dependent effects appeared only for items that were generated during study and not for items that were simply read (**Table 3**). The authors replicated these findings in other experiments within the series, and this effect has since been replicated by others as well (Beck and McBee, 1995).

Taking a different approach, Eich et al. (1994) investigated this question by asking subjects to generate events from their own lives. The experimenters manipulated mood by inducing either a pleasant or an unpleasant mood while subjects performed this task. Later, subjects were asked to recall the gist of events they had generated earlier while experiencing either the same mood as before or a different mood. Two interesting effects emerged: (1) in the first session, subjects generated events that were consistent with their mood (either pleasant or unpleasant), producing a mood congruency effect (Blaney, 1986); (2) in the second session, subjects were better at recalling those events that matched their mood at retrieval than they were at those that mismatched, thereby producing a mood-dependent memory effect. These studies emphasize the special role of internal states in producing mood effects in line with Eich and Metcalfe's arguments that mood-dependency effects only occur for self-generated activities (i.e., for internally generated thoughts) and not for externally produced events. Furthermore, the role of internal resources becomes even more important when we consider the nature of the retrieval task that effectively produces these effects. As with place-dependent memory, mood-dependent memory effects are also observed more reliably in free recall than in recognition (Eich and Metcalfe, 1989). At a broader level, this cluster of findings from manipulations of place, state, and mood lends further support to the theme that internal resources play an important role in mediating encoding–retrieval interactions.

Table 3 Probability of recall as a function of item type and encoding/retrieval condition

	Test condition			
	Read words		*Generated words*	
Encoding condition	*Happy*	*Sad*	*Happy*	*Sad*
Happy	.09	.04	.32	.17
Sad	.05	.07	.17	.27

Adapted from Experiment 1 in Eich E and Metcalfe J (1989) Mood dependent memory for internal versus external events. *J. Exp. Psychol. Learn. Mem. Cogn.* 15(3): 443–455.

The place-, state-, and mood-dependent memory effects reviewed so far show the complexities involved in studying variables that are multidimensional. Their complexities pose a challenge to researchers in being able to reinstate the exact conditions across study and test. In fact, some of these variables can sometimes be confounded with each other such that one variable (e.g., mood) can mediate the effects of another variable (e.g., state) and further complicate our understanding of encoding–retrieval interactions. For example, Eich (1995a) has argued that place-dependent memory is actually just a special case of mood-dependent memory. In an experiment examining this hypothesis (Eich, 1995b, Experiment 3), participants generated autobiographical events in a pleasant environment and in a pleasant mood. Later, they were asked to recall this information in one of four distinct conditions defined by the 2 × 2 factorial combination of (1) same versus different place and (2) same versus different mood. In this study, it made no difference whether participants were tested in the same versus a different place. However, there was a significant difference when participants were tested in the same mood (55% recall) versus a different mood (45% recall). Based upon these results, it is possible to conclude that how well information transfers from one place to another depends not on how similar the two locations look, but rather on how similar the two locations feel. A similar argument has been set forth regarding state-dependent memory effects. The drugs that most reliably produce state-dependent retrieval effects (such as alcohol and amphetamines) are accompanied by large mood changes. This led Bower (1981) to conclude that state-dependent effects are achieved as a result of the confounded mood-dependent effects.

In brief, thus far in this section, we have reviewed classic and representative studies that show how encoding and retrieval interactions reveal effects of specificity in memory. Together, studies on place-dependent, state-dependent, and mood-dependent memory also show the importance of the types of cue and the task selection at retrieval for detecting these patterns of specificity.

2.16.3.2 The Transfer-Appropriate Processing Framework

The encoding specificity principle proposes that memories are associated with particular cues, and recall is predicted to be enhanced if the cues at retrieval are the same as those that were encoded in the memory traces formed at encoding. We now turn to a discussion of another influential approach – known as the transfer-appropriate processing framework (Roediger et al., 1989; Roediger, 1990) – that is similar to the encoding specificity principle but emphasizes the processes and procedures of mind (Kolers and Roediger, 1984) rather than its structural contents to explain the interactions between encoding and retrieval. In this processing approach, recall is predicted to be enhanced when the processing at retrieval is the same type of processing as encoding. For example, this approach predicts superior memory for 'shallow' encoding of items if the retrieval task capitalizes on the processing of shallow aspects of the study material (Morris et al., 1977; Roediger et al., 1989). This prediction is at odds with the classic and robust demonstrations of the levels of processing effect we discussed earlier, where information processed for meaning is retrieved better than information processed for its shallow aspects such as phonemic details (Craik and Lockhart, 1972; Craik and Tulving, 1975). But the two phenomena can be reconciled if we take into account the critical role retrieval processes play in tapping the encoded information. In their study, Morris et al. (1977) factorially varied the type of encoding task with the type of retrieval task. In particular, during encoding, participants were asked to determine either whether a given word fit into a sentence (a deep semantic encoding task) or whether it rhymed with another word (a shallow phonetic encoding task). Later, participants were either given a standard recognition task or a recognition task involving rhymes (i.e., "does this word rhyme with a previously seen word?"). When the encoding rhyme questions required 'yes' judgments ("does dog rhyme with hog"?), a very interesting pattern of results emerged on the later memory tasks; while semantic acquisition was superior to rhyme acquisition when tested using a standard recognition task, the converse was true when tested using the rhyme recognition task. Based upon these results, Morris and colleagues concluded that shallow encoding is not necessarily inferior to deep encoding and that the effectiveness of any given encoding task depends upon the relationship between the encoding task and retrieval task.

In the late 1980s and early 1990s, Roddy Roediger and his colleagues (Roediger et al., 1989; Roediger, 1990) published a comprehensive framework for testing the principles of transfer-appropriate processing. This framework inspired an empirical revolution that sought to specify the nature of encoding and retrieval processes and the ways in which the selection of these processes can impair or maximize memory performance. A full description of this framework, its tenets, and the major findings are beyond the scope of this chapter, but we recommend several comprehensive reviews to the reader on the theoretical and empirical developments in this area of research (Roediger et al., 1989, 1990; Roediger, 1990; Roediger and McDermott, 1993). In brief, this framework states that memory performance improves to the extent that cognitive processes engaged during test match the processes that were engaged during study. Consistent with this main tenet, extensive research has now shown that subtleties in the match or mismatch of processes during encoding and retrieval can produce large effects on memory performance. As a result, it is critical to select retrieval tasks that closely match the encoding task in their processing requirements. We will discuss some empirical illustrations of this key conclusion in the next section, where we describe the impact of retrieval mode on memory performance.

To briefly summarize the arguments thus far, the encoding specificity principle postulates that memory is enhanced when the cues at recall match the cues at encoding (as is the case in place-, state-, and mood-dependent memory). In a similar vein, the transfer-appropriate processing approach postulates that memory is enhanced when the processes engaged during recall match the processes engaged during encoding. Together, these studies demonstrate the importance of arranging the retrieval conditions so that we can optimize accessibility to learned information.

2.16.4 Retrieval Mode

In his chapter for the Tallinn conference, Roediger (2000) discussed the concept of retrieval mode and its power to reveal aspects of memory that might otherwise remain concealed. We expand upon this notion in this section. We will consider the significance of retrieval mode from two perspectives that Roediger noted: (1) explicit and implicit modes of retrieval and (2) remembering and knowing information from the past. Each perspective has brought into focus many important questions concerning retrieval and has led to substantial empirical and theoretical developments on these issues. We refer the reader to two directly relevant chapters in this volume that tackle each of these topics in depth – one by D. L. Schacter on implicit memory (*See* Chapter 2.33) and another by J. M. Gardiner on remembering and knowing (*See* Chapter 2.17). In this section, we discuss a few examples to demonstrate how a change in the retrieval mode can bring about changes in accessibility to studied information.

2.16.4.1 Explicit versus Implicit Memory

The relevance of task differences and encoding–retrieval interactions in improving accessibility comes together in rather dramatic ways when we consider the explicit versus implicit modes of retrieval in which people engage while doing memory tasks. In their seminal papers, Warrington and Weiskrantz (1968, 1970) reported findings that nicely illustrate how retrieval mode can affect the memory product. In these studies, amnesic subjects performed poorly, as would be expected, when asked to think back on the study episode and recall what was studied (as in free recall). But these subjects exhibited, rather surprisingly, normal memory performance when they were asked to complete a memory task with the first response in the manner of problem solving (for example, complete the physically impoverished cues in a word fragment completion task with the first response that comes to mind). Graf and Schacter (1985) introduced the distinction between explicit and implicit memory to respectively capture this difference between a mode of retrieval where people think back on the study episode (all the memory tasks discussed in the other sections of this chapter) and a mode where no reference is made to study episode during test performance.

These differences in the retrieval task instructions can change memory performance of not only individuals who have amnesia but also individuals who possess intact memory functions (see Schacter, 1987, 1990; Roediger et al., 1989, 1990; Roediger, 1990; Roediger and McDermott, 1993, for representative reviews.) We will discuss some findings observed in individuals with intact memory to elaborate this point. In the previous section, we discussed the classic levels of processing effect on tasks such as free recall and recognition (Craik and Tulving, 1975) and the reversal of this effect when the recognition task provided phonemic cues as opposed to the standard cues (Morris et al., 1977). Interestingly, the conceptual advantage of levels of processing disappears if test conditions require implicit retrieval in response to perceptual test cues. In other words, on tasks such as word identification (reading words presented rapidly at threshold durations), word fragment completion (presenting test cues with some letters missing, e.g., _ t r _ _ b _ r _ _), or word stem completion (str________), completing the cues with the first solution that comes to mind confers little advantage for words studied for meaning compared to words studied for their perceptual features (e.g., Jacoby and Dallas, 1981; Graf and Mandler, 1984; Roediger et al., 1992). Thus, the levels of processing effect can vary as a result of the tasks used; it occurs on free recall and recognition (Craik and Tulving, 1975), reverses on a phonemic cued-recall task (Morris et al., 1977), and disappears on implicit tasks that rely on perceptual processes for completion. These findings once again highlight the importance of retrieval cues in accessing learned information.

The disappearance of study differences on implicit tasks can change the way we theorize about the significance of encoding (or storage) versus retrieval. For instance, the advantage in free recall for concrete words (such as table, bus, strawberry – words that can be imaged or represented as objects) over abstract words (such as pledge, destiny, care) has been attributed to dual storage of concrete words in verbal and image codes compared to single representations of abstract words (only verbal code) (Paivio et al., 1968; Paivio, 1969). Yet, in a study from our lab (Hamilton and Rajaram, 2001) we found that on implicit tests such as word fragment completion (_ t r _ _ b _ r _ _) and implicit general knowledge test (what fruit wears its seeds on its skin?), there was an equivalent

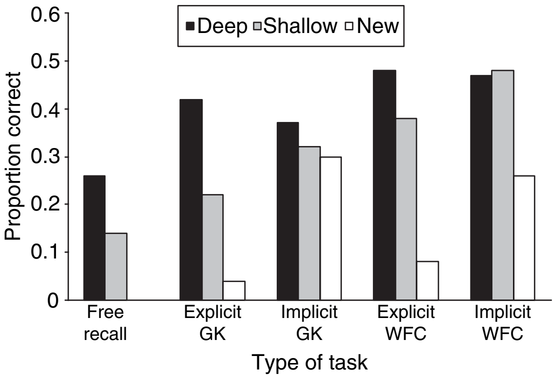

Figure 1 Mean proportion of correct responses for each item type for each of the five tasks used (GK, general knowledge task; WFC, word fragment completion task). Adapted from Experiment 2 in Hamilton M and Rajaram S (2001) The concreteness effect in implicit and explicit memory tests. *J. Mem. Lang.* 44(1): 96–117.

advantage for producing studied concrete words and studied abstract words over their nonstudied counterparts (**Figure 1**). In other words, on an implicit memory task there was no memorial benefit of concrete words over abstract words. Therefore, the concrete/abstract distinction in memory cannot be discussed only in the context of differential encoding or storage. This distinction demands a more complex explanation because this effect is not ubiquitous – it can be specific to a particular mode of retrieval.

A converse pattern can also emerge by changing the retrieval mode such that some study differences do not affect explicit memory but produce changes in implicit memory. For example, changing the modality of presentation at study – presenting words either in the auditory or the visual modality – does not change the level of free recall (Blaxton, 1989; Srinivas and Roediger, 1990; Rajaram and Roediger, 1993), and this null finding suggests that modality of presentation at study does not matter. However, this conclusion is only partly correct as we (Rajaram and Roediger, 1993) found in our study with four different implicit tasks involving perceptual cues (see **Figure 2**). When subjects were presented with impoverished cues such as word fragments, word stems, rapidly presented words in the word identification task, or anagrams (brtaserwyr) to solve in the anagram solution task (strawberry) and were asked to perform these tasks with the first solution that comes to mind, performance improved on these implicit tests if the study and test materials were presented in the same modality compared to different modalities (see also Jacoby and Dallas, 1981; Kirsner et al., 1983; Graf and Mandler, 1984; Roediger and Blaxton, 1987; Blaxton, 1989; Srinivas and Roediger, 1990; Weldon, 1991). In other words, the impact of a study variable is sometimes detectable only when subjects used the implicit retrieval mode. (As an aside, but consistent with the general argument about the impact of retrieval cues in modulating memory performance, we also found that studied pictures produced the worst performance on these implicit tasks that provided word-based cues. This, of course, is contrary to the pattern that is typically observed in free recall and recognition, where memory for pictures is better than that for words (Paivio et al., 1968; Madigan, 1983; Weldon and Roediger, 1987; Rajaram, 1993).)

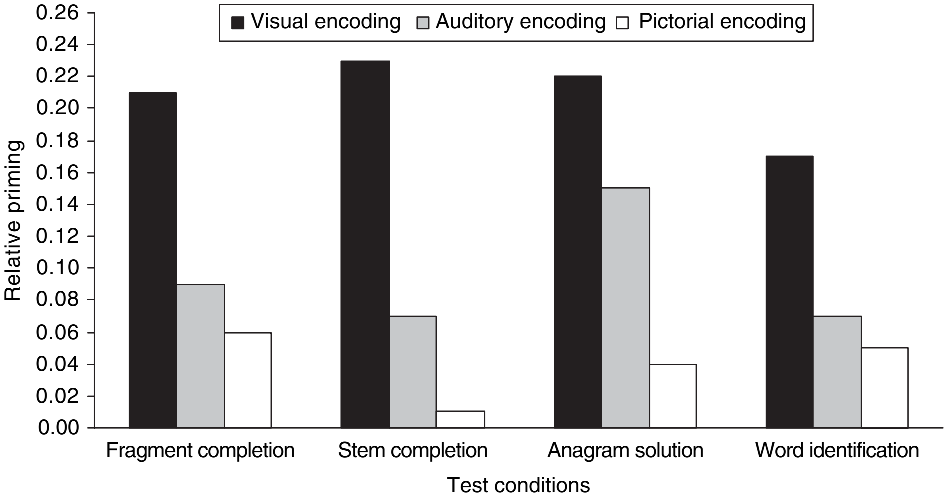

Figure 2 Relative priming for the four implicit memory tasks across different encoding conditions. Adapted from Rajaram S and Roediger HL (1993) Direct comparison of four implicit memory tests. *J. Exp. Psychol. Learn. Mem. Cogn.* 19(4): 765–776.

The impact of retrieval mode on memory performance can be seen even when the retrieval cues themselves are held constant and only the mode of retrieval is varied through instructions, or when the retrieval intentionality criterion is met by the experimental conditions (Schacter et al., 1989). For example, when performance on free recall is contrasted with performance on a task such as implicit word fragment completion, the retrieval mode changes, but so do the test cues (no test cues in free recall and perceptually degraded cues in fragment completion, e.g., _ t r _ _ b _ r _ _). But the role of retrieval mode in detecting memory would be more persuasive if dissociations between explicit and implicit memory could be observed even when the same test cues were used in both conditions. Graf and Mandler (1984) reported such a dissociation between an explicit word stem cued-recall task and an explicit word stem completion task where the same test cues (e.g., ele________) were used, and the levels of processing effect occurred on the explicit but not the implicit version of the task. In a large-scale study, Roediger et al. (1992) reported similar patterns of performance when they contrasted explicit and implicit versions of the test using identical stem cues (e.g., ele________) as well as explicit and implicit versions of the test using identical fragment cues (e.g., _ l _ p _ a n _). Along the same lines, in our study with concrete and abstract words we just described, we found that the presence of the concreteness effect in free recall also extended to the explicit retrieval version of the general knowledge test (complete the following question with a studied word: "What fruit wears its seeds on its skin?") but, as noted earlier, not to the implicit version of the general knowledge test (Hamilton and Rajaram, 2001). In other words, we demonstrated dissociative effects on explicit and implicit versions of a different type of task, namely general knowledge, while holding the test cues constant (see again **Figure 1**).

2.16.4.2 Differentiating between Conceptual and Perceptual Retrieval Cues

While explicit and implicit retrieval modes can produce various dissociations of theoretical significance such as the ones just described, dissociations can also occur *within* one retrieval mode – for example, with differences in implicit retrieval cues provided to the participants. In previous sections, we described how differences in retrieval cues can bring about changes in memory performance within the context of explicit memory tasks such as free recall, cued recall, and recognition. The tenets of the transfer-appropriate processing framework (Roediger et al., 1989; Roediger, 1990) predict systematic differences even within implicit memory tasks, depending on the type of process demanded by the tasks. If the implicit memory task largely depends on perceptual processes for its successful completion – as in the cases of word fragment completion, word stem completion, perceptual identification tasks – then encoding orientation produces one type of effect. But if the implicit task mainly relies on conceptual processes – as in the cases of the general knowledge test described earlier and also tests such as implicit category association test (given a category name, participants are asked to produce all the exemplars that come to mind within 30 s) – then the same encoding orientation produces the opposite effect. So, for example, the modality effect observed across different *perceptual* implicit tasks described in the study by Rajaram and Roediger (1993) disappears on *conceptual* implicit tasks because changes in modality of presentation are not important for accessing meaning (e.g., Blaxton, 1989; Srinivas and Roediger, 1990). Encoding variables that differentiate the extent to which meaning (rather than surface information as in the modality manipulation) is varied during study produce the opposite effect: As we described earlier in this section, the levels-of-processing effect that reflects changes in conceptual processing of information disappears on *perceptual* implicit tasks. But this effect is reliably observed on *conceptual* implicit tasks such as the implicit general knowledge test (Hamilton and Rajaram, 2001) and the implicit category association test (Hamann, 1990; Srinivas and Roediger, 1990). Together, these patterns show that, while retrieval modes of explicit and implicit retrieval change accessibility in dramatic ways, the nature of the process demanded by the retrieval task (conceptual versus perceptual) can also change accessibility in a manner that is powerful and that can be orthogonal to the retrieval mode itself.

2.16.4.3 Remembering and Knowing

We now turn to a brief discussion of another type of distinction between two retrieval modes – remembering versus knowing one's past. Unlike the explicit–implicit distinction, where people are, respectively, either aware or not aware of the connection between the past and present, the remember–know distinction is made when people are aware of the connection. This distinction instead concerns the quality of retrieval experience that accompanies retrieval (Tulving, 1985). A person is said to engage in remembering if the retrieved memories are vivid and detailed. Remembering involves being able to think back to episodes and mentally reliving the past event, and in this way it is also said to involve mental time travel (Tulving, 2002). In brief, remembering is considered to be the purest measure of episodic memory. The experience of knowing is associated with semantic knowledge. Sometimes, retrieved information is associated with the past (unlike the case of implicit memory), but its rooting in the past lacks a sense of immediacy or detail such that one cannot tell when and where this information was encountered before. Despite having confidence in this type of memory, one experiences less personal connection and more of a generic sense about this information. In brief, Tulving proposed that the experience of knowing provided a measure of semantic memory. Tulving (1985) introduced the remember–know paradigm to enable quantitative measurements of these qualitative distinctions in retrieval.

The remember–know paradigm has been used widely to study the nature of retrieval experience and has produced both a large body of systematic findings and considerable debate (see Jacoby et al., 1997; Rajaram and Roediger, 1997; Gardiner and Conway, 1999; Rajaram, 1999; Gardiner and Richardson-Klavehn, 2000; Roediger et al., 2007, for reviews). For present purposes, we emphasize the dissociations and associations that systematically occur between these two distinct retrieval experiences. We have already discussed ways in which the levels-of-processing effect can vary as a function of encoding–retrieval interactions and explicit–implicit retrieval instructions. The presence of the levels of processing effect in explicit memory retrieval suggests that this effect should manifest itself in both remember and know judgments. However, the findings show that items studied for their meaning are given more remember judgments than items studied for their surface features, but this pattern is not observed for know judgments (Gardiner, 1988; Rajaram, 1993). Thus, retrieval can vary for the same set of encoding conditions even within the domain of explicit memory, once again emphasizing the important role that retrieval probes play in revealing the nature of memory.

In summary, we use the term retrieval mode to refer to distinct methods and experiences of retrieving information. Explicit retrieval refers to the conscious and intentional recall of previous experiences. In contrast, implicit retrieval refers to performance changes that are a result of prior experience but are unaccompanied by intentional or conscious recall of previous learning. Dissociations can occur between these two retrieval modes such that some factors (e.g., concrete/abstract words) can influence explicit memory but not implicit memory, while other factors (e.g., modality of presentation) can influence implicit memory but not explicit memory. Interestingly, the distinction between explicit and implicit memory retrieval is modified by the processing demands of these retrieval tasks such that dissociations can also occur *within* a particular mode of retrieval if the retrieval cues rely on different types of processes. As a result of this, *conceptual* implicit cues reveal the levels-of-processing differences but remain insensitive to modality changes, whereas *perceptual* implicit memory cues produce a reverse pattern of memory performance.

The notion of changes in the retrieval mode can also be applied to a distinction within explicit memory in terms of remembering and knowing – a distinction that is based on the quality of the information that is recalled. Remembering refers to recall that is accompanied by vivid details and a sense of mental time travel. In contrast, knowing refers to recall without specific details or a sense of when the information was encountered before. A dissociation also occurs between these two retrieval modes such that some factors (such as depth of processing) can influence remembering but not knowing. A variety of studies have also shown reverse dissociations and some associations as well between these two experiential modes of retrieval.

2.16.5 Repeated Retrieval

In previous sections, we focused on changes in the retrieval context – task differences, the match between encoding–retrieval interactions, and changes in the retrieval modes – to explore how retrieval processes affect detection of memory. We now review a class of retrieval phenomena that are quite different from the preceding ones but are equally important in revealing the nature of memory. These phenomena have to do with repeated attempts at thinking about a particular event. It is common experience to repeatedly try to recall something from the past that simply eludes us at a given moment. Are such efforts useful? In a research context, we might ask, do repeated attempts at recall improve memory performance? The brief answer to this question is yes. As Roediger and Karpicke (2006b) recently noted in their comprehensive review of research on testing effects,

> . . . testing not only measures knowledge, but also changes it, often greatly improving the retention of the tested knowledge. (Roediger and Karpicke, 2006b: 181)

Improvement in memory performance through repeated retrieval attempts can be understood by examining two related but distinct phenomena – hypermnesia and repeated testing. Hypermnesia refers to an improvement in the total amount of material recalled across repeated attempts, and it is usually obtained with free recall and not so often with other tasks. Repeated testing benefits occur when having taken a prior test – either recall or recognition – improves performance on a later test – again, either recall or recognition. We will review selective studies on both these phenomena as they reveal the importance of retrieval attempts.

Systematic efforts toward understanding the positive effects of repeated attempts – or hypermnesia – can be traced back to Ballard's (1913) and W. Brown's (1923) classic papers. Ballard proposed the concept of reminiscence and defined it as, "the remembering again of the forgotten without re-learning" (Ballard, 1913: 17). W. Brown introduced the phenomena of inter-test forgetting – the number of items that were recalled on the first attempt but not on the second – and inter-test recovery – the number of additional items recalled on the second attempt – to capture the effects of repeated recall on memory output. W. Brown's findings showed that repeated attempts at recalling a list of studied words (or recall of states) resulted both in inter-test forgetting and inter-test recovery, but there was an overall improvement in memory performance such that inter-test recovery exceeded inter-test forgetting across recall attempts. Erdelyi and Becker (1974) termed this reliable net gain across repeated attempts at recall as hypermnesia. Modern interest in research on hypermnesia can be traced back to the findings that Erdelyi and colleagues reported in the 1980s (see Erdelyi and Kleinbard, 1978; Erdelyi, 1984; Erdelyi et al., 1989).

Interestingly, for memory to improve with repeated testing, recall attempts do not have to occur necessarily in the form of consecutive and distinct recall tests. Roediger and Thorpe (1978) asked subjects to study 60 words or 60 pictures and attempt recall either in three successive recall tests (each lasting 7 min) or a single recall test that lasted 21 min. In both testing conditions, subjects were asked to draw a line after each minute of recall. Pictures produced greater hypermnesia than did words, a finding that seems to hold in other studies as well (see also Erdelyi and Becker, 1974; Payne, 1986), and this was true for three successive recalls as well as for one long recall that was equal in duration to three successive recalls. More relevant to the present point is the finding that recall increased over time in both retrieval conditions, and it did so at the same rate. An important implication of this finding for educational purposes is that having more time to retrieve information benefits performance even when the study efforts remain the same.

The presence of hypermnesia in Roediger and Thorpe's (1978) design shows that repeated retrieval effort over an extended period of time is the key to improving memory. But could memory improve simply by increasing the time that elapses between study and recall? This is, of course, a counterintuitive possibility because we expect delay to worsen memory, not improve it. However, in a standard repeated-testing design, the delay between study and a given recall test is confounded with the timing of multiple tests. That is, the second test comes much later in time than the first, and so on. Also, Shapiro and Erdelyi (1974) found that recall of studied pictures improved when the delay between study and recall was 5 min compared to when it was 30 s. The key to understanding this unexpected outcome may lie in the instructions subjects received during the 5-min delay; subjects were asked to covertly review the materials they had studied earlier. As Roediger and Payne (1982) argued, when subjects engaged in thinking about the study materials in Shapiro and Erdelyi's study, this act amounted to repeated retrieval practice and produced memory benefits despite the delay between study and recall.

To address this possibility, Roediger and Payne systematically examined the selective influence of delay between study and test and of the number of prior recall tests in a repeated testing design. In their study, all the subjects performed three recall tasks, but one group started the sequence after a short delay, the second group started the sequence at the time when the first group performed the second recall test, and the third group started the sequence at the time the first group performed the third recall test (**Table 4**). As the recall findings from this study show, recall was equivalent on the first recall test

Table 4 Mean recall on the three successive tests for each delay condition

Condition	*Items recalled*				
Immediate	Test 1	Test 2	Test 3		
	25.6	27.9	30.1		
Short delay		Test 1	Test 2	Test 3	
		25.1	27.5	29.8	
Long delay			Test 1	Test 2	Test 3
			25.6	28.9	31.3

Adapted from Roediger HL and Payne DG (1982) Hypermnesia: The role of repeated testing. *J. Exp. Psychol. Learn. Mem. Cogn.* 8(1): 66–72.

regardless of when the first test occurred (short delay, 25.6; intermediate delay, 25.1; long delay, 25.6). In contrast, recall increased during the same temporal window if the number of prior recall tests increased (the first test for the long-delay group, 25.6; the second test for the intermediate-delay group, 27.5; and the third test for the short-delay group, 30.1). Interestingly, many of these findings in hypermnesia studies have been secured with the study of pictures but not always with the study of words. We refer the reader to comprehensive reviews by Payne (1987) and Roediger and Challis (1989) for discussions on this and other complicating issues as well as for theoretical considerations in hypermnesia research. Regardless, these studies decisively point to the critical and specific role played by repeated attempts at retrieval in improving memory.

Repeated retrieval improves access to studied material in yet another way. Sometimes, the differential effects of different study methods that do not emerge on the first recall test are revealed on a later second test. For instance, in a study by Wheeler and Roediger (1992), subjects studied 60 pictures either presented one by one and accompanied with auditory presentation of the names or presented in the same manner visually but accompanied with an auditory presentation of a story. Shortly after completing a distractor task, subjects recalled the names of the pictures on one, two, or three successive tests. All the subjects returned 1 week later and also completed a final free-recall test. Their performance on this final test distinguished between the benefits of multiple retrievals for different study methods. Subjects' final recall was substantially higher for pictures that were embedded in a story than pictures that were presented without a story during study, and this difference became increasingly pronounced as the number of prior recall tests increased. Once again, we see the power of retrieval processes in that repeated retrieval can increase not only memory output when the study conditions remain the same; it can do so by bringing out the differential efficacy of study methods that might otherwise remain obscure.

As the preceding discussion shows, repeated retrieval clearly increases accessibility and produces improvements in memory. But in a discussion that emphasizes the importance of retrieval, it is important to ask what is more effective – repeated retrieval or repeated study? After all, a vast empirical literature in cognitive psychology shows that repeating information at study reliably improves recall and recognition (*see* the chapter by R. L. Greene in this volume on repetition and spacing effects; Chapter 2.06). There are many interesting phenomena associated with repetition at study, including the nearly ubiquitous demonstration that spaced repetition at study – that is, repeating items with one or more intervening trials in the study list – produces better memory compared to massed presentation – that is, repeating items twice or more in consecutive trials in the study list. Given the beneficial effects of repeated study, it is logical to ask how repeated retrieval fares in comparison. This question has been tested in many ways and from different theoretical as well as applied perspectives. Yet, the answer is impressively consistent. Repeated retrieval not only benefits memory, it does so to a greater extent than does repeated study. We recommend Roediger and Karpicke's (2006b) review that we earlier referenced for an in-depth discussion of different theoretical and empirical issues related to this broad question, and for the practical implications from this research for improving educational practices. Here, we will review a selection of studies that demonstrate this conclusion. In these studies, the focus is not on hypermnesia that arises when the same test is taken multiple times but on benefits of repeated testing where the successive tests are not necessarily identical, but having taken the prior tests nevertheless improves performance on the later tests.

As early as the first quarter of the twentieth century, two studies demonstrated many of the key findings from repeated-testing designs. In one study, Gates (1917) varied the amount of time given to subjects for only studying versus for recalling while being able to refresh memory for the forgotten material. On a final (serial) recall test of the studied material (nonsense syllables or biographies), Gates found that spending more time on recall with opportunities to refresh the forgotten information produced better final recall than more time devoted only for study – provided that a certain, minimum amount of time was first spent for study in the former condition (see also Thompson et al., 1978).

In another study, Spitzer (1939) found that two attempts at retrieval improved memory on a multiple-choice recognition memory test. Furthermore, the sooner the first test was administered, the less was the forgetting and the higher was the performance on a later second test. The inoculating effects of the first test, and of its timing, have received considerable attention in the repeated-testing literature. While the inoculating effects of the first test on later memory seem secure (Wheeler and Roediger, 1992), the specifics concerning the optimal timings of multiple tests continue to be investigated (Landauer and Bjork, 1978; Balota et al., 2006, 2007; Logan and Balota, in press).

The early intimations of a relative advantage of increased testing over increased studying in the studies by Gates (1917) and Spitzer (1939) have been systematically tested from various perspectives in the modern literature and have produced a very nice body of data. A key factor in predicting the relative advantage of repeated study versus repeated retrieval concerns the delay between study and the final memory test. In a seminal study, Tulving (1967) used a comprehensive design that included comparisons of various study–test schedules for a total of 24 trials each and had subjects study a total of 36 words – alternating study and test (STST, STST, and so on), three study and one test (SSST, SSST, and so on), and one study and three tests (STTT, STTT, and so on.) Also critical for present purposes, subjects were given 1 s per item to study and an equivalent total of time for test (so, subjects received 36 s to recall all the studied items.) The results showed that recall performance was comparable over the 24 trials across the three different study-test schedules. In other words, repeated testing did not improve memory over repeated study.

Tulving's findings were surprising in light of the general conclusion we have already stated, but these findings were replicated by others (e.g., Lachman and Laughery, 1968; Rosner, 1970; Birnbaum and Eichner, 1971; Donaldson, 1971). Also, these findings make sense if we consider them in light of Roediger and Thorpe's (1978) findings we discussed earlier; recall improves as subjects receive additional time to do the task. However, in Tulving's experiment subjects were given only 36 s to recall 36 words. Even if the words had been perfectly learned, this is a very short time period with which to recall them. Initial support for this possibility was found in a study where subjects either studied a list of 40 words four times or studied it once and recalled it three times (Hogan and Kintsch, 1971; see also Thompson et al., 1978). In a final recall test conducted 2 days later, prior training with multiple tests produced 5% better recall than prior training with multiple study.

Roediger and Karpicke (2006a, Experiment 2) recently published a study using educational materials that provides an impressive resolution to the question concerning the relative importance of repeated study versus repeated tests. Subjects studied prose passages on scientific topics and were tested on a recall test that was similar to essays in its format. In one condition, subjects studied the passage four times (SSSS). In a second condition, subjects studied the passages three times and were tested once (SSST), and in the final condition, subjects studied the passages once and were tested three consecutive times (STTT). Subjects also took a final recall test either 5 min or 1 week after this learning sequence. As can be seen in **Figure 3**, more idea units were recalled following repeated study if the final recall test occurred after a short delay of 5 min. But the final recall performance was better after repeated testing if

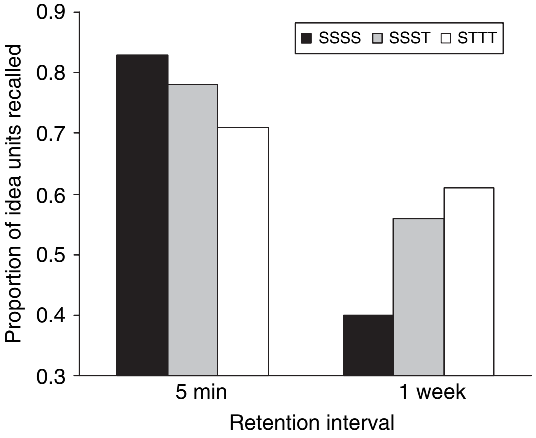

Figure 3 Mean proportion of idea units recalled on the final test after a 5-min or 1-week retention interval as a function of learning condition (SSSS, SSST, or STTT). The labels for the learning conditions indicate the order of study (S) and test (T) periods. Adapted from Experiment 2 in Roediger HL III and Karpicke JD (2006a) Test-enhanced learning: Taking memory tests improves long-term retention. *Psychol. Sci.* 17(3): 249–255, with permission from Blackwell Publishing.

the final test occurred after a long delay of 1 week. In summary, these findings pinpoint the key conditions that are responsible for when study and retrieval repetitions can produce differential benefits in memory; repeated study improves memory in the short term, but repeated testing produces improvements in the long term. This long-term advantage of repeated testing over repeated study seems secure because it has been shown to also occur with word lists (Wheeler et al., 2003).

A general explanation for why repeated retrieval benefits long-term retention more than repeated study harkens back to the principle of transfer-appropriate processing we discussed in earlier sections on encoding–retrieval interactions and retrieval mode (Morris et al., 1977; Roediger et al., 1989). Roediger and Karpicke (2006b) recently noted that one reason for the superiority of repeated retrieval is that the same processes are engaged when people retrieve information again, whereas, as McDaniel (2007) has argued, different processes are often engaged across learning and testing situations. The match in processes in the former condition illustrates the operation of transfer-appropriate processing.

Another explanation of the benefit of repeated testing is that initial testing results in the creation of multiple retrieval routes to the to-be-remembered item, thus making recall more likely at a later test. In a study by McDaniel and Masson (1985), subjects were given either a phonemic or a semantic encoding task followed by a cued-recall test with either semantic or phonemic cues. Thus, half of the subjects received the same type of information at encoding and the first test, and half of the subjects received a different type of information at encoding than at the first test. Later, subjects were able to recall more information on a second test when the cues from the first test had not matched the original encoding. This finding is consistent with the idea that the initial test improves recall on a later test if it is able to produce an elaboration of the existing memory trace by increasing the variability of the encoded information (see also McDaniel et al., 1989). From a retrieval point of view, this means not only that retrieval is changing the existing memory representation, but that varied changes make subsequent retrieval more and more likely to occur.

Roediger and Karpicke (2006b) have reviewed a sizeable literature that points to yet another related but distinct basis for benefits from repeated retrieval, namely the process of generation. Briefly, just as the generation processes at encoding improve memory such that items generated from semantic cues are later recalled and recognized more often than items that were simply read, generation of studied items during first recall improves performance on a following test (see Jacoby, 1978; Bjork and Bjork, 1992; Bjork, 1994, 1999; Roediger and Karpicke, 2006a). Consistent with this idea, a prior recall test that requires generation of studied information (such as providing short answers) improves performance on later recall (short answers) as well as recognition (multiple-choice format), whereas a prior recognition test (that does not require generation because the studied items are presented again) does not produce comparable benefits on later tests (Kang et al., 2007). Recent work (McDaniel et al., 2007) has also demonstrated this effect in a college course. In this study a benefit was found for short-answer quizzes (a recall test) over additional study but not for multiple-choice quizzes (a recognition test) over additional study on a final exam. This is particularly impressive given not only the variability of additional studying and motivation of the students within the class, but also the fact that the quizzes were administered up to 5 weeks prior to the final exam. Findings such as these reveal the specificity of effects that prior retrieval produces on later retrieval and point to the underlying processes that mediate such patterns.

In conclusion, testing – or retrieval – not only has a powerful influence on long-term retention but is also an effective learning device with important educational implications. The judicious use of testing in educational settings should benefit students' performance. This goal is embodied in recent cognitive research that aims to identify optimal retrieval practices for improving retention and academic performance. We refer the reader to M. A. McDaniel's chapter on 'Education and Learning' in this volume (*see* Chapter 2.43) for an in-depth discussion of these important issues.

2.16.6 Retrieval in a Social Context

For decades now, experimental studies on memory have typically focused on the individual, and the study of retrieval processes has been no exception. But just as we retrieve the past not just once but often repeatedly, we also retrieve the past not just alone but often in collaboration with others. People recall the past in dyads (e.g., friends and couples), triads (e.g., friends, colleagues), or in larger groups. It was only around the mid- to late 1990s that research on the effects of social context on memory started to gain momentum. We review some of the core findings from this area of research as relevant to the process of retrieval here and refer the readers to scholarly reviews by Weldon (2001) for the historical antecedents and the emerging research on social processes in memory, and by M. Ross (*see* Chapter 2.47) and J. V. Wertsch (*see* Chapter 2.48) in this volume on the nature of social memory processes and collective memory, respectively.

Both the early neglect of group processes and the recent focus on group processes make sense on theoretical and empirical grounds, because assessment of how social processes influence retrieval first requires a clear understanding of how individual memory processes work in isolation. Now that a substantial body of evidence and major theoretical frameworks are in place on the nature of individual memory, researchers have the necessary empirical and theoretical bases against which the social influences on individual memory can be measured. Similarly, researchers can also test for potential similarities and differences between individual memory and group memory processes.

We first focus on group memory because retrieval processes appear to play a central role in mediating group memory effects. Studies that report group retrieval – or collaborative memory – effects typically compare collaborating groups to nominal (or control) groups. In collaborative groups, members collaborate during retrieval. In nominal groups the nonredundant responses of an equal number of individuals who worked alone are pooled together (Basden et al., 1997; Weldon and Bellinger, 1997). Collaboration in the experimental group is instantiated by asking subjects to contribute their retrieved responses in any order or in a turn-taking order. Results do not seem to change as a function of the particular procedure used for collaboration (Basden et al., 1997; Weldon and Bellinger, 1997; Weldon et al., 2000; Wright and Klumpp, 2004).

The central finding in group retrieval studies turns out to be counterintuitive. Collaborating groups recall significantly fewer studied items than nominal groups (Basden et al. 1997; Weldon and Bellinger, 1997), a phenomenon that Weldon and Bellinger (1997) call collaborative inhibition. In Weldon and Bellinger's experiment, participants encoded a list of words alone. Later, they were asked to recall the information either individually or in a collaborative group of three individuals. When the participants recalled individually, a nominal group score was created that consisted of counting up all the nonredundant answers of three individuals. The results indicated that, while collaborative groups recalled more than the average individual, the nonredundant responses of three individuals recalling alone (i.e., nominal groups) exceeded collaborative group performance.

Collaborative inhibition appears to be largely a retrieval phenomenon, as this effect is reliably observed when the encoding conditions are held constant across the nominal and collaborative groups. The retrieval basis of this effect is further supported by the proposal that collaborative inhibition is similar to another well-known retrieval phenomenon, namely, the part-list cuing inhibition effect (Slamecka, 1968; Basden et al., 1977; Roediger and Neely, 1982; Basden and Basden, 1995). The part-list cuing inhibition refers to yet another counterintuitive phenomenon in memory; when subjects are presented with a partial list of studied words during recall and are asked to recall the remaining studied words, their recall is poorer for the remaining subset compared to a condition where none of the studied items are provided during recall. Thus, having access to a part of the studied lists inhibits the recall of the remaining words. The locus of this effect appears to be at retrieval because recall for the remaining subset improves on a later trial if the partial list is no longer provided. Thus, the dip in recall during the first trial turns out to be temporary and does not reflect poorer encoding or storage in the part-list condition. This finding then begs the question – why do partial lists inhibit recall? Evidence shows that individuals develop their own idiosyncratic organization of the studied material and use it during recall (Tulving, 1962; Roenker et al., 1971; Rundus, 1971). The presence of a subset of items during recall disrupts such organizational and retrieval strategies and leads to suboptimal recall performance (Basden and Basden, 1995).

B. H. Basden and colleagues extended the logic of retrieval disruption to the collaboration situation and tested the idea that collaborative inhibition observed in group memory is similar to the part-list cuing inhibition effect in individual memory. The logic behind this theoretical extension goes like this. Recall of a given member is reduced in a collaborative group because responses produced by other group members serve as part-list cues and disrupt the idiosyncratic retrieval strategies on which each individual member relies during group recall. Such retrieval disruption – resulting from the input of other group members – reduces the individual contributions from each member and leads to lowered group recall.

B. H. Basden et al. (1997) reported evidence that supports the retrieval disruption hypothesis. In this series of experiments, B. H. Basden and colleagues also reported the same pattern of results as Weldon and Bellinger (1997), showing that nominal recall was greater than collaborative recall. However, they also showed that this effect was mediated by the extent to which collaboration disrupts the individual's organizational structure. For example, in their first study, participants were given one of two types of encoding tasks. Some participants were asked to learn many (15) instances of a few (6) categories. Other participants were asked to learn few (6) instances of many (15) categories. D. R. Basden and Draper (1973) had previously argued that within-category organization is more likely to occur with large categories. As a result, each individual's retrieval strategy should be at more variance from another individual's retrieval strategy when the categories are large. If collaborative inhibition is due to retrieval disruption, there should be greater collaborative inhibition for participants who studied large categories (15 instances of 6 categories) than for participants who studied small categories (6 instances of 15 categories). Consistent with this hypothesis, the magnitude of collaborative inhibition varied as a function of list structure. In fact, collaborative inhibition was found only for participants who studied large categories and not for participants who studied small categories.

The collaborative inhibition effect in group retrieval and the part-list cuing inhibition effect in individual retrieval are related in yet another interesting way. As we have described, both phenomena are said to occur because of retrieval disruption during retrieval. It turns out that in both cases retrieval disruption does not impair individual memory beyond the conditions where it operates. As we noted earlier, in the case of part-list cuing inhibition, there is evidence that, if the part-list cues are removed during subsequent individual recall, subjects elicit previously blocked studied words (Basden et al., 1977). Similarly, after the completion of the group retrieval session, if each group member individually recalls studied items, the 'lost' items during collaboration resurface in later individual recall (Finlay et al., 2000; see also Weldon and Bellinger, 1997). These interesting parallels suggest that group retrieval can be sensitive to the same cognitive mechanisms that mediate individual retrieval.

In an earlier section on task differences, we discussed the critical role retrieval cues play in determining the accessibility of studied information. Initial evidence from studies on collaborative memory suggests retrieval cues also modulate the key finding on which we have focused here – collaborative inhibition in group retrieval. Collaborative inhibition typically occurs when a collaborative group engages in free recall (Basden et al., 1997; Weldon and Bellinger, 1997). This outcome is consistent with the retrieval disruption account because, as we have noted, free recall relies heavily on the internal organization and strategies of each participant, and the disruption of this strategy lowers each member's contribution to the group product.

This logic predicts that, if more cues are provided as external aids during retrieval, each participant group member would need to rely much less on internal resources. As a result, disruption is less likely to be a factor during the process of collaboration when retrieval cues are present. Current evidence supports this argument. While collaborative inhibition consistently occurs in free recall, this effect disappears in a paired-associate recall task that provides partial study cues, and even reverses in a recognition memory task that recapitulates the entire study item. Finlay et al. (2000) reported a study in which subjects studied pairs of weakly related words. At test, subjects received the first word of the studied pair and recalled the second pair either individually or in pairs. Nominal dyad performance (nonredundant, pooled recall of two individuals who worked alone) did not differ from that of the collaborating dyads even though the typical collaborative inhibition effect occurred with the free-recall task.

Clark and colleagues (2000) used the recognition memory task in their study on collaborative memory with the aim of elucidating the nature of the collaboration process from a different perspective. But their findings are interesting in the present context for yet another, related, reason – the effects of maximal retrieval cues on mediating collaborative memory. Subjects studied a list of unrelated words and were later tested on a recognition memory task that consisted of an intermixed list of studied and nonstudied words. These researchers assessed the performance of three-member collaborative groups against three measures derived from the nominal groups of same size – the best group member, the majority vote, and the average of the group. In all three comparisons, the recognition performance of the collaborative groups exceeded that of the nominal groups. In other words, Clark et al. reported that there was a collaborative facilitation effect in recognition memory.

We have focused on group retrieval to discuss the role of retrieval in assessing memory in a social context. We close this section by briefly describing evidence that has just started to emerge on how social processes can affect individual retrieval. As we noted earlier, the disruptive effects of collaboration are temporary, and later individual recall shows recovery of studied items that were not produced during collaboration.

In a study from our own lab, we examined this effect in recognition. We presented subjects with a list of unrelated words to study and later gave a recognition task in which we assessed effects of collaborative discussion on individual memory (Rajaram and Pereira-Pasarin, 2007). We found that collaborative discussion just prior to making individual recognition responses led to more accurate performance (in both d′ and hits–false alarm measures) than in a retrieval condition that required no prior collaboration. The beneficial effects of collaboration here are impressive because collaboration can potentially affect individual recognition in a negative or a positive direction. It can increase an individual's propensity to go along with the group's input regardless of whether or not it is correct. Individuals can accept nonstudied items as studied, reject studied items, or do both, thereby producing lower memory accuracy. Or, individual subjects can reject more nonstudied items or accept more studied items, or do both, thereby increasing memory accuracy. Yet, group input in our study enhanced individual recognition, and this advantage persisted up to 1 week (see **Figure 4**). As we discuss in a later section titled 'Retrieval errors and other retrieval phenomena,' such benefits do not always occur, because other researchers have shown that input from other group members can sometimes increase memory errors. Regardless, this cluster of findings shows that encoding in and of itself does not determine how much or what an individual will ultimately remember. Retrieval processes – either inherent in the individual or modified by social input – play a large role in determining the final memory output.

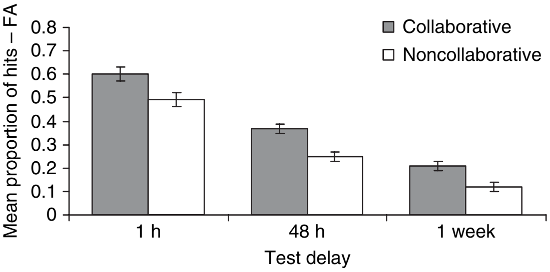

Figure 4 Mean proportion of hits minus false alarms (FA) as a function of collaborative and noncollaborative conditions and retention interval. Adapted from Experiment 2 in Rajaram S and Pereira-Pasarin L (2007) Collaboration can improve individual recognition memory: Evidence from immediate and delayed tests. *Psychon. Bull. Rev.* 14: 95–100.

As Gardner (1985) noted, researchers have tended to set aside social, emotional, and cultural processes in the pursuit of understanding cognition. In other words, researchers have typically viewed social, emotional, and cultural processes as contextual factors whose influences need to be controlled for rather than as key components in understanding cognition. But memory – or more specifically, retrieval – is usually a social process (Weldon, 2001). Not only do people often recall with others (as discussed in this section, and to some extent also in a later section on retrieval errors), but how the recalled information is interpreted is often a function of the person's sociocultural environment. Theories of memory that are based only on the individual are therefore incomplete. The initial evidence (briefly presented earlier; *see* Chapter 2.47) provides initial support for these conclusions and also suggests that future research should focus on social processes of memory as a factor rather than a confounding variable.

To summarize, collaborative inhibition is the counterintuitive finding that collaborative groups are able to recall less information than the pooled nonredundant responses of nominal groups of equal size. This is theorized to be a retrieval effect similar to the part-list cuing effect. Retrieval disruption (created by the recall products of other group members in the case of collaborative retrieval) disrupts individuals' idiosyncratic retrieval strategies and causes poorer overall memory performance. However, this disruption does not seem to impair subsequent individual memory, and in some cases (for instance, as with recognition memory) may actually enhance individual memory.

2.16.7 Retrieval Errors and Other Retrieval Phenomena

Earlier, we reviewed research that shows that repeated retrieval improves memory. As Bjork (1975) noted, retrieval is a memory modifier. Interestingly, the act of retrieval can also reduce memory accuracy. People recall emotional, significant, or entertaining events from their lives often, and it is all too common to embellish the events from one telling to the next or from one audience to another. Bartlett's (1932) classic study is often cited to illustrate how memory output can change from one recall to the next. In this study, people were asked to read a Native American story called 'The War of the Ghosts.' Importantly, the significance of many details in this story was not apparent to people of different cultural backgrounds. The more times that people were asked to retell the story, the more the stories became distorted such that subjects omitted unfamiliar details and inserted materials to make the story consistent with their schemas. These dramatic changes across repeated retrievals have since been replicated in a study by Bergman and Roediger (1999).

Bartlett's (1932) study and Bergman and Roediger's (1999) critical replication show that individuals modify story output even without any intervention from outside sources. It is easy to imagine then that the social situations individuals encounter can change the contents of what individuals might retrieve from one occasion to the next. For example, social situations often dictate whether a story should be told in an accurate or entertaining fashion. In a study by Dudukovic et al. (2004) participants were asked to either retell a story with a goal to be accurate, or with a goal to be entertaining. While the participants did not differ on a later recognition test, they did differ on a later recall test. The participants who had originally told the story accurately recalled more information with less exaggeration than the participants who had originally told the story for entertainment. Thus, the way that we recount information to others influences the way that information is later recalled. As we will describe next, retrieval errors can also creep into individual performance when others provide input during retrieval.

In a previous section on retrieval in a social context, we discussed evidence that shows positive influences of input from others. But individuals also make more retrieval errors under certain conditions if they previously received erroneous input from others. In a study that assessed the effects of social contagion, Roediger et al. (2001) presented subjects with everyday scenes (e.g., a kitchen) during the study phase. Later, subjects recalled the scenes along with a confederate who inserted related but nonstudied items during recall (e.g., toaster). On a final test where subjects engaged in recall alone, they falsely recalled related but nonstudied items more often if they had been inserted by a confederate in the earlier recall phase than if no mention of them had been made.

Basden et al. (2002) reported similar effects of social input in a study where they presented semantically related 'DRM' (Deese-Roediger-McDermott) lists during study and constructed a perceived group-recall situation with the use of interconnected computers. DRM lists consist of thematically related words such as 'dream,' 'bed,' 'night,' etc., where a critical word such as 'sleep' is missing. In individual memory studies, subjects erroneously recall these critical nonpresented words at levels as high as true recall and also give 'remember' responses indicating vivid memory for having seen them before (Roediger and McDermott, 1995). In Basden et al.'s study, subjects engaged in perceived group recall followed by individual recall. During perceived group recall, the subjects were led to believe that they viewed the responses of other group members on the computer screen during recall but in fact the generated responses were controlled by the experimenter. In one condition of perceived group recall, subjects saw the critical, nonpresented lures, and in another condition these items were not included in the supposed responses from other members. Subjects included more erroneous responses in their final individual recall protocols if they had previously participated in one of the two perceived group-recall phases than if they had not participated in the perceived group-recall phase. In this way, individual retrieval can be socially influenced. The process of collaboration can lead to individual retrieval benefits as discussed in the previous section but also to retrieval errors, as these studies show (also see Basden et al., 2000, 2002; Reysen, 2005, for related findings).

Another topic of considerable interest in memory retrieval focuses on the subjects' ability to identify the source of information they recall – a phenomenon called reality monitoring (Johnson and Raye, 1981) The general approach here is to ask subjects whether the item they recalled (or recognized) was presented to them (i.e., the item originated from perception) or was internally generated (i.e., the item was something they imagined or dreamed). According to this framework (e.g., Johnson, 1991; Johnson et al., 1993), people do not explicitly tag memories with source information. Rather, they typically make source attributions based on a generalized evaluation of whether a memory's qualities match expectations. These judgments capitalize on the average differences of the characteristic qualities of memories from different sources. For instance, perceived events tend to include more information about perceptual, temporal, spatial, and affective characteristics and less information about cognitive processes than imagined events. A judgment of 'perceived' rather than 'imagined' should therefore be given if the evaluation of a memory's qualities results in a great deal of information about perceptual and spatial details, accompanied by little information about the cognitive processes that took place during encoding. Attributing a memory to the source for which that memory's qualities are most characteristic maximizes the odds of accurately judging the memory's source. Reality-monitoring failures occur when people falsely claim either that something was perceived when it was actually internally generated or that something was internally generated when it was actually perceived. A detailed review of this topic can be found in a chapter on source monitoring by S. Lindsay (*see* Chapter 2.19) in this volume.

These processes in reality monitoring constitute yet another form of retrieval, one that is characterized by metamemory judgments, because subjects make judgments about information retrieved from memory. In an earlier section on retrieval mode, we described remember and know judgments, which can also be considered metamemory judgments because subjects report the quality of memory for the information they retrieve (see Rajaram and Roediger, 1997; Rajaram, 1999; Roediger et al., 2007). There are also other well-known metamemory judgments such as feelings of knowing (see Koriat, 1995) and the tip-of-the-tongue state (see Brown, 1991; Schwartz et al., 2000) that researchers study to find out subjects' sense of what they can retrieve even when recall does not succeed. These judgments reveal interesting – metacognitive – aspects of the retrieval process as subjects make judgments about the likelihood of retrieval under certain circumstances. In the feeling-of-knowing state (see Koriat, 1995) subjects can reliably report whether they can recognize an item on a multiple-choice test even though they were unable to recall that item, and in the tip-of-the-tongue state, people can reliably indicate whether or not the information they are trying to retrieve is on the tip of their tongue and could be retrieved. We recommend chapters by A. Koriat on control processes in remembering (*see* Chapter 2.18) and by A. S. Brown on the tip-of-the-tongue states (*see* Chapter 2.22) for detailed discussions of these topics.

In conclusion, the ways in which retrieval conditions are arranged to a large extent determine how much memory accessibility can improve. But in many situations, retrieval can also act as a memory modifier and can do so in systematic ways. Such situations can lead to systematic errors in retrieval, as revealed by the DRM effect. Furthermore, when recalling information, people are motivated not only to present a coherent story, but also to tell the story with a particular purpose (for example, to be entertaining). Both of these motivations can serve to lower overall memory accuracy. Retrieval errors can also be the result of social influences (believing that you saw something that someone else endorsed seeing), or reality monitoring errors (believing that you saw something that you only imagined seeing). Finally, many meta-memory processes such as the tip-of-the-tongue phenomenon also modulate the success of retrieval.

2.16.8 Concluding Comments

As we noted in the introduction, much of memory research has been guided by a focus on three putative components – encoding, storage, and retrieval. But from the perspective of the rememberer, it is the act of retrieval that constitutes memory. In this chapter, we have taken this perspective to explore various phenomena in memory research that tell us something important about the process of retrieval and ways in which this process enables access to what we have learned. The phenomena and findings reviewed in this chapter point to the unique role that retrieval processes play in modifying the effects of different encoding processes. Above all, these findings show that, without a proper understanding of the nature and power of retrieval, our understanding of how memory works is not only incomplete but also flawed.

References

Ballard PB (1913) Obliviscence and reminiscence. *Br. J. Psychol.* 1(II): 82.

Balota DA, Duchek JM, Sergent-Marshall SD, and Roediger HL III (2006) Does expanded retrieval produce benefits over equal-interval spacing? Explorations of spacing effects in healthy aging and early stage Alzheimer's disease. *Psychol. Aging* 21(1): 19–31.

Balota DA, Duchek JM, and Logan JM (2007) Is expanded retrieval practice a superior form of spaced retrieval? A critical review of the extant literature. In: Nairne JS (ed.)

The Foundation of Remembering: Essays in Honor of Henry L. Roediger, III, pp. 83–105. New York: Psychology Press.

Bartlett FC (1932) *Remembering: A Study in Experimental and Social Psychology*. Oxford, England: Macmillan.

Basden BH, Basden DR, Bryner S, and Thomas RL III (1997) A comparison of group and individual remembering: Does collaboration disrupt retrieval strategies? *J. Exp. Psychol. Learn. Mem. Cogn.* 23(5): 1176–1191.

Basden BH, Basden DR, and Henry S (2000) Costs and benefits of collaborative remembering. *Appl. Cogn. Psychol.* 14: 497–507.

Basden BH, Reysen MB, and Basden DR (2002) Transmitting false memories in social groups. *Am. J. Psychol.* 115(2): 211–231.

Basden DR and Basden BH (1995) Some tests of the strategy disruption interpretation of part-list cuing inhibition. *J. Exp. Psychol. Learn. Mem. Cogn.* 21(6): 1656–1669.

Basden DR, Basden BH, and Galloway BC (1977) Inhibition with part-list cuing: Some tests of the item strength hypothesis. *J. Exp. Psychol. Hum. Learn. Mem.* 3(1): 100–108.

Basden DR and Draper JS (1973) Effect of cueing with list members in free recall as a function of number of categories, taxonomic frequency, and presentation order. *Can. J. Psychol.* 27(3): 327–333.

Beck RC and McBee W (1995) Mood-dependent memory for generated and repeated words: Replication and extension. *Cogn. Emot.* 9(4): 289–307.

Bergman ET and Roediger HL III (1999) Can Bartlett's repeated reproduction experiments be replicated? *Mem. Cognit.* 27(6): 937–947.

Birnbaum IM and Eichner JT (1971) Study versus test trials and long-term retention in free-recall learning. *J. Verbal Learn. Verbal Behav.* 10(5): 516–521.

Bjork RA (1975) Retrieval as a memory modifier. In: Solso R (ed.) *Information Processing and Cognition: The Loyola Symposium*, pp. 123–144. Hillsdale, NJ: Erlbaum.

Bjork RA (1994) Memory and metamemory considerations in the training of human beings. In: Metcalfe J and Shimamura AP (eds.) *Metacognition: Knowing about Knowing*, pp. 185–205. Cambridge, MA: The MIT Press.

Bjork RA (1999) Assessing our own competence: Heuristics and illusions. In: Gopher D and Koriat A (eds.) *Attention and Performance XVII: Cognitive Regulation of Performance: Interaction of Theory and Application*, pp. 435–459. Cambridge, MA: The MIT Press.

Bjork RA and Bjork EL (1992) A new theory of disuse and an old theory of stimulus fluctuation. In: Healy AF, Kosslyn SM, and Shiffrin RM (eds.) *Essays in Honor of William K. Estes, Vol. 2: From Learning Processes to Cognitive Processes*, pp. 35–67. Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Blaney PH (1986) Affect and memory: A review. *Psychol. Bull.* 99(2): 229–246.

Blaxton TA (1989) Investing dissociations among memory measures: Support for a transfer-appropriate processing framework. *J. Exp. Psychol. Learn. Mem. Cogn.* 15: 657–668.

Bower GH (1981) Mood and memory. *Am. Psychol.* 36(2): 129–148.

Bower GH and Mayer JD (1989) In search of mood-dependent retrieval. *J. Soc. Behav. Personal.* 4(2): 121–156.

Bower GH, Monteiro KP, and Gilligan SG (1978) Emotional mood as a context for learning and recall. *J. Verbal Learn. Verbal Behav.* 17(5): 573–585.

Brown AS (1991) A review of the tip-of-the-tongue experience. *Psychol. Bull.* 109(2): 204–223.

Brown W (1923) To what extent is memory measured by a single recall? *J. Exp. Psychol.* 6(5): 377–382.

Clark SE, Hori A, Putnam A, and Martin TP (2000) Group collaboration in recognition memory. *J. Exp. Psychol. Learn. Mem. Cogn.* 26(6): 1578–1588.

Craik FI and Lockhart RS (1972) Levels of processing: A framework for memory research. *J. Verbal Learn. Verbal Behav.* 11(6): 671–684.

Craik FI and Tulving E (1975) Depth of processing and the retention of words in episodic memory. *J. Exp. Psychol. Gen.* 104(3): 268–294.

Donaldson W (1971) Output effects in multitrial free recall. *J. Verbal Learn. Verbal Behav.* 10(5): 577–585.

Dudukovic NM, Marsh EJ, and Tversky B (2004) Telling a story or telling it straight: The effects of entertaining versus accurate retellings on memory. *Appl. Cogn. Psychol.* 18(2): 125–143.

Eich E (1985) Context, memory, and integrated item/context imagery. *J. Exp. Psychol. Learn. Mem. Cogn.* 11(4): 764–770.

Eich E (1995a) Mood as a mediator of place dependent memory. *J. Exp. Psychol. Gen.* 124(3): 293–308.

Eich E (1995b) Searching for mood dependent memory. *Psychol. Sci.* 6(2): 67–75.

Eich E, Macaulay D, and Ryan L (1994) Mood dependent memory for events of the personal past. *J. Exp. Psychol. Gen.* 123(2): 201–215.

Eich E and Metcalfe J (1989) Mood dependent memory for internal versus external events. *J. Exp. Psychol. Learn. Mem. Cogn.* 15(3): 443–455.

Eich JE (1980) The cue-dependent nature of state-dependent retrieval. *Mem. Cognit.* 8(2): 157–173.

Eich JE, Weingartner H, Stillman RC, and Gillin JC (1975) State-dependent accessibility of retrieval cues in the retention of a categorized list. *J. Verbal Learn. Verbal Behav.* 14(4): 408–417.

Erdelyi MH (1984) The recovery of unconscious (inaccessible) memories: Laboratory studies of hypermnesia. In: Bower GH (ed.) *The Psychology of Learning and Motivation: Advances in Research and Theory,* vol. 18, pp. 95–127. New York: Academic Press.

Erdelyi MH and Becker J (1974) Hypermnesia for pictures: Incremental memory for pictures but not words in multiple recall trials. *Cogn. Psychol.* 6(1): 159–171.

Erdelyi MH, Finks J, and Feigin-Pfau MB (1989) The effect of response bias on recall performance, with some observations on processing bias. *J. Exp. Psychol. Gen.* 118(3): 245–254.

Erdelyi MH and Kleinbard J (1978) Has Ebbinghaus decayed with time? The growth of recall (hypermnesia) over days. *J. Exp. Psychol. Hum. Learn. Mem.* 4(4): 275–289.

Fernandez A and Glenberg AM (1985) Changing environmental context does not reliably affect memory. *Mem. Cognit.* 13(4): 333–345.

Finlay F, Hitch GJ, and Meudell PR (2000) Mutual inhibition in collaborative recall: Evidence for a retrieval-based account. *J. Exp. Psychol. Learn. Mem. Cogn.* 26(6): 1556–1567.

Gardiner JM (1988) Functional aspects of recollective experience. *Mem. Cognit.* 16(4): 309–313.

Gardiner JM and Conway MA (1999) Levels of awareness and varieties of experience. In: Challis BH and Velichkovsky BM (eds.) *Stratification in Cognition and Consciousness*, pp. 237–254. Amsterdam: John Benjamins Publishing Company.

Gardiner JM and Richardson-Klavehn A (2000) Remembering and knowing. In: Tulving E and Craik FIM (eds.) *The Oxford Handbook of Memory*, pp. 229–244. New York: Oxford University Press.

Gardner H (1985) *The Mind's New Science: A History of the Cognitive Revolution*. New York: Basic Books.

Gates AI (1917) Recitation as a factor in memorizing. *Arch. Psychol.* 6(40).

Godden DR and Baddeley AD (1975) Context-dependent memory in two natural environments: On land and underwater. *Br. J. Psychol.* 66(3): 325–331.

Graf P and Mandler G (1984) Activation makes words more accessible, but not necessarily more retrievable. *J. Verbal Learn. Verbal Behav.* 23(5): 553–568.

Graf P and Schacter DL (1985) Implicit and explicit memory for new associations in normal and amnesic subjects. *J. Exp. Psychol. Learn. Mem. Cogn.* 11(3): 501–518.

Hamann SB (1990) Level-of-processing effects in conceptually driven implicit tasks. *J. Exp. Psychol. Learn. Mem. Cognit.* 16: 970–977.

Hamilton M and Rajaram S (2001) The concreteness effect in implicit and explicit memory tests. *J. Mem. Lang.* 44(1): 96–117.

Hamilton M and Rajaram S (2003) States of awareness across multiple memory tasks: Obtaining a 'pure' measure of conscious recollection. *Acta Psychol.* 112(1): 43–69.

Hogan RM and Kintsch W (1971) Differential effects of study and test trials on long-term recognition and recall. *J. Verbal Learn. Verbal Behav.* 10(5): 562–567.

Jacoby LL (1978) On interpreting the effects of repetition: Solving a problem versus remembering a solution. *J. Verbal Learn. Verbal Behav.* 17(6): 649–667.

Jacoby LL and Dallas M (1981) On the relationship between autobiographical memory and perceptual learning. *J. Exp. Psychol. Gen.* 110(3): 306–340.

Jacoby LL, Yonelinas AP, and Jennings JM (1997) The relation between conscious and unconscious (automatic) influences: A declaration of independence. In: Cohen JD and Schooler JW (eds.) *Scientific Approaches to Consciousness*, pp. 13–47. Hillsdale, NJ: Lawrence Erlbaum Associates.

Johnson MK (1991) Reflection, reality monitoring, and the self. In: Kunzendorf RG (ed.) *Mental Imagery*, pp. 3–16. New York: Plenum Press.

Johnson MK, Hashtroudi S, and Lindsay DS (1993) Source monitoring. *Psychol. Bull.* 114(1): 3–28.

Johnson MK and Raye CL (1981) Reality monitoring. *Psychol. Rev.* 88(1): 67–85.

Kang SHK, McDermott KB, and Roediger HL (2007) Test format and corrective feedback modify the effect of testing on memory retention. *Eur. J. Cogn. Psychol.* 19: 528–558.

Kirsner K, Milech D, and Standen P (1983) Common and modality-specific processes in the mental lexicon. *Mem. Cognit.* 11: 621–630.

Kohler W (1947) *Gestalt Psychology,* 2nd edn. Oxford: Liveright.

Kolers PA and Roediger HL (1984) Procedures or mind. *J. Verbal Learn. Verbal Behav.* 23: 425–449.

Koriat A (1995) Dissociating knowing and the feeling of knowing: Further evidence for the accessibility model. *J. Exp. Psychol. Gen.* 124(3): 311–333.

Lachman ROY and Laughery KR (1968) Is a test trial a training trial in free recall learning? *J. Exp. Psychol.* 76(1, Pt.1): 40–50.

Landauer TK and Bjork RA (1978) Optimum rehearsal patterns and name learning. In: Gruneberg MM, Morris PE, and Sykes RN (eds.) *Practical Aspects of Memory*, pp. 625–632. London: Academic Press.

Lockhart RS and Craik FI (1990) Levels of processing: A retrospective commentary on a framework for memory research. *Can. J. Psychol.* 44(1): 87–112.

Logan JM and Balota DA (in press) Expanded versus equal interval spaced retrieval practice: Exploration of schedule of spacing and retention interval in younger and older adults. *Aging Neuropsychol. Cognit.*

Lowe G (1982) Alcohol-induced state-dependent learning: Differentiating stimulus and storage hypotheses. *Curr. Psychol. Res.* 2(3): 215–222.

Madigan S (1983) Picture memory. In: Yuille JC (ed.) *Imagery, Memory, and Cognition: Essays in Honor of Allan Paivio*, pp. 65–89. Hillsdale, NJ: Erlbaum Associates.

McDaniel MA (2007) Transfer. In: Roediger HL III, Dudai Y, and Fitzpatrick SM (eds.) *The Science of Learning and Memory: Concepts*, pp. 267–270. Oxford: Oxford University Press.

McDaniel MA, Anderson DC, Einstein GO, and O'Halloran CM (1989) Modulation of environmental reinstatement effects through encoding strategies. *Am. J. Psychol.* 102(4): 523–548.

McDaniel MA, Anderson JL, and Derbish MH (2007) Testing the testing effect in the classroom. *Eur. J. Cogn. Psychol.* 19: 494–513.

McDaniel MA, Kowitz MD, and Dunay PK (1989) Altering memory through recall: The effects of cue-guided retrieval processing. *Mem. Cognit.* 17(4): 423–434.

McDaniel MA and Masson ME (1985) Altering memory representations through retrieval. *J. Exp. Psychol. Learn. Mem. Cogn.* 11(2): 371–385.

Morris CD, Bransford JD, and Franks JJ (1977) Levels of processing versus transfer appropriate processing. *J. Verbal Learn. Verbal Behav.* 16(5): 519–533.

Paivio A (1969) Mental imagery in associative learning and memory. *Psychol. Rev.* 76(3): 241–263.

Paivio A, Rogers TB, and Smythe PC (1968) Why are pictures easier to recall than words? *Psychon. Sci.* 11(4): 137–138.

Payne DG (1986) Hypermnesia for pictures and words: Testing the recall level hypothesis. *J. Exp. Psychol. Learn. Mem. Cogn.* 12(1): 16–29.

Payne DG (1987) Hypermnesia and reminiscence in recall: A historic and empirical review. *Psychol. Bull.* 101: 5–27.

Rajaram S (1993) Remembering and knowing: Two means of access to the personal past. *Mem. Cognit.* 21(1): 89–102.

Rajaram S (1999) Assessing the nature of retrieval experience: Advances and challenges. In: Challis BH and Velichkovsky BM (eds.) *Stratification in Cognition and Consciousness*, pp. 255–275. Amsterdam, Netherlands: John Benjamins Publishing Company.

Rajaram S and Pereira-Pasarin L (2007) Collaboration can improve individual recognition memory: Evidence from immediate and delayed tests. *Psychon. Bull. Rev.* 14: 95–100.

Rajaram S and Roediger HL (1993) Direct comparison of four implicit memory tests. *J. Exp. Psychol. Learn. Mem. Cogn.* 19(4): 765–776.

Rajaram S and Roediger HL III (1997) Remembering and knowing as states of consciousness during retrieval. In: Cohen JD and Schooler JW (eds.) *Scientific Approaches to Consciousness*, pp. 213–240. Hillsdale, NJ: Lawrence Erlbaum Associates.

Reysen MB (2005) The effects of conformity on recognition judgments. *Memory* 13: 87–94.

Roediger HL (1990) Implicit memory: Retention without remembering. *Am. Psychol.* 45(9): 1043–1056.

Roediger HL III (2000) Why retrieval is the key process in understanding human memory. In: Tulving E (ed.) *Memory, Consciousness, and the Brain: The Tallinn Conference*, pp. 52–75. New York: Psychology Press.

Roediger HL and Blaxton TA (1987) Effects of varying modality, surface features, and retention interval on priming in word-fragment completion. *Mem. Cognit.* 15: 379–388.

Roediger HL III and Challis BH (1989) Hypermnesia: Improvements in recall with repeated testing. In: Izawa C (ed.) *Current Issues in Cognitive Processes: The Tulane Flowerree Symposium on Cognition*, pp. 175–199. Hillsdale, NJ: Lawrence Erlbaum Associates.

Roediger HL III and Guynn MJ (1996) Retrieval processes. In: Bjork EL and Bjork RA (eds.) *Memory*, pp. 197–236. San Diego, CA: Academic Press.

Roediger HL III and Karpicke JD (2006a) Test-enhanced learning: Taking memory tests improves long-term retention. *Psychol. Sci.* 17(3): 249–255.

Roediger HL and Karpicke JD (2006b) The power of testing memory: Basic research and implications for educational practice. *Perspect. Psychol. Sci.* 1: 181–210.

Roediger HL and McDermott K (1993) Implicit memory in normal human subjects. In: Boller F and Grafman J (eds.) *Handbook* *of Neuropsychology,* vol. 8, pp. 63–131. Amsterdam: Elsevier.

Roediger HL and McDermott KB (1995) Creating false memories: Remembering words not presented in lists. *J. Exp. Psychol. Learn. Mem. Cogn.* 21(4): 803–814.

Roediger HL III, Meade ML, and Bergman ET (2001) Social contagion of memory. *Psychon. Bull. Rev.* 8(2): 365–371.

Roediger HL and Neely JH (1982) Retrieval blocks in episodic and semantic memory. *Can. J. Psychol.* 36(2): 213–242.

Roediger HL and Payne DG (1982) Hypermnesia: The role of repeated testing. *J. Exp. Psychol. Learn. Mem. Cogn.* 8(1): 66–72.

Roediger HL, Rajaram S, and Geraci L (2007) Three forms of consciousness in retrieving memories. In: Moscovitch M, Zelazo P, and Thompson E (eds.) *Cambridge Handbook of Consciousness*, pp. 251–288. London: Cambridge University Press.

Roediger HL, Rajaram S, and Srinivas K (1990) Specifying criteria for postulating memory systems. *Ann. N. Y. Acad. Sci.* 608: 572–595.

Roediger HL and Thorpe LA (1978) The role of recall time in producing hypermnesia. *Mem. Cognit.* 6(3): 296–305.

Roediger HL III, Weldon MS, and Challis BH (1989) Explaining dissociations between implicit and explicit measures of retention: A processing account. In: Roediger HL III and Craik FIM (eds.) *Varieties of Memory and Consciousness: Essays in Honour of Endel Tulving*, pp. 3–41. Hillsdale, NJ: Lawrence Erlbaum Associates.

Roediger HL, Weldon MS, Stadler ML, and Riegler GL (1992) Direct comparison of two implicit memory tests: Word fragment and word stem completion. *J. Exp. Psychol. Learn. Mem. Cogn.* 18(6): 1251–1269.

Roenker DL, Thompson CP, and Brown SC (1971) Comparison of measures for the estimation of clustering in free recall. *Psychol. Bull.* 76(1): 45–48.

Rosner SR (1970) The effects of presentation and recall trials on organization in multitrial free recall. *J. Verbal Learn. Verbal Behav.* 9(1): 69–74.

Rundus D (1971) Analysis of rehearsal processes in free recall. *J. Exp. Psychol.* 89: 63–77.

Schacter DL (1982) *Stranger behind the Engram: Theories of Memory and the Psychology of Science*. Hillsdale, NJ: Erlbaum Associates.

Schacter DL (1987) Implicit memory: History and current status. *J. Exp. Psychol. Learn. Mem. Cogn.* 13(3): 501–518.

Schacter DL (1990) Introduction to 'Implicit memory: Multiple perspectives.' Bull. Psychon. Soc.28(4): 338–340.

Schacter DL (2001) *Forgotten Ideas, Neglected Pioneers: Richard Semon and the Story of Memory*. New York: Psychology Press.

Schacter DL, Bowers J, and Booker J (1989) Intention, awareness, and implicit memory: The retrieval intentionality criterion. In: Lewandowsky S, Dunn JC, and Kirsner K (eds.) *Implicit Memory: Theoretical Issues*, pp. 47–65. Hillsdale, NJ: Lawrence Erlbaum Associates.

Schacter DL, Eich JE, and Tulving E (1978) Richard Semon's theory of memory. *J. Verbal Learn. Verbal Behav.* 17(6): 721–743.

Schwartz BL, Travis DM, Castro AM, and Smith SM (2000) The phenomenology of real and illusory tip-of-the-tongue states. *Mem. Cognit.* 28(1): 18–27.

Semon R (1921) *The Mneme*. London: Allen and Unwin.

Shapiro SR and Erdelyi MH (1974) Hypermnesia for pictures but not for words. *J. Exp. Psychol.* 103: 1218–1219.

Slamecka NJ (1968) An examination of trace storage in free recall. *J. Exp. Psychol.* 76(4, Pt.1): 504–513.

Smith SM (1988) Environmental context – dependent memory. In: Davies GM and Thomson DM (eds.) *Memory in Context: Context in Memory*, pp. 13–34. Oxford: John Wiley and Sons.

Smith SM, Glenberg A, and Bjork RA (1978) Environmental context and human memory. *Mem. Cognit.* 6(4): 342–353.

Spitzer (1939) Studies in retention. *J. Educ. Psychol.* 30: 641–656.

Srinivas K and Roediger HL (1990) Classifying implicit memory tests: Category association and anagram solution. *J. Mem. Lang.* 29: 389–412.

Thompson CP, Wenger SK, and Bartling CA (1978) How recall facilitates subsequent recall: A reappraisal. *J. Exp. Psychol. Hum. Learn. Mem.* 4(3): 210–221.

Thomson DM and Tulving E (1970) Associative encoding and retrieval: Weak and strong cues. *J. Exp. Psychol.* 86(2): 255–262.

Tulving E (1962) Subjective organization in free recall of 'unrelated' words. *Psychol. Rev.* 69(4): 344–354.

Tulving E (1967) The effects of presentation and recall of material in free-recall learning. *J. Verbal Learn. Verbal Behav.* 6(2): 175–184.

Tulving E (1974) Cue-dependent forgetting. *Am. Sci.* 62(1): 74–82.

Tulving E (1983) *Elements of Episodic Memory*. New York: Oxford University Press.

Tulving E (1985) Memory and consciousness. *Can. Psychol.* 26(1): 1–12.

Tulving E (2002) Episodic memory: From mind to brain. *Annu. Rev. Psychol.* 53(1): 1–25.

Tulving E and Osler S (1968) Effectiveness of retrieval cues in memory for words. *J. Exp. Psychol.* 77(4): 593–601.

Tulving E and Pearlstone Z (1966) Availability versus accessibility of information in memory for words. *J. Verbal Learn. Verbal Behav.* 5(4): 381–391.

Tulving E and Thomson DM (1973) Encoding specificity and retrieval processes in episodic memory. *Psychol. Rev.* 80(5): 352–373.

Warrington EK and Weiskrantz L (1968) A study of learning and retention in amnesic patients. *Neuropsychologia* 6(3): 283–291.

Warrington EK and Weiskrantz L (1970) Amnesic syndrome: Consolidation or retrieval? *Nature* 228: 628–630.

Weingartner H, Miller H, and Murphy DL (1977) Mood-state-dependent retrieval of verbal associations. *J. Abnorm. Psychol.* 86(3): 276–284.

Weldon MS (1991) Mechanisms underlying priming on perceptual tests. *J. Exp. Psychol. Learn. Mem. Cogn.* 17: 526–541.

Weldon MS (2001) Remembering as a social process. In: Medin DL (ed.) *The Psychology of Learning and Motivation: Advances in Research and Theory,* vol. 40, pp. 67–120. San Diego, CA: Academic Press.

Weldon MS and Bellinger KD (1997) Collective memory: Collaborative and individual processes in remembering. *J. Exp. Psychol. Learn. Mem. Cogn.* 23(5): 1160–1175.

Weldon MS, Blair C, and Huebsch D (2000) Group remembering: Does social loafing underlie collaborative inhibition? *J. Exp. Psychol. Learn. Mem. Cogn.* 26(6): 1568–1577.

Weldon MS and Roediger HL (1987) Altering retrieval demands reverses the picture superiority effect. *Mem. Cognit.* 15: 269–280.

Wheeler MA, Ewers M, and Buonanno JF (2003) Different rates of forgetting following study versus test trials. *Memory* 11(6): 571–580.

Wheeler MA and Roediger HL (1992) Disparate effects of repeated testing: Reconciling Ballard's (1913) and Bartlett's (1932) results. *Psychol. Sci.* 3(4): 240–245.

Wright DB and Klumpp A (2004) Collaborative inhibition is due to the product, not the process, of recalling in groups. *Psychon. Bull. Rev.* 11(6): 1080–1083.