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The Six R's of Remembering

COLIN M. MacLEOD
University of Waterloo

Abstract
Although complex and multifaceted, memory can be distilled into a small set of very fundamental principles—the six R's of memory. The first is *recoding*, whereby what is actually experienced is transformed on its way into memory with the goal of establishing associations that enrich memory. The second is *rehearsal*, whereby what has been experienced (and likely recoded) is reviewed with the goal of strengthening memory. The third is *relearning*, whereby memory is enhanced by reexperiencing, without the necessity of awareness. The fourth is *reminding*, whereby the encoding of an event invokes the memory of a related previous event, which in turn benefits remembering. The fifth is *retrieval*, whereby what has already entered memory is recollected, typically with the goal of responding but also with significant implications for subsequent remembering. The sixth is *reconstruction*, whereby the components of episodes are assembled for the purpose of recollection and where the use of schemata and associations alters memory. Together, these six processes capture much of the richness and power of memory.

Keywords: memory, recoding, rehearsal, relearning, reminding, retrieval, reconstruction

In a century and a half of empirical and theoretical research on memory, we have learned a great deal about how this most human of systems works. As is true for any science, however, we still have a very long way to go: One of the beautiful things about learning is that it is never completed. It has been my privilege to be a part of this quest to understand what makes us ourselves for 40 years, decades that have passed with the fleeting yet indelible quality of memory itself. In that time, I have been struck by the recurrence of one letter—the letter "R." I have not felt persecuted, as Miller (1956) felt by the digit "7," but I have felt . . . watched or guided by the letter "R." So many of what I think of as the basic components of remembering—the processes that have interested me for these four decades—begin with this letter that I have decided to build this article around the letter "R" in tribute.

Table 1 contains a list of the six R's that I see as fundamental to how memory works. In what follows, I will take each of these in turn and describe in brief some of the influential research that has validated that process. This will certainly not be a thorough and complete analysis of each process—this is not meant to be a review article and anyway, each of these would warrant a review in its own right—but hopefully the centrality of each process will become evident. As it happens, in one way or another through my career, I have investigated all of these, and consequently I will also incorporate some personal examples in this sketch.

These six processes can be roughly categorized into two groups. Recoding, rehearsal, and relearning correspond more to what are traditionally thought of as encoding processes, in that they promote entry of events into memory; reminding, retrieval, and reconstruction correspond more closely to what are traditionally thought of as recovery processes, in that they promote inspection of events already in memory. I note this distinction with some trepidation because I am very much a proceduralist, influenced by the ideas of Kolers (1973) and Kolers and Roediger (1984). Under the proceduralist analysis, as we process an event, we create a record of that processing, integrating the present with the remembered past. Later, we can replay that record, which, if accompanied by conscious recognition, will produce the experience of remembering and which will also augment memory. In this framing of memory, each instance of encoding involves retrieval, and each instance of retrieval involves encoding, so that there is no sharp dividing line to separate encoding from retrieval.

Proceduralism stands in stark contrast to the more common, received view of memory based on the library metaphor. In this much less dynamic view, information is abstracted from the events that are experienced, and this extracted information is stored away. It is rather like reading a book, extracting some information, and then putting only the extracted information away on the library shelf. This is what is learned, what is encoded. When it is time to remember, the stored extract is taken from its shelf and consulted; this is retrieval. There is much less room for the active construction

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Correspondence concerning this article should be addressed to Colin M. MacLeod, Department of Psychology, University of Waterloo, Waterloo, ON N2L 3G1, Canada. E-mail: cmacleod@uwaterloo.ca

Table 1
The Six Rs of Remembering

Process	Definition
Recoding	The transformation of what is actually experienced on its way into memory
Rehearsal	The review of an already recoded experience in memory
Relearning	The (unaware) enhancement of memory by reexperiencing
Reminding	The association in memory between two related events
Retrieval	The recovery of previously learned information from memory
Reconstruction	The assembling of an episode in memory for the purpose of recollection

and reconstruction operations that we now know characterize memory. Memory is simply too static under this perspective.

So let us examine the operations of memory from the standpoint of the dynamic proceduralist view and consider how these operations are orchestrated to enable the many memory feats that we can accomplish. The six R's articulate beautifully to permit us to interact successfully with the environment in much the way that vision does—imperfectly but optimally. If we could see much better than we do, we would likely be seeing the random firings on our retinas; if we could remember much better than we do, we would remember events that we do not want to remember, events that are best forgotten. It is for this reason that William James wrote, in one of his most famous passages, "In the practical use of our intellect, forgetting is as important a function as remembering . . .. If we remembered everything, we should on most occasions be as ill off as if we remembered nothing" (James, 1890, p. 680). The operations that correspond to the six R's make this optimization possible.

Recoding

The very fact that we experience illusions—the tone that keeps on getting higher (Shepard, 1964) or the apparent motion of a sequence of dots that brighten sequentially (Wertheimer, 1912)—is indicative that we do not experience the world around us isomorphically to the way it really is. We interpret the world, and in so doing we change it to mesh with existing memories. There is evidence of this interpretation throughout the many levels of processing that we perform. From the beginning of the cognitive revolution, recoding has played a central role, demonstrating that we routinely go beyond the stimuli that are present.[1]

Recoding was really the major focus of the classic "7 ± 2" article by Miller (1956), one of Psychology's most cited articles ever. For this very reason, he introduced the concept of the "chunk"—the idea of grouping input to make it easier to handle. What is a chunk? Miller did not really define it, but almost 20 years later, Simon (1974) tried to, concluding that a chunk is essentially a pointer from working memory to a coherent entity in long-term memory. The letters "N," "A," "T," and "E" are four chunks until I notice that they spell out my son's name, at which point they become one chunk. Chunks recode events into superordinate events.

If you are presented with a letter string such as QVANROZJ and asked look at it and recall it, you will almost certainly do a better job than if the presented string is PVGEDTCB. Yet each string is eight letters, so why is the second string harder? What Conrad (1964) and Wickelgren (1965a, 1965b) demonstrated in early studies of working memory is that visual information is routinely recoded to be auditory, consistent with the idea that working memory really serves language. And once you recode these strings, you suffer much more interference for the second string because all of the letters sound alike. Despite the visual presentation, then, it is the auditory recoding in working memory that you work with.

At a higher level of processing, we see recoding in memory in the demonstration of false memory introduced by Deese (1959) and reintroduced by Roediger and McDermott (1995). In what is now known as the DRM paradigm, you are exposed to a list of 12 words, such as *web, insect, bug, fright, fly, arachnid, crawl, tarantula, poison, bite, creepy,* and *animal* for study. Later on, in attempting to recall this list, you are very likely to intrude one particular word that you did not study—*spider*. Presumably, you interpreted the words semantically as you experienced them, leading to recoding that resulted in the one unstudied word that was associated to each of the studied words being "experienced" as well. Intriguingly, this routine processing occurs even when your attention is directed away from the words: The false recall of "spider" is just as likely after naming the colors in which the words are printed as after reading the words themselves (Dodd & MacLeod, 2004).

One of the best known demonstrations of recoding is the classic study of Carmichael, Hogan, and Walter (1932) using as the study materials simple pictures like two circles joined by a line. Some subjects were given the verbal description "barbell," whereas others were given the verbal description "eyeglasses." When subjects later tried to draw the pictures from memory, they drew pictures that clearly were influenced by the verbal labels. This study has been highly influential, including providing a starting point for the eyewitness memory research of Loftus (e.g., Loftus, Miller, & Burns, 1978), who argued similarly that verbal and visual information become integrated. The Carmichael et al. study is often used to suggest integration during encoding, but a much less well-known study by Hanawalt and Demarest (1939) questions whether this is the whole story. They simply showed the Carmichael et al. pictures at the time of study without any labels at all but then prompted picture recall with the different labels at the time of test and obtained essentially identical results to those of Carmichael et al. Does the recoding of the pictures occur during encoding or during retrieval? Based on these two studies, the answer seems to be "yes": It occurs during both, exactly what a proceduralist would expect.

An obscure little study of mine also makes the point that the recoding can occur at the time of test (MacLeod, 1986). Subjects were shown a series of 20 "Droodle" pictures without labels at study (examples are shown in Figure 1; see Price, 1972). All subjects were naïve about Droodles. Then at test they were given 40 labels one at a time and asked whether they had seen that picture during study. They could not have recoded the pictures

[1] Using the term "recoding" instead of encoding helps to emphasize that what enters memory is not what is experienced, but an interpretation of what is experienced.

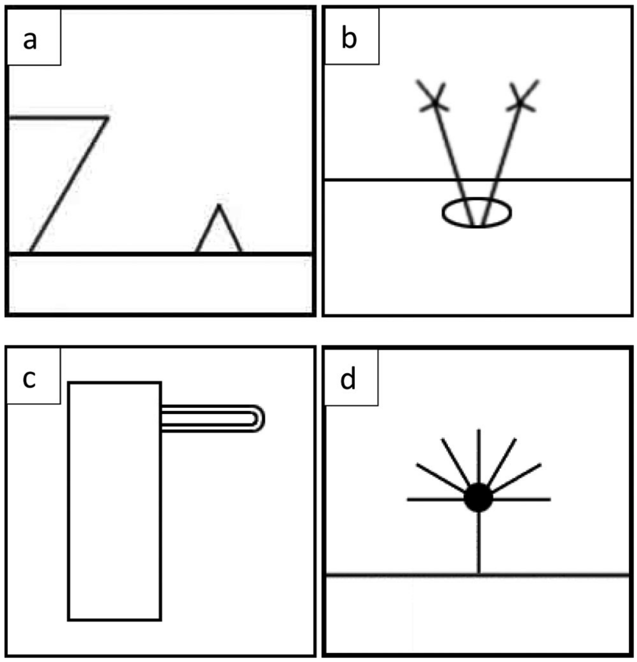

Figure 1. Four examples of Droodle line-drawing pictures used in MacLeod (1986). (a) A ship approaching a drowning witch, (b) an early bird who caught a strong worm, (c) a tall man playing a trombone in a phone booth, and (d) a spider doing a handstand.

with these labels during study; indeed, subjects often reported the labels that they did try to create, which were never the Droodle labels. Yet they were excellent at differentiating labels for studied Droodles from those for unstudied Droodles, often with laughing recognition. Clearly, we can recode information even when it is already stored in memory in a different format.

Most recently, with the graduate students in my laboratory, I have been conducting a series of experiments on a phenomenon that we call the *production effect*. Very simply, saying a word aloud leads to better memory than does reading a word silently (Forrin, Ozubko, & MacLeod, 2012; Hourihan & MacLeod, 2008; Lin & MacLeod, 2012; MacLeod, 2011; MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010; Ozubko, Gopie, & MacLeod, 2012; Ozubko, Hourihan, & MacLeod, 2012; Ozubko & MacLeod, 2010). We now know that the act of production, whether oral or not (e.g., written or typed), increments both recognition and recall substantially. Moreover, this act appears to provide a constant boost beyond the improvement caused by a number of other stimulus changes: Figure 2 illustrates this for recall of pictures and words, which appear to benefit equally from production (MacLeod, Ozubko, Forrin, & Hourihan, 2012; see also Forrin, MacLeod, & Jonker, 2012).

Production is a very simple recoding, perhaps the simplest one of all, yet it makes a substantial difference in memory. In this section, we have seen just how powerfully recoding influences memory, from working memory through long-term memory. Recoding can condense a stimulus event to "pack more in" (e.g., via chunking), or it can elaborate an experience, enriching it and associating it to existing memories (e.g., eyewitness memory). The job of recoding is to make records that are entering memory—or that are being recovered from memory—more compatible with the records that are already there.

Rehearsal

Everyone uses rehearsal. We recycle a phone number in our "mind's ear" until we can actually dial it. We go over a joke repeatedly so that we can remember it and pass it on. Studying for an exam, we go over and over the material, the repetition intended to "stamp in" the material. Simple rote rehearsal of this form may in fact be the single learning strategy to which we turn with the highest frequency, despite a vast memory literature telling us that this is not a good way to learn. We assume, for example, that actors learn their lines by rote repetition, but research with actors indicates that this is not what they do: Instead, they use strategies like elaboration, self-reference, generation, and distinctiveness (Noice & Noice, 2006), all principles of effective learning that have been introduced and studied by memory researchers. Yet rehearsal lives on.

In the influential Atkinson and Shiffrin (1968) model, a primary function of short-term memory is rehearsal, both to keep information active (sometimes called maintenance rehearsal) and to promote the transfer of information to long-term memory (sometimes called elaborative rehearsal). Rehearsal is viewed as internal repetition in working memory. We know that repetition improves memory (Hintzman, 1976; Nelson, 1977), and research also shows that rehearsal improves memory. Rundus (1971) had subjects rehearse aloud so that he could count their rehearsals and was able to show a tight correlation between the number of rehearsals that an item received and its likelihood of later recall. He even showed that an odd item in a list, which is well established to be well remembered (cf. the von Restorff effect), was remembered so well in large part because it was rehearsed more often than other items (see Kelley & Nairne, 2001, for a detailed account).

For my part, I have long been interested in rehearsal in the context of directed forgetting (Golding, Long, & MacLeod, 1994; Hourihan & MacLeod, 2008; Hourihan, Ozubko, & MacLeod, 2009; MacLeod, 1975, 1989a, 1999; MacLeod & Daniels, 2000; for a review, see MacLeod, 1998). There are two directed forgetting variants, one where each item is followed by an instruction either to remember or forget that item—the item method—and

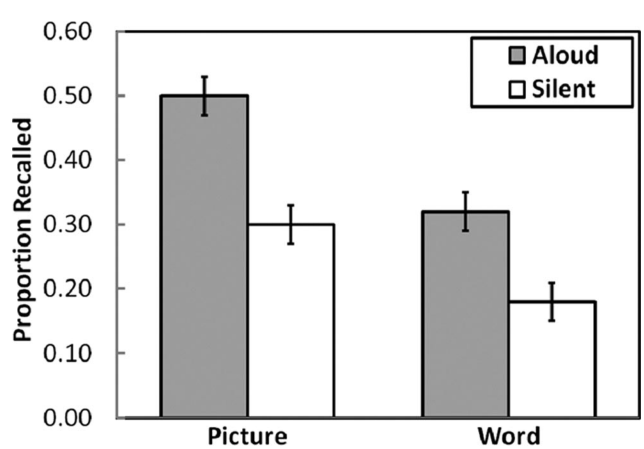

Figure 2. Proportion of pictures and words correctly recalled as a function of whether they were named/read aloud versus silently at study. Error bars are standard errors. Data are taken from MacLeod, Ozubko, Forrin, and Hourihan (2012, Experiment 4).

another where an initial list is followed by an instruction to forget and a subsequent list is followed by an instruction to remember—the list method. In both cases, later recall is poorer for the to-be-forgotten items. In the item method, but not in the list method, later recognition is also poorer. For this reason, it is frequently argued that in the item method the active ingredient is rehearsal. The idea is that subjects hold each item in abeyance in working memory until its instruction appears. If the item is to-be-remembered, then it is actively rehearsed. If the item is to-be-forgotten, it receives no further processing; indeed, any available time might instead be devoted to rehearsal of prior to-be-remembered items. This selective rehearsal of to-be-remembered items fully accounts for their later superior memory.

It has been argued that the list method requires a different mechanism given that subjects do not know that there will be an instruction to forget the first list. Two alternative mechanisms have been put forth: inhibition and context change. Under the inhibition view (Geiselman, Bjork, & Fishman, 1983), when the instruction to forget is given, the subject then suppresses the first list, which is consequently made less available for retrieval-demanding recall, leading to a directed forgetting effect in recall. For recognition, however, because the actual studied items are present at test, there is no directed forgetting effect. You cannot inhibit an item that is in front of you. Under the context change view (Sahakyan & Kelley, 2002), because the test follows the remember list, the context cues available at test better match the more recent remember list than the older forget list, resulting in a recall cost for the to-be-forgotten items. The absence of a directed forgetting effect in recognition also makes sense in that context change generally does not affect recognition, certainly not to the extent that it affects recall.

Either of these accounts could be correct—although I have argued elsewhere against inhibition accounts of memory (MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003)— but in Sheard and MacLeod (2005), we suggested that selective rehearsal could also account for the list method results. Essentially, we argued that the smaller directed forgetting effect under the list method relative to the item method could be caused by selective rehearsal of only some of the items in the forget set—notably, the items near the end of the to-be-forgotten list, which have not yet been extensively rehearsed when the instruction to forget is given. We should see these terminal items of the to-be-forgotten list showing especially poor memory if their rehearsal is truncated by the instruction. And that is indeed what we did see in a serial position analysis of list method directed forgetting, as portrayed in Figure 3. Moreover, the marked primacy of the to-be-remembered list makes sense, too, in that rehearsals would be diverted from the last few to-be-forgotten items to the first few to-be-remembered items. The selective rehearsal account readily handles these list method sequence patterns, and it certainly would be more parsimonious to have a single explanation for the findings from the two methods.

Rehearsal patterns can help us to understand memory phenomena that might otherwise require more elaborate explanations, as the von Restorff results of Rundus (1971) demonstrated. Consider flashbulb memories, the vivid, compelling memories that we have for signal emotional events, such as the assassination of John F. Kennedy or the 9/11 attack on the World Trade Center. Since the original study by Brown and Kulik (1977), this type of memory has fascinated researchers and the general public. Although it is

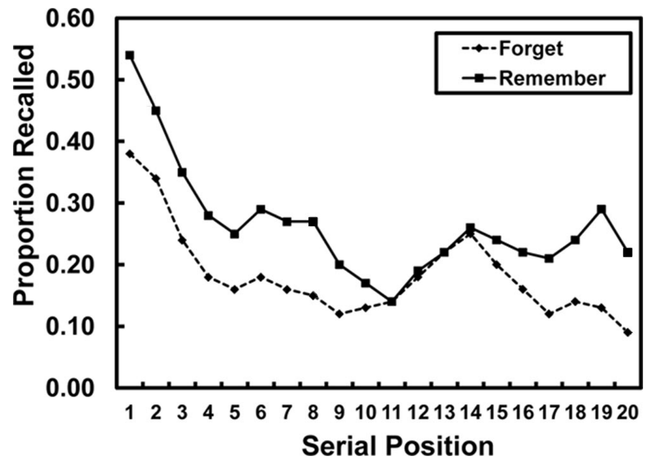

Figure 3. Proportion of words correctly recalled from the to-be-forgotten and to-be-remembered lists as a function of list serial position in a list method directed forgetting experiment. Data are taken from Sheard and MacLeod (2005).

true that the experience of a flashbulb memory seems to require a high level of surprise and perhaps emotional arousal, when these two factors are sufficiently high, according to Brown and Kulik (p. 73), "they seem, most directly, to affect the frequency of rehearsal, covert and overt, which, in turn, affects the degree of elaboration in the narrative of the memory" (see also Rubin & Kozin, 1984). Talarico and Rubin (2003) suggest that the principal characteristic of flashbulb memories is not their accuracy, which numerous studies have questioned (e.g., McCloskey, Wible, & Cohen, 1988; Neisser & Harsch, 1992), but their *perceived* accuracy—the confidence that we have in them, confidence that appears to be misplaced. Rehearsal may well underlie this heightened confidence.

Clearly, then, rehearsal is critical to remembering. People often attribute their successful remembering of something—a certain fact or a domain of knowledge—to factors such as motivation or interest or even ease. However, it is very likely that each of these factors, when operative, exerts its influence through rehearsal: That I am interested in popular music leads me to rehearse that knowledge, both overtly and covertly, more often than I do other domains, and it is that rehearsal that underlies my good memory. McGeoch (1932) captured this idea well in arguing that it is not the age of the memory that causes it to be forgotten, but the processes that have occurred in that time. Very often, rehearsal is that process.

Relearning

"You never forget how to ride a bicycle." Unpacking this familiar adage a little, what it is really saying is that there is something left in memory even long after an event and that memory residue is useful when the event is encountered again. The idea is that this residue can help you learn faster on a second occasion even if you have no conscious memory for the first occasion. Intriguingly, this principle formed the basis of the earliest empirical research on memory. In his studies of his own memory, Ebbinghaus (1885; see Nelson, 1985) would learn a list of nonsense syllables, manipulating a factor such as list length or retention interval, and then later would learn the list again. He measured how many trials it took him to learn the list on each occasion, and if it was fewer on the second occasion, then he took this as evidence of retention of some information from the first occasion. This method—called relearning—allowed him to measure the residue in memory, and this residue has come to be called *savings*. It is important to realize that this method required no conscious knowledge of the previous occasion, so Ebbinghaus really introduced the first implicit measure of memory. The distinction between implicit (unaware) memory and explicit (aware) memory has been one of the most influential ideas in the study of memory in the past 30 years (Graf & Schacter, 1985; Schacter, 1987).

The savings technique reappeared aperiodically over the years, but was revived in the 1970s by Nelson (1971), Nelson, Fehling, and Moore-Glascock (1979), and Kolers (1976). Kolers used relearning to measure retention of skill, in particular the skill of reading text in unusual orientations, such as upside down and backwards, and demonstrated extraordinary memory for form even a year after a single reading, despite no conscious recollection at all. Nelson used relearning to explore the nature of the savings residue, demonstrating savings for the sound and the meaning of words and showing savings to be a very sensitive index, able to detect small amounts of information left in memory from a prior processing event (Nelson, 1978).

In my dissertation (MacLeod, 1976), I had subjects learn a list of paired associates, some in English and some in French (e.g., 27-maison; 56-horse; 81-chair), in a study session. Weeks later, when they returned to be tested, they had forgotten many of the pairs. I then presented them with a new list composed of some identical pairs (e.g., 56-horse), some translated pairs (e.g., 27-house), and some wholly new pairs (e.g., 81-pencil). The focus was on how well subjects relearned pairs that they had forgotten during the retention interval. Compared with control (new) pairs, how did subjects relearn identical versus translated pairs? The answer was that they relearned these equivalently: Savings appeared to be essentially language-free, preserving meaning regardless of language.

Some years later, I extended my exploration of savings to the domain of pictures (MacLeod, 1988). In a series of experiments, I showed savings for words and pictures, both line drawings and more complex photographs. Confirming Nelson's (1978) finding, this savings was evident even when the test that determined what was forgotten (prior to relearning) was recognition, again showing the sensitivity of relearning. Interestingly, though, the test following relearning had to be recall: A post-relearning recognition test gave no evidence of savings. This suggested to me at the time that relearning might actually influence retrieval, and not just encoding, given that recognition would appear to require less retrieval than recall.

Earlier, I noted the importance of the implicit/explicit distinction in memory research over the past 30 years or so. This has also been an aspect of memory in which I have been particularly interested (e.g., Bassili, Smith, & MacLeod, 1989; Hourihan & MacLeod, 2007; MacDonald & MacLeod, 1998; MacLeod, 1976, 1988, 1989a, 1989b, 1996, 2008; MacLeod & Daniels, 2000; MacLeod & Masson, 1997, 2000; Masson & MacLeod, 1992, 1996, 2002; Roefs et al., 2011; Smith, MacLeod, Bain, & Hoppe, 1989; Szymanski & MacLeod, 1996). Relearning is one technique for examining implicit memory, but there are many others. Just to illustrate, in MacLeod (1989b), I examined the role of context in implicit memory. Subjects read isolated words in lists or they read words embedded in disconnected text or in meaningful text. Afterward, they were asked to do a word fragment completion task, where words with letters removed were to be solved (e.g., A - - A - - I N). Some of the word fragments were studied words; some were not. The results showed that priming—the benefit for word fragments previously studied over those not previously studied—was greatest for isolated word, then for words in disconnected text, and finally for words in connected text. Essentially, the more embedded words were in context, the less they showed benefits in implicit memory. It was clear that context plays a role in implicit memory.

In fact, the term priming, like the term relearning, suggests a first time and a second time for learning, but of course, we are constantly relearning. Indeed, presumably every time we reencounter an event, we do some relearning, which may be in large part responsible for the preservation of memories over the long term. This would be true when the reencounter is in the world, when it is in a retrieved memory, or when the two collide—when something in the world makes contact with a memory, by way of a reminding. Relearning is neither encoding nor retrieval: it is the coming together of encoding and retrieval. It can be explicit, as when we consciously restudy material in preparing for an exam, but is more frequently implicit, as when we drive a route again or play a card game again. This leads smoothly, then, to consideration of the next three R's, which are more connected to retrieval.

Reminding

You notice your neighbor in his driveway and suddenly think, "Oh, I've been meaning to ask him if I can borrow some lawn chairs for the party next week." Your neighbor is the prompt for your intention in memory. Reminding happens all the time, as one event bridges to another event in memory. Possibly the best example of this is the whole class of events that has come to be called prospective memory—memory for the future, as in remembering that you have a doctor's appointment coming up this afternoon. A burgeoning literature now exists on prospective memory (see, e.g., Einstein & McDaniel, 2008).

Studies of reminding outside the domain of prospective memory are considerably less common (see Benjamin, 2011). Recently, however, Hintzman (2004, 2008, 2010, 2011) has been championing an analysis of reminding, laying out the core idea this way:

> The basic memory system encodes information automatically whenever we pay attention to something. Remindings—and recursive encodings of the experience of reminding—also arise automatically as a result of our interaction with the environment. An encoded reminding represents the relationship between two (or more) experiences that took place at different times. (Hintzman, 2011, p. 267)

The idea is that experiencing an event a second time (or experiencing an event closely related to an earlier event) should routinely cause a reminding, creating a third encoding to accompany the original encoding and the second encoding. This third encoding should be very beneficial for recall, where retrieval demands are greatest, but less so for recognition, where retrieval demands are less. As well, in keeping with the transfer appropriate processing principle (Morris, Bransford, & Franks, 1977), a reminding should be most beneficial when encoding of the two occurrences of an event is done in a very similar way so that good contact is made.

With my colleagues, I have recently begun to try to explore reminding (MacLeod, Pottruff, Forrin, & Masson, 2012). We had subjects study a list of words where some were read once, some were read twice, some were generated once from a definition (e.g., the tiny infant who sleeps in a cradle—b?), and some were generated twice from the same definition. We expected to see benefits of generating (Bertsch, Pesta, Wiscott, & McDaniel, 2007; Slamecka & Graf, 1978) and of repeated reading (Hintzman, 1970, 1976; Nelson, 1977), but our interest centered on what would happen for repeated generation. Figure 4 provides the answer. What we saw was a very large boost in recall for items generated twice, but a smaller effect in recognition, consistent with a reminding providing a retrieval benefit. When we modeled the data, the fit was much better when we included the additional reminding encoding than when we did not include it. We are currently pursuing other ways to examine the role of reminding.

Over 25 years ago, I had approached reminding differently (MacLeod, 1985). I was interested in the best way to learn and sought to compare two different ways to study. The first was the standard procedure, wherein subjects have multiple cycles of studying and being tested on all of the material. The second was selective reminding (Buschke, 1973), wherein items correct on any given test cycle are dropped out of subsequent study cycles and are only tested thereafter (if they were incorrect on a subsequent test, they were reinstated into study until they were correct again, at which point they were dropped out again). It turned out that performance under the two procedures was identical in many ways: cycles to reach errorless performance, number of items correct on a delayed test, number of items relearned, subjective organization on all tests, and error patterns on all tests. Indeed, it appeared that there were no performance differences at all, but there was a major difference nonetheless: Subjects learned a lot faster under the selective reminding procedure because they did not have to restudy items that they already had learned. Selective reminding saved time and did so with apparently no cost, as long as these learned items continued to be tested.

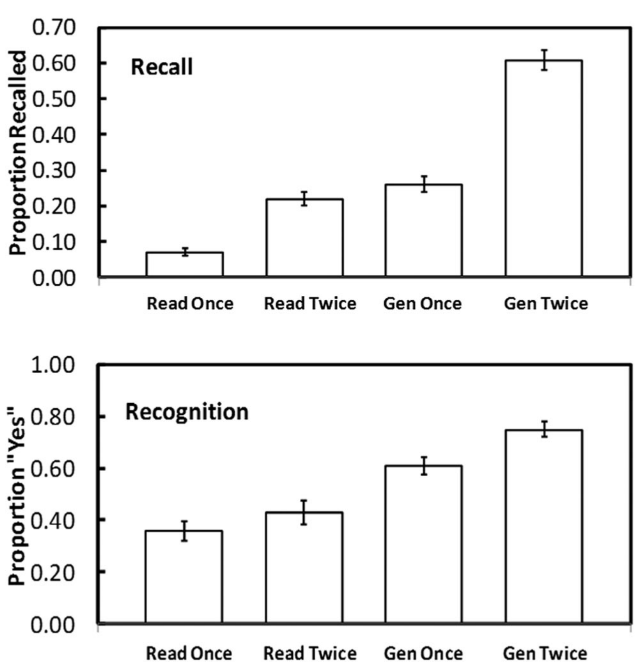

Figure 4. Proportion of words correctly recalled (top panel) and correctly recognized (bottom panel) as a function of whether the word was read or generated once or twice. Error bars are standard errors. For the recognition data, the false alarm rate was .16. Data are taken from MacLeod, Pottruff, Forrin, and Masson (2012, Experiments 2a and 2b).

Hintzman (2011) is right: Reminding warrants further study. What would happen, for example, in a continuous recognition paradigm (see, e.g., MacLeod & Nelson, 1976) wherein subjects judge for each item whether they have seen it before in the list? This would allow determination of whether conscious recognition of repetition is necessary for the benefit of reminding to be observed. My strong suspicion is that consciousness is necessary, but it would certainly be interesting to know. Perhaps, if there are unconscious remindings, this might shed a different light on phenomena such as déjà vu (see Brown, 2003, Brown & Marsh, 2010). The concept of reminding is, of course, closely related to the concept of retrieval, to which I turn next.

Retrieval

People tend to think of learning as the difficult problem and memory as taking care of itself. They accept that it is hard to study but assume that once you have studied sufficiently, remembering what you have studied should be quite automatic. Memory researchers know how wrong this perspective is. Retrieval is not automatic. This is revealed by the importance of the match between the processes engaged during encoding and those engaged during retrieval, as articulated by the transfer appropriate processing principle (Morris et al., 1977; see also the encoding specificity principle, Tulving & Thomson, 1973). The contexts of encoding and retrieval are critical; indeed, memory is exquisitely contextual. Examples of this abound, including state-dependent memory, where remembering is more successful when in the same state at both encoding and retrieval (see, e.g., Eich, 1989). An oft-cited example is that scuba divers remember better if they are on land or under water for both encoding and retrieval and less well if the encoding and retrieval conditions differ (Godden & Baddeley, 1975).

However, the issues surrounding retrieval are even more complicated. The natural assumption about retrieval seems to be that it is simply the "read out" of information from memory, with no consequences for memory. This, too, is wrong. Every retrieval is also an encoding, altering what is retrieved. Ordinarily, the alteration strengthens the memory, but there can also be distortions through adding new information, or the like. We will see more about how memories change during retrieval in the next section on reconstruction. For now, I want to consider how retrieval functions to improve memory, focusing first on the recent work on the testing effect.

The testing effect refers to the benefit of retrieval practice—of how testing oneself on information improves memory for that information (see, e.g., Carpenter, Pashler, Wixted, & Vul, 2008; Roediger & Karpicke, 2006). A study by Karpicke and Roediger (2008) shows just how strong this effect is. They had subjects learn 40 Swahili-English pairs under one of four study–test regimens. One group followed the standard practice of studying and testing all pairs on every study–test cycle (AS,AT). Another group followed the selective reminding procedure described in the previous section: When a pair was correct on a test, that pair was removed from subsequent study, such that only incorrect pairs were studied but all pairs were tested (IS,AT). For the third group, when a pair was correct, it continued to be studied, but only incorrect pairs were tested again (AS,IT). For the final group, only items that had been incorrect were studied and tested in subsequent cycles (IS,IT).

All groups learned the list of pairs equally well. What was remarkable, however, was how they performed on a test 1 week later. These data are shown in Figure 5. The huge difference between the two groups on the left versus on the right in the figure is accounted for not by study but by test. Groups AS,AT and IS,AT differed in whether items were studied further once they had been correct once, yet that did not matter. (It is worth noting that this replicates the finding in MacLeod [1985].) The same was true of Groups AS,IT and IS,IT: They differed in study but not in test, but again that did not matter. What did matter—a great deal—was the extent of testing. Yet the subjects were completely unaware of the benefit of testing. Indeed, this study flies in the face of the popular wisdom that once something is learned, it is all right to stop testing it further. In fact, testing continues to be very beneficial.

Our understanding of the value of testing continues to grow. Very recently, Brewer and Unsworth (2012) have demonstrated reliable individual differences in the degree of benefit from the testing effect, showing that students of lower intelligence and poorer memory abilities benefit more from testing than do students of higher ability. It is quite rare to find treatments that actually decrease the learning gap, so this is really very promising. Rawson and Dunlosky (2011) have also suggested how to optimize the testing benefit, concluding on the basis of their research that students should practice recalling information until they have been successful three times and then should relearn that information three further times, spacing the relearning intervals out widely. This conclusion regarding spreading practice out nicely articulates with longstanding advice (see Landauer & Bjork, 1978) and recent evidence as well (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006) concerning the value of dispersing learning. What is also clear is that the dispersion of testing, not just of studying, is important.

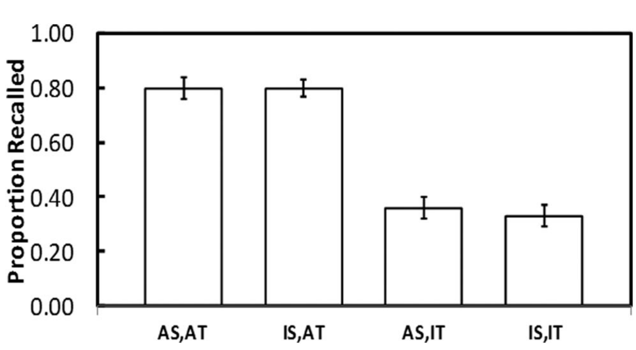

Figure 5. Proportions of Swahili-English word pairs correctly recalled after one week. For each study-test cycle, the conditions are: all studied, all tested (AS,AT); incorrect studied, all tested (IS,AT); all studied, incorrect tested (AS,IT); incorrect studied, incorrect tested (IS,IT). Error bars are standard errors. Data are taken from Karpicke and Roediger (2008).

When we think about retrieval, we need to think not only about what is being retrieved but also about how that information has been transmitted. Everyone has had the experience of having trouble remembering where they obtained a piece of information—from a friend, the TV, the newspaper? This problem is the problem of source memory, which has been extensively studied (see, e.g., Johnson, Hashtroudi, & Lindsay, 1993, for a review). Recently, though, it occurred to me that the opposite problem also exists: remembering to whom I transmitted information, which can be referred to (for parallelism) as the issue of destination memory. In Gopie and MacLeod (2009), we began to explore this problem.

We reasoned that it would be informative to compare destination memory to source memory, given the extensive source memory literature. The paradigm we came up with involved simple facts and famous faces. When the fact (e.g., "a shrimp's heart is in its head") was presented after the famous face (e.g., Oprah Winfrey), this was as if the person was telling the subject the fact, a source memory situation. When the fact was presented before the face, then the subject was to tell the fact to the face, a destination memory situation. When we did this experiment, we found that destination memory was worse than source memory. Two further experiments helped to elucidate the reason. First, when we made the destination more salient by having the subject say the famous person's name aloud before relaying the fact, destination memory errors decreased. Second, when we switched the information to be more personal (e.g., "My astrological sign is Pisces"), destination memory errors increased.

From these data patterns, we reasoned that destination memory is poor because we tend to focus on ourselves and what we are saying, rather than thinking about the person to whom we are relaying the information. This self-focus increases when the information being relayed is personal; it decreases when we take steps to enhance the salience of the destination. Although self-focus can enhance encoding and retrieval more generally (see Rogers, Kuiper, & Kirker, 1977), it appears to undermine retrieval of destination information because it directs attention away from the destination. Gopie, Craik, and Hasher (2010) have gone on to show that destination memory is a particular problem for aging as well.

Retrieval clearly plays a crucial role in the successful operation of memory. What is not intuitive, but what the literature resoundingly shows, is that retrieval plays a critical role in encoding as well as in recovering memories. For successful remembering, we must not only encode effectively, but we must be certain that we can readily access the encoded information, and retrieval practice plays a pivotal role in ensuring that access. Yet it is also important to realize that retrieval can change what is in memory and that it is never a perfectly accurate representation of experience, given the recoding, rehearsal, relearning, and reminding processes that have preceded it. This is best demonstrated in the context of the final R.

Reconstruction

In launching the new field with his book, *Cognitive Psychology*, Neisser (1967) developed a few key themes as superordinate principles of cognition. A major one of these was that cognition is—from perception right through to higher cognitive processes—constructive or reconstructive. The system is not literal: It builds cognitions from the available information, stitching the pieces together with the best "story line" that it can create. Top-down processes are every bit as important as bottom-up processes. Nowhere did he see this as more true than in the domain of memory, strongly influenced by Bartlett (1932).

This idea of reconstruction, so revolutionary in 1967, is now fundamental to our understanding of memory. We can see it in the classic work of Bransford and Franks (1971), which showed that once overarching ideas had been abstracted from a set of component inputs, it was not possible to go backward to the components. We often rely on gist, from which we build a plausible memory (see Reyna & Brainerd, 1992). We can see reconstruction in the false memory work in the lab (Roediger & McDermott, 1995) and beyond (Laney & Loftus, 2010), but most of all, we can see it in the highly influential work of Loftus on eyewitness memory (Loftus, 1979; Loftus & Ketcham, 1991). The combining of information from different sources is just one aspect of this reconstruction that Loftus has shown to be highly influential in our memory for events that we have witnessed.

A good illustration comes from one of the very earliest of the studies of eyewitness memory from the Loftus laboratory. Loftus and Palmer (1974) showed subjects slides of a staged car accident and then asked them questions. One of the questions manipulated the verb, asking "How fast were the cars going when they ________ each other?" Subjects gave higher speed estimates to more dramatic verbs (i.e., "smashed into" led to higher speed estimates than did "contacted"). The finding that the verbs influenced memory is by itself interesting and consistent with reconstructive remembering, but what was especially interesting was that when subjects were later asked, "Did you see any broken glass?" they were significantly more likely to say "yes" after having heard the dramatic verb. In reconstructing the visual information in memory, the speed estimates clearly were taken into account despite the fact that the initial speed question did not specifically address broken glass at all.

We did a study some years ago that shows just how broad this integration is in memory (Wiseman, MacLeod, & Lootsteen, 1985). We showed people a quite large set of natural photographs of diverse scenes. For some of these photos, a blank screen followed; this was the control condition. For others, a sentence followed. Sometimes the sentence was unrelated to the photo, as in a photo of a skiing scene followed by the sentence "This university has an excellent reputation for research and is considered to have a top-ranking student population." Sometimes the sentence could be related, but in a different way than is usually done in experiments that explore integration. An example would be a photo of a busy intersection in a city that was followed by the sentence, "A serious traffic accident occurred here yesterday." In our related case, there was nothing in the picture that the sentence explicitly pointed to; instead, the sentence just provided a kind of nonvisual context for a more extended story. Relative to no sentence, even an unrelated sentence improved memory for a picture, but a related one improved memory more. Because they followed the pictures, these sentences clearly were augmenting memory for the pictures. We hypothesized that the sentences led subjects to review and rehearse the pictures, so even unrelated sentences were beneficial, but that by introducing context, the related sentences led to the development of a larger story.

It is certainly apparent, then, that reconstruction has a sweeping influence on memory. However, it should not be surprising, given the five other R's that have already been described. Because from the outset we do not have a literal memory of exactly what happened, construction of an episode or event initially and reconstruction of that episode or event subsequently are necessary, and with each construction or reconstruction, change is inevitable.

The Big Picture

In this article, I have sketched with the lightest strokes a picture of some of the key processes in memory. What emerges is a picture of a remarkably dynamic system, not at all the videotape model that people often assume. Memory is constantly changing—from the online processing of the world around us and the events that take place in that world to our subsequent recollections of our experience. I have also tried to show how this perspective has influenced my own research over the years with some example studies of my own, relating them to some of the hallmark studies in the field of memory. I will end by showing how the six R's fit together in the context of one "real world" memory situation.

To return to one of the earlier themes in this article, consider again flashbulb memories—vivid, compelling memories for major events in the world or in our lives, such as the terrorist attack of 9/11. Even during our first experience of the event, we alter it, recoding what is happening online. Our past experience inevitably influences how we see what is happening now; existing memories color new memories. Moreover our memory for such events is very much a function of the covert and overt rehearsal that we do of these events. We think about these events over and over and we tell and retell our story to others—and listen in turn to their stories. All of this influences our memory, providing repeated opportunities for relearning so that what we remember over time becomes an amalgam of these diverse experiences. Related events—an airline crash or a terrorist attack elsewhere in the world—remind us of the target event, leading to further rehearsal and further opportunities for integration across events. Even our own retrievals contaminate our initial recollection, and each time we retrieve and tell our story, we are reconstructing it, taking the pieces—old and new—and assembling them into a plausible account, one that will subsequently modify our memory yet again.

I am not plagued by the six R's; I am intrigued by them. They contribute to the richness of memory, the literature of mind. Memory is what we are, who we are, so doing research to understand how memory works is a high calling, and, of course, as a new science, we have only begun to peel away the layers. Just as our memory will never be full, our understanding of memory will never be complete—but the journey will always be fascinating.

Résumé

Complexe et à multiples facettes, la mémoire peut être divisée en six unités de principes fondamentaux, les six R. Le premier élément est la reprogrammation, qui permet de transformer ce qui est vécu dans son cheminement vers la mémoire, dans le but d'établir des associations qui enrichissent la mémoire. Le deuxième est la répétition, qui permet de revoir ce qui a été vécu (et probablement reprogrammé) dans le but de renforcir la mémoire. Le troisième élément est le réapprentissage, qui permet l'amélioration de la mémoire par la reviviscence, même en l'absence de la conscience. Le quatrième est le rappel, où

l'encodage d'un événement invoque la mémoire d'un autre événement antérieur, qui en retour favorise le rappel. Le cinquième est la récupération : ce qui est déjà en mémoire est rappelé à l'esprit, le plus souvent dans le but de réagir, mais cette fonction a aussi des répercussions importantes pour le rappel ultérieur. Le sixième est la reconstruction : les éléments des épisodes sont réunis à des fins de remémoration, et l'usage de schémas et d'associations modifie la mémoire. Ensemble, ces six processus captent en grande partie toute la richesse et la puissance de la mémoire.

Mots-clés : mémoire, reprogrammation, répétition, réapprentissage, rappel, récupération, reconstruction.

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