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ON THE SYMBIOSIS OF REMEMBERING, FORGETTING, AND LEARNING

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It is natural for people to think that learning is a matter of building up skills or knowledge in one's memory, and that forgetting is a matter of losing some of what was built up. From that perspective, learning is a good thing and forgetting is a bad thing. The relationship between learning and forgetting is not, however, so simple, and in certain important respects is quite the opposite: Conditions that produce forgetting often enable additional learning, for example, and learning or recalling some things is a contributor to the forgetting of other things.

My goal in this chapter is to characterize the interdependencies of remembering, forgetting, and learning—interdependencies that essentially define the unique functional architecture of how humans learn and remember, or fail to learn and remember. After some comments on the importance of forgetting, I discuss how learning and remembering contribute to forgetting; why forgetting enables, rather than undoes, learning; and why the interplay of forgetting, remembering, and learning is adaptive and yet poorly understood by the user.

WHY FORGETTING IS IMPORTANT

One of the "important peculiarities of human memory" that motivated Elizabeth Bjork and me to propose our new theory of disuse framework (Bjork & Bjork, 1992), to which I refer intermittently in this chapter, is that human memory is characterized by a storage capacity that is essentially unlimited, coupled with a retrieval capacity that is severely limited. At any one point in time, most of the vast amount of information that exists in our memories (names, facts, procedures, numbers, events, and so forth), all of which was recallable at earlier points in time, is not recallable. Even the most overlearned information, such as a combination lock number, or phone number, or street address, which may have been instantly and automatically recallable after a long period of use, becomes nonrecallable after a long enough period of disuse—but remains in memory.

We labeled our framework a "new theory of disuse" to distinguish it from Thorndike's (1914) original "law of disuse," which asserted that memories, without continued use or access, decay from memory. Instead, we argue—as many others have—that although memories become inaccessible without continued use and access, they remain in memory. The theory distinguishes between the *retrieval strength* of a memory representation—that is, how activated or accessible it is at a given point in time, which is influenced by local conditions, such as recency and current cues—and the *storage strength* of that representation, which is an index of how entrenched or interassociated that representation is with related representations in memory. Recall is assumed to be entirely determined by current retrieval strength, whereas storage strength is a latent variable that acts to retard the loss (forgetting) and enhance the gain of retrieval strength. Other assumptions of the theory are mentioned below where they are relevant to particular interactions of remembering, forgetting, and learning.

The failure to recall information we know exists in our memories is a major frustration, but were everything in our memories to be recallable, we would suffer greater frustrations. Even recalling one's current phone number, for example, would become a slow and error-prone process if every number one has had across one's lifetime were to come to mind, requiring some kind of decision process to select the current number. As William James (1980) was one of the first to emphasize, "If we remembered everything, we should on most occasions be as ill off as if we remembered nothing" (p. 680).

In short, because we remember so much, we do not *want* everything in our memories to be accessible. We have a constant burden, for example, to keep our memories current. We need to remember our current phone number, not our prior phone number; we need to remember where we parked the car today, not yesterday or a week ago; we need to remember how some current software or hardware works, not how the prior versions work; and on and on. Such updating, as I and my

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collaborators have argued in multiple papers over the years (e.g., Bjork, 1970, 1972, 1978, 1989; Bjork, Bjork, & Anderson, 1998), requires some mechanism to set aside, inhibit, or erase information that is now out of date and, hence, a source of errors and confusion. Without some such mechanism, I have argued, we would "degenerate to a proactive-interference-induced state of total confusion" (Bjork, 1972, p. 218).

The mechanism in the case of human memory, in my view, is retrieval inhibition, which I have argued is a broadly adaptive mechanism in human memory (Bjork, 1989). Without continuing access and use, previously learned information and procedures are not lost from memory, but become inaccessible—except, possibly, when highly distinctive situational, interpersonal, or body state cues associated with a given memory are reinstated. That is, retrieval of the information or procedures in question becomes inhibited—and, as I sketch in the next section, learning and remembering other information and procedures contributes to such inhibition.

HOW LEARNING AND REMEMBERING CONTRIBUTE TO FORGETTING

Why do we forget information that was once recallable? The principal answer to that question, alluded to above, is not that the information—like footprints in the sand—fades away or decays in our memories over time, as was thought to be the case by researchers during the early decades of controlled research on memory (e.g., Thorndike, 1914). The decay idea, which remains compelling to most people based on their introspections, was instantiated in Thorndike's law of disuse, as mentioned above. Thorndike's law, though, came to be thoroughly discredited, starting with a devastating critique by McGeoch (1932). Instead, McGeoch argued, information that has been stored in our long-term memories tends to remain there, but it can become inaccessible (forgotten) owing to one or both of two factors: "reproductive inhibition," which refers to losing access to information in memory by virtue of interference from competing information in memory; and "altered stimulating conditions," which refers to the changing of the retrievel cues that are available to us as we move on with our lives. (For a brief history of research on interference and forgetting, see Bjork, 2003).

Learning, therefore, contributes to forgetting. As we learn new information, procedures, and skills, we create the potential for competition with related information, skills, and procedures that already exist in memory. Access to that earlier learning can then be inhibited or blocked by related aspects of the newer, and perhaps more accessible, learning. (Whether the primary mechanism is inhibition or blocking remains a matter of current dispute; see the section on inhibition in Roediger, Dudai, & Fitzpatrick, 2007). Such competition, however, goes both ways: Earlier learned information can also block or inhibit access to more recently learned information. That is, to use the jargon of research on interference and forgetting, we are subject to both retroactive interference and proactive interference.

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Retrieval as a Memory Modifier

The results of more recent research add to the picture sketched above. The act of retrieving information from our memories does much more than simply reveal that the information in question exists in our memories. In fact, retrieving information modifies our memories: The retrieved information becomes more recallable than it would have been otherwise, and other information in competition with the retrieved information—that is, information associated to the same retrieval cue or set of cues—becomes less accessible. Using our memories, in effect, alters our memories; that is, retrieval is a "memory modifier" (Bjork, 1975). In our new theory of disuse, Elizabeth Bjork and I concur with Thorndike's assertion that disuse is a key factor in forgetting, but not because unused memories decay, but rather because access to those memories becomes inhibited—owing, primarily, to retrieval of competing memories (Bjork & Bjork, 1992).

Demonstrations of what might be considered the positive effects of retrieval as a memory modifier—that retrieving information from memory is a powerful learning event—trace back across almost 100 years of the research literature (e.g., Bjork, 1975, 1988; Carrier & Pashler, 1992; Gates, 1917; Glover, 1989; Hogan & Kintsch, 1971; Izawa, 1970; Landauer & Bjork, 1978; Landauer & Eldridge, 1967; McDaniel & Masson, 1985; Spitzer, 1939; Tulving, 1967; Whitten & Bjork, 1977), and there has recently been renewed interest in such effects, given their pedagogical implications (e.g., Karpicke & Roediger, 2008; Morris & Fritz, 2000; Pashler, Zarow, & Triplett, 2003; Roediger & Karpicke, 2006a; Storm, Bjork, & Storm, in press). For present purposes, however, it is the negative effects of retrieval as a memory modifier—termed *retrieval-induced forgetting* by Anderson, Bjork, and Bjork (1994)—that are of interest: that is, the loss of access to information that is in competition with the retrieved information.

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It is only from one perspective, however, that retrieval-induced forgetting is a negative effect. From another perspective, retrieval-induced forgetting modifies the accessibility of information in memory in adaptive ways. As we use our memories, we make more accessible the information, procedures, and skills we are using, and we make less accessible competing information, procedures, or skills. The interpretation my collaborators and I have advocated (e.g., Anderson, 2003; Anderson et al., 1994; Anderson, Bjork, & Bjork, 2000; Anderson & Spellman, AU: 1998 meant? 1995; Bjork, Bjork, & Anderson, 1996; Storm, Bjork, Bjork, & Nestojko, 2007) is that the act of recalling information from memory requires AU: 2006 in references. not only that the information be selected and produced, but also that other information associated to the same cues be selected against and not produced. The information selected against is inhibited, rendering it less accessible should it be the target of recall in the future (for arguments against inhibitory accounts, see MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003; Perfect et al., 2004). How long such inhibitory effects might last is a matter of current research and debate, but Storm, Bjork, and Bjork (2008) have obtained evidence that the recall of items repeatedly suggested against goes to essentially zero within a single experimental session. Whether repeatedly making items the target of retrieval-induced forgetting across experimental sessions would make those items permanently inaccessible—at least in the absence of very specialized and discriminating retrieval cues—remains to be seen.

Adaptive Aspects of the Interplay of Forgetting and Remembering

Beyond the general consideration that forgetting is important, given the storage and retrieval characteristics of human memory and the ongoing need we have to keep our memories current, there are other, more specific reasons why the interplay of forgetting and remembering is adaptive. Compared to some kind of system in which out-of-date memories were to be overwritten or erased, for example, having such memories become inaccessible, but remain in storage, has important advantages. Because those memories are inaccessible, they do not interfere with the retrieval of current information and procedures, but because they remain in memory they can—at least under some circumstances—be recognized when presented and, more importantly, be relearned at an accelerated rate, should that be desirable. In fact, some of the findings discussed in the next section suggest that such inhibited memories are uniquely relearnable, especially if they were strongly encoded in memory at some earlier point. Phrased in terms of the assumptions of the new theory of disuse, the largest increments in both storage and retrieval strength occur when the to-be-learned (or relearned) information has low retrieval strength and high storage strength. Thus, some name or number or procedure from one's past, even one's distant past, can be relearned with great efficiency, should it become relevant again.

Another consideration has to do with the statistics of use. Information and procedures we will need in the near future tend to be from the recent past, which is one reason that computer programs and electronic gadgets, such as cell phones, make recently accessed documents, addresses, and numbers more readily accessible than other documents, addresses, and numbers. In the case of human memory, remembering information makes that information more accessible in the near future and any competing information and procedures less accessible.

In that context, another "important peculiarity of human memory" (Bjork & Bjork, 1992) is relevant—namely, that with disuse of two competing memory representations, access shifts toward the earlier learned representation with time. Such a shift from recency to primacy across a period of disuse is a very general effect, one that occurs on multiple timescales and for many different types of memories. I have speculated elsewhere (Bjork, 2001) as to the mechanisms that might be responsible for such regression effects, but the important point for present purposes is that such regression effects, from the standpoint of the statistics of use, may also be adaptive. The reason has to do with *why*, in real-world contexts, people might stop using the most recent of competing representations. Often, those reasons will be accompanied by the earlier learned representation again becoming needed. One of many possible examples might be returning to the United States after a prolonged stay in Great Britain, during which driving a car and staying alive required acquiring a set of perceptual and procedural routines that differ, markedly, from the corresponding routines in the United States. Disuse of the newer, Great Britain-appropriate routines could mean a number of things, including having a fatal accident somewhere in Great Britain, but it is more likely to mean that one has returned to the United States, where it is now advantageous to have the earlier learned routines be most accessible.

Finally, in principle, the contributions of remembering to forgetting can make unwanted memories less accessible. That is, to the extent that memories one wants to recall are associated with the sames cues or contexts as memories one does not want to recall, repeatedly recalling the more positive memories can, via retrieval-induced forgetting, inhibit access to the unwanted memories (Anderson & Green, 2001; Levy and Anderson, 2008; Bjork et al., 1998). Whether retrieval-induced forgetting, or a more explicit and directed inhibitory mechanism (e.g., Anderson & Green, 2002; Levy & Anderson, 2008), actually provides a mechanism for repression is a matter of current controversy (see Anderson & Levy, 2006).

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FORGETTING AS A FACILITATOR OF LEARNING

There are a variety of conditions of learning in which some manipulation known to produce forgetting, when introduced between learning opportunities, enhances learning. Ted Allen and I found, for example, that introducing a more difficult shadowing activity after a first opportunity to study a to-be-learned word triad impaired recall of that triad, relative to recall following an easier shadowing activity, but enhanced the learning of the triad (Bjork & Allen, 1970). That is, if—rather than be tested for recall of the triad—participants were provided a second study opportunity at the same point in time, later recall was enhanced by the more difficult intervening activity. Similarly, Steve Smith, Arthur Glenberg, and I found that introducing forgetting via a change in environmental context enhanced learning (Smith, Glenberg, & Bjork, 1978). When participants were given a list of items to study in a first environmental context and then came back after three hours and studied the list again, either in the same setting or a new setting, their subsquent recall in a neutral context was enhanced by having studied the list in two different contexts. Context change induces forgetting, so had the participants been tested at the time of the second study session their recall of the list would, presumably, have been impaired by the change in context, but their learning, as measured by their subsequent recall, was enhanced.

Perhaps the prime example of forgetting enhancing learning is the *spacing effect*, one of the most robust and general effects from the entire history of experimental psychology (for reviews, see Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Dempster, 1996). When a second study opportunity is provided after a delay following a first study opportunity, rather than being presented with little or no delay, long-term recall is enhanced, often very significantly. Again, though, were the studied material to be tested following a short delay or a long delay, we would observe that the longer delay results in poorer recall of the studied material—that is, more forgetting. Similarly, interleaving, rather than blocking, the learning trials on separate to-be-learned tasks produces more forgetting between trials on a given task during the learning phase, but tends to enhance long-term retention and transfer (e.g., Kornell & Bjork, 2008; Shea & Morgan, 1978; Simon & Bjork, 2001).

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Finally, we recently tested, and obtained support for, an unintuitive prediction of the new theory of disuse—namely, that materials subjected to retrieval-induced forgetting should be relearned more effectively than materials not subject to such forgetting (Storm, Bjork, & Bjork, 2008). This prediction follows because retrieval-induced forgetting is assumed to lower retrieval strength, but not storage strength, and the theory assumes that increments in storage strength and retrieval strength resulting from relearning are greater the *lower* the current retrieval strength of the to-be-relearned material.

Forgetting and Desirable Difficulties

The foregoing examples illustrate a subset of the manipulations I have labeled "desirable difficulties" (Bjork, 1994a, 1994b). Manipulations such as variation, spacing, introducing contextual interference, and using tests, rather than presentations, as learning events, all share the property that they appear *during* the learning process to impede learning, but they then often enhance learning as measured by posttraining tests of retention and transfer. Conversely, manipulations such as keeping conditions constant and predictable and massing trials on a given task often appear to enhance the rate of learning during instruction or training, but then typically fail to support long-term retention and transfer (for a broader discussion of desirable difficulties, see Bjork & Bjork, in press; Bjork, 1999). As I and my colleagues have argued (Bjork & Bjork, AU: Please update. AU: Please update. in press; Bjork & Linn, 2006; Christina & Bjork, 1991; Ghodsian, Bjork, & Benjamin, 1997; Richland, Linn, & Bjork, 2007; Schmidt & Bjork, 1992), this pattern of effects has the potential to mislead instructors and students alike. Instructors become susceptible to choosing poorer conditions of learning over better conditions of learning, and students become susceptible to preferring those poorer conditions over better conditions (for a discussion of when desirable difficulties are desirable and when they are not, see McDaniel & Butler, this volume).

Why Do Conditions That Induce Forgetting Often Enhance Learning?

Why is it that forgetting, rather than undoing learning, often creates the conditions for more effective learning? In the context of the new theory of disuse framework the answer is straightforward: Gains in storage strength (learning) are a decreasing function of current retrieval strength. Any forgetting (i.e., decrease in retrieval strength) will, therefore, increase the acquisition of storage strength.

The new theory of disuse is not, however, a process model, so that answer is unsatisfying in terms of clarifying the processes responsible for the fact that forgetting often enables learning. The following non-mutually-exclusive mechanisms may all play a role in why the conditions that create forgetting often also create opportunities for additional learning.

Encoding Variability One possibility is illustrated by Estes's (1955) fluctuation model, which assumes that to-be-learned responses are associated with cues in the environment, only some of which are "sampled" by the learner at any one point in time. Which cues are sampled ("available" in Estes's terminology) is assumed to fluctuate across time as a function of changes in the learner's physical, emotional, and cognitive state and changes in the environment itself. Forgetting is then a consequence of more new (unassociated) cues and fewer old (associated) cues being sampled as a retention interval increases. What such forgetting also does, though, is provide additional cues that can be associated to the target response, which results in more total cues being sampled and associated to the target response—that is, more learning, which is assumed to be a function of the percentage of the total population of cues that are associated to the response in question. Spacing or context change between trials will enhance learning, whereas massed learning trials will result in very little forgetting between trials, but also very little learning.

The fluctuation model, which was originally developed to account for animal learning phenomena, but was extended by Bower (1972) and others to human learning, including verbal/conceptual learning, is able to account nicely not only for spacing effects, but also for results such as the Bjork and Allen (1970) and Smith et al. (1978) findings summarized above.

The more general idea the fluctuation model embodies is *encoding variability.* Contextual cues, including environmental, interpersonal, mood state, and body state cues, influence not only what is accessible from memory, but also how to-be-learned information is encoded or interpreted. Context change across repetitions of to-be-learned material induces forgetting, because current cues differ from prior cues, but also enhance learning because the material in question becomes associated with a greater range of contextual cues or encoded in more than one way. Such encoding variability will, in turn, faciliate access to learned materials, especially at a delay and across multiple contexts.

Retrieval Practice Another possible explanation as to why forgetting can enable learning hinges on the fact that retrieving information from memory is a learning event, and the more involved or difficult the act of retrieval, provided it succeeds, the greater the learning benefit (see, e.g., Appleton-Knapp, Bjork, & Wickens, 2005; Benjamin & Ross, this volume; Bjork, 1988; Landauer & Bjork, 1978; Whitten & Bjork, 1977). The basic idea is that retrieving information from long-term memory is a fallible and probabilistic process—a kind of skill that, like other skills, profits from practice. The more difficult or involved the act of retrieving to-be-learned materials during the learning phase, the more that act exercises the processes that will be needed later, after the learning phase (see Pyc & Rawson, 2009, for recent evidence consistent with the idea that the more difficult an act of retrieval, provided it succeeds, the more that retrieval enhances subsequent recall). Forgetting, therefore, by rendering access to to-be-learned information more difficult, can enhance learning.

From a practical standpoint, it is important to realize not only that effortful retrieval can enhance learning, but also that the converse is true as well: Trivially easy retrievals appear to result in essentially no learning. Demonstrations of how ineffective easy/immediate retrievals of information can be for learning go back to the 1960s—and probably before. James Greeno demonstrated, for example, using anticipation trials in paired-associate learning, that providing some items with an extra and immediate second presentation during each cylce through a list did nothing for the long-term learning of those items (Greeno, 1964). AU: Please provide in references. The participants were essentially perfect in being able to anticipate (generate) the associated response after just having been presented an anticipation trial on a given pair, but that perfect responding resulted in no learning, as measured by the subsequent first trials on each such item on succeeding cycles through the list. In my own dissertation research, in which I used a Markov model to account for the combination of short-term memory and long-term learning effects in paired-associate learning, I found that the best-fitting estimate of the probability of an item going to the learned state after being studied while in the short-term-memory state was exactly zero (Bjork, 1966). AU: Please provide in references. That is, if a given to-be-learned pair had not already made a transition to the learned state, but was available in short-term memory (owing to recency), studying that item had no effect on its learning.

Basically, when something is maximally accessible from memory, little or no learning results from studying or retrieving that something. Stated in terms of the new theory of disuse, when information already is at maximum retrieval strength, owing to recency or other factors, retrieving (or studying) that information has essentially no effect on the information's storage strength, and it is storage strength, not retrieval strength, that corresponds to the relatively permanent changes that define learning.

Solving a Problem Versus Remembering the Solution Another conjecture as to why forgetting enables learning traces to research by Larry Jacoby (1978). AU: Please provide in references. The basic idea is that learning has a problem-solving aspect—learners must find encoding or retrieval activities that will make studied materials accessible after a delay—and forgetting between learning trials is necessary for learners to carry out additional such activities. In

Jacoby's experiment, participants were asked to study pairs such as Foot: Shoe and were later tested via cued recall (Foot: ________?). A given study trial was either a read trial, in which a pair was shown intact, or a construct trial, in which the response had to be constructed from letter cues (S**e) and its semantic relationship to the stimulus term.

Consistent with research on generation effects (e.g., Hirshman & Bjork, 1988; deWinstanley, Bjork, & Bjork, 1996; Slamecka & Graf, 1978), there was a very large advantage in later recall—more than two to one—when an item was constructed, rather than simply read. Of special interest, though, are the conditions when an item was studied intact and then, after either 0 or 20 intervening trials on other pairs, either studied again intact or constructed. A repetition after 20 intervening trials had the effects one would expect: a clear benefit of repetition on later cued recall and a substantially greater benefit when the response member had to be constructed rather than simply read. However, when the repetition was essentially immediate, final cued recall profited very little from either an additional study or construct trial. In particular, studying the item intact on one trial and then having to construct it on the next trial produced poorer final recall (42%) than did having only a single construct trial (57%).

In Jacoby's analysis, construct trials involve a kind of problem-solving activity—namely, deciding what semantic associate of the stimulus fits the letter cues provided—an activity that supports participants' later ability to recall the response term when shown only the stimulus term. When, however, the answer to the problem has just been shown, those processes are nullified: The solution needs only to be remembered from the preceding trial, not constructed, and such immediate recall is not effective practice for the later cued-recall test. If, though, enough intervening trials are inserted to produce forgetting, it becomes necessary for the learner to solve the problem, not just remember the solution, which enhances later recall.

Reloading Procedures and Skills A related idea from the motor skills literature is the reloading hypothesis, advocated by Lee and Magill (1983, 1985) to explain why randomly interleaving trials on separate to-be-learned movement patterns, versus blocking those trials by movement pattern, enhances long-term retention and transfer. Once again, the findings in the motor skills literature are that blocking appears optimal, based on the rate of improvement of performance *during* practice, but random/interleaved practice proves superior as measured by post-training tests of retention or transfer.

The advantages of interleaved over blocked learning trials have been demonstrated in a wide variety of laboratory and real-world tasks. Examples range from learning simple movement patterns (e.g., Shea & Morgan, 1978; Simon & Bjork, 2001); to acquiring sports skills, such as learning the several kinds of serves in badminton (Goode & Magill, 1986); to learning procedures, such as carrying out transactions on automated teller machines (Jamieson & Rogers, 2000); to more purely cognitive tasks, such as learning boolean logic operations (Carlson & Yaure, 1990) or the formulas for the volumes of solids (Rohrer & Taylor, 2007), inducing the styles of artists from examples of their paintings (Kornell & Bjork, 2008), and moving from calculating the answers to multiplication problems to achieving direct retrieval of those answers (Rickard, Lau, & Pashler, 2008). For possible limitations on the advantages of random/interleaved practice, see Wulf and Shea (2002).

According to the reloading hypothesis, interleaving the learning of each of several motor movement tasks enhances learning because it produces, in effect, a desirable kind of forgetting. The trials on the other to-be-learned movement patterns that intervene between successive trials on a given pattern result in a loss of access to the motor program that corresponds to that pattern, which then requires that the program be reloaded or reconstructed. Such reloading is assumed, as in the case of the retrieval of verbal information, to support the learning of—and later retrieval of—that movement pattern. In the case of a blocked practice trial on a given pattern, no such reloading—or at least no such effortful and, hence, productive reloading—is required.

HOW WE LEARN VERSUS HOW WE *THINK* WE LEARN

In a number of prior papers, my colleagues and I have stressed that the accumulated body of research on how people learn, or fail to learn, has very important implications for optimizing instruction and training (e.g., Bjork, 1994a, 1994b, 1999, 2009; Bjork & Bjork, in press; Bjork & Linn, 2006; Christina & Bjork, 1991; deWinstanley & Bjork, 2002; Ghodsian et al., 1997; Jacoby, Bjork, & Kelley, 1994; Kornell & Bjork, 2007; Schmidt & Bjork, 1992). Current customs and standard practices in instruction, training, and schooling do not, for the most part, seem to be informed by an understanding of the complex and unintuitive dynamics that characterize human learning and memory. Nor do we, as individuals, seem to understand how to engage fully our remarkable capacity to learn. Instead, we seem guided by a faulty mental model of ourselves as learners that leads us to manage our own learning activities in far from optimal ways.

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Why We Develop Faulty Mental Models of Ourselves as Learners

It is very puzzling, in fact, that as lifelong users of our memories and learning capabilities, we do not end up with a more accurate mental model of how we learn, or fail to learn. Why is it, in short, that we are not educated by the "trials and errors of everyday living and learning" (Bjork, 1999, p. 455)? One consideration is that the functional architecture of how humans forget, remember, and learn is unlike the corresponding processes in man-made devices. Most of us do not, of course, understand the engineering details of how information is stored, added, lost, or overwritten in man-made devices, such as a computer or video recorder, but the functional architecture of such systems is simpler and more understandable than is the complex architecture of human learning and memory. To the extent, for example, that we do think of ourselves as working like such devices, we become prone to assuming that exposing ourselves to information and procedures will lead to storage (i.e., recording) of such information or procedures in our memories—that the information will write itself in one's memory, so to speak.

Also, if we think of human memory as akin to the memory in a man-made device of some kind, we are unlikely to appreciate the extent to which retrieving information from our memory increases the subsequent accessibility of that information and reduces the accessibility of competing information. Retrieving information from a compact disc or computer memory leaves the status of that information and related information unperturbed. More globally, we may fail to appreciate the volatility that characterizes access to information from our memories as conditions change, events intervene, and new learning happens. Recent findings (Koriat, Bjork, Sheffer, & Bar, 2004; Kornell & Bjork, 2009) suggest that learners are susceptible to what Kornell and Bjork have termed a *stability bias*—a tendency to think that access to information in memory will remain stable across a retention interval or additional study opportunities.

Another consideration is that it may be natural for us to think of the memory traces that correspond to stored information or procedures as varying along some single dimension of strength. That is, the full multidimensionality of memory representations may be virtually impossible to appreciate based on intuition and experience alone. Without being privy to the amazing array of interactions of encoding conditions and test conditions that have been demonstrated in controlled experiments, for example, how might someone come to appreciate those interactions? We may have a general idea that some learning activities produce better retention than others, but how, based in intuition and experience alone, would we ever come to appreciate fully that our performance on a test of a certain type—whether free or cued recall, or some type of recognition, priming, or savings test—will depend on a complex interaction of the nature of our encoding activities, how long it has been since those activities, and what cues will or will not be available at test?

To the extent that we do not realize the multidimensional character of human memory, we also become prone to being misled as to the degree that learning has or has not happened and whether we will or will not be able to access needed information or procedures at a later time. Interpreting current performance (retrieval strength) as learning (storage strength) is perilous, for example, because current retrieval strength is heavily influenced not only by recency, but also by retrieval cues that are available now, but are likely to be unavailable later. Various subjective indices, too, can mislead us. The sense of familiarity or perceptual fluency, for example, can be taken as an index of understanding when it may reflect factors that are unrelated to understanding, such as perceptual priming (see, e.g., Reder & Ritter, 1992). Similarly, the sense of retrieval fluency—that is, how readily information "comes to mind"—can be misleading when it is the product of conditions that are available now, but will not be available later (Benjamin & Bjork, 1996; Benjamin, Bjork, & Schwartz, 1998).

A major factor in our being overinfluenced by current objective or subjective indices of performance is that we fail to understand fully the degree to which the ability to retrieve information and procedures is cue dependent. We are apparently not only unable to look forward in time to a test situation and assess how the cues available then will differ from the current cues, but also to assess how that difference will affect our performance. Koriat and Bjork (2005, 2006) have demonstrated, for example, that participants are subject to what they term a *foresight bias*: When an answer is available at the time of study, people are prone to overestimate the likelihood that the answer will come to mind when it is required, but absent, on a later test. More specifically, as defined by Koriat and Bjork (2006), "Judgments of learning (JOLs) are inflated whenever information that is present at study and absent, but solicited, at test, such as the targets in cue–target paired associates, highlights aspects of cues that are less apparent when those cues are presented alone" (p. 959). Thus, for example, people overestimate the likelihood when presented a word pair such as *light-lamp* that they will later be able to recall "lamp" when cued with "light-____?" because they are unable to envision that other associates of *light*, such as *dark* or *heavy*, will come to mind, and compete with the retrieval of *lamp*, when *light* is presented alone.

Similarly, Benjamin et al. (1998) demonstrated that participants—in predicting the likelihood that they would later be able to free-recall the answers they gave to general-knowledge questions (without the questions again being presented)—were fooled by how quickly an answer to a given question came to mind. The participants assumed, apparently, that answers that come to mind quickly in the presence of the question would again come to mind quickly when the question is absent. To have predicted the actual relationship—namely, that the *longer* it took to answer a question, the more likely that answer would be recallable later—requires that someone understand two poorly understood characteristics of human memory: (1) that retrieval is a learning event and the more difficult a (successful) retrieval, the more potent the learning, and (2) that semantic memory, as tested by the original question, differs from episodic memory, as tested by the later free-recall test.

The Importance of Becoming Metacognitively Sophisticated as a Learner

Whatever the reasons for our not developing accurate mental models of ourselves as learners, the importance of becoming sophisticated as a learner cannot be overemphasized. Increasingly, coping with the changes that characterize today's world—technological changes, job and career changes, and changes in how much of formal and informal education happens in the classroom versus at a computer terminal, coupled with the range of information and procedures that need to be acquired—requires that we learn how to learn. Also, because more and more of our learning will be what Whitten, Rabinowitz, and Whitten (2006) have labeled *unsupervised learning*, we need, in effect, to know how to manage our own learning activities.

To become effective in managing one's own learning requires not only some understanding of the complex and unintuitive processes that underlie one's encoding, retention, and retrieval of information and skills, but also, in my opinion, avoiding certain attribution errors. In social psychology, the *fundamental attribution error* (Ross, 1977) refers to the tendency, in explaining the behaviors of others, to overvalue the role of personality characteristics and undervalue the role of situational factors. That is, behaviors tend to be overattributed to a behaving individual's or group's characteristics and underattributed to situational constraints and influences. In the case of human metacognitive processes, there is both a parallel error and an error that I see as essentially the opposite. The parallel error is to overattribute the degree to which students and others learn or remember to innate ability. Differences in ability between individuals are overappreciated, whereas differences in effort, encoding activities, and whether the prior learning that is a foundation for the new learning in question has been acquired are underappreciated.

The second attribution error, very different in kind, has to do with one's own learning and the tendency to attribute whether one learns efficiently or not to factors largely beyond one's control, as opposed to being a consequence of one's own efforts or activities. One manifestation of such attributions is the widespread appeal of the learning styles idea: If what is to be learned will only be presented in a way that meshes with one's learning style, one's learning will not only be greatly enhanced, but easy as well (for a review of the learning styles idea and evidence for and against the idea, see Pashler, McDaniel, Rohrer, & Bjork, 2009). Another manifestation is in the context of tasks requiring participants to predict their own future performance. In such tasks, people tend to be very sensitive to item difficulty and largely insensitive to factors such as how many times they will be allowed to study the to-be-learned items (Kornell & Bjork, 2009) or how long the retention interval will be before they are tested (Koriat et al., 2004). That is, people seem prone to assume that the properties of to-be-learned materials will largely determine their future ability to recall those materials, versus assuming that their later recall will depend on factors under their control, such as how effectively they encode those materials.

Becoming maximally sophisticated as a learner is, in a sense, not enough. Becoming a truly effective learner also requires an appreciation of one's capacity to learn and a commitment to the proposition that one's learning *is* under one's control.

CONCLUDING COMMENT

Among the definitions of *symbiosis* is "a relationship of mutual benefit or dependence" (American Heritage Dictionary, 2000). In this chapter I have tried to emphasize that the relationships among remembering, forgetting, and learning are complex, unintuitive, and often beneficial. Forgetting focuses remembering and fosters learning; remembering generates learning and causes forgetting; learning causes forgetting, begets remembering, and supports new learning. In concert, those interdependencies act to modify in adaptive ways what is and is not accessible from our memories as we live and learn. It is a system that is remarkably interesting and effective, if fallable, and it is no less remarkable by virtue of being so frequently unappreciated and misunderstood by the user.

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