Retrieval Inhibition and Related Adaptive Peculiarities of Human Memory

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ABSTRACT

The functional properties of the human as an information-processing device differ in significant ways from the corresponding properties of the standard digital computer. One such important difference is that items in human long-term memory (e.g., names, numbers, facts) differ greatly in accessibility--that is, in the likelihood that they can be retrieved (recalled) when needed. Retrieval of information from long-term memory is erratic, probabilistic, and context dependent in ways that would seem intolerable in the search of a computer's memory.

From one perspective, the unreliable nature of the retrieval of information from human memory seems nothing more than a weakness of the system. From another perspective, however, the retrieval failures we suffer are a by-product of a system that is, overall, adaptive. Given the virtually unlimited storage capacity of human memory, and the relatively slow rate of neural transmission, we do not *want* everything in our long-term memories to be accessible, particularly when that information is irrelevant or out of date (such as where we left the car *yesterday*, or the address where an important business associate *used* to work).

We argue herein that the pattern of accessibility across items in memory changes in dynamic and adaptive ways as a consequence of input (presentation) events, output (recall) events, and shifts in environmental, social, and mood-state cues, and that inhibitory processes (and recovery over time from such inhibition) play a central role in such changes.

INTRODUCTION

In general, we have a poor understanding of how our own memories work. Our assumptions, usually implicit, about how we store (or do not store) and later recall (or do not recall) information are wrong in most important respects. As a consequence, we do not use our memories efficiently, nor do we have appropriate expectations as to what our friends, family members, and co-workers will or will not remember on the basis of our interactions with those individuals. Faulty assumptions about human memory also result in poorly designed instructional programs in educational, industrial and military settings and--in the consumer domain--less than optimal marketing and advertising programs.

It is surprising, from a trial-and-error standpoint, that we do not learn more about the characteristics of our own memories. Our experience would seem to provide each of us with extensive feedback as to the circumstances in which our memories succeed and fail. There are two reasons, in our opinion, why individuals do not gain a good understanding of human memory based on experience alone. First, there is the simple fact that introspection, as demonstrated across many fields in psychology, is of limited value in learning about ourselves. Second, and of more importance for present purposes, is that people understand the basic characteristics of man-made devices, such as a tape recorder, or the memory in a computer, better than they understand the characteristics of human memory, and they assume, (implicitly) that human memory works in roughly the same fashion. Given that the characteristics of human memory differ in most important respects from the characteristics of such man-made devices, we end up with a seriously flawed mental model of our own memory system.

Among cognitive scientists, there is a growing realization that they, too, like the hypothetical layperson referred to above, may have been misled by an inappropriate analogy between man and machine. For several decades, the information-processing approach to the study of human memory, based on the assumption that the processing of information by humans is roughly analogous to the way programs run on a serial digital computer, dominated research on human memory. (For a good example of such flow-chart models of memory, see Atkinson and Shiffrin 1971; and see Bettman, 1979, for an elegant extension of such models to consumer behavior.) In the last half of the 1980s, however, a variety of empirical and theoretical developments in the behavioral, brain and clinical research domains have convinced cognitive scientists that the basic information-processing architecture in humans differs dramatically from the processing architecture in the typical computer. It is beyond the scope of the present paper to summarize those developments in any detail. A major factor, however, was the emergence of PDP (parallel distributed processing) models based on an analogy to neural networks (see, e.g., McClelland, Rumelhart, and Hinton 1986). In general, it became increasingly apparent that the sequential nature of symbol processing in typical computers limits the extent to which they can simulate the complex cognitive processes characteristic of humans. Theorizing in the human-memory field has entered an era in which a brain metaphor is replacing a computer metaphor.

One consequence of the long-term dominance of the computer metaphor was to bias the types of processes researchers hypothesized within their theories. It was natural to postulate buffers and more permanent storage systems of various types, and to postulate processes such as scanning, sorting, chunking, transferring, and filing. Among the processes it was *not* natural to postulate, are the inhibitory mechanisms that are the focus of this symposium. Across the last several years, researchers in several fields, particularly attention, memory, and language, have begun to argue that inhibitory processes are fundamental to human cognitive processes (see, e.g., Bjork 1989, Hasher and Zacks

1988, and Tipper 1985). It is the goal of the present paper to argue that the inhibition of retrieval access to items in memory, and recovery from such inhibition over time, play an important and adaptive role in the everyday functioning of human memory. Before we pursue that argument further, it is necessary to describe some important characteristics of storage and retrieval processes in human memory.

RETRIEVAL PROCESSES VERSUS STORAGE PROCESSES

Retrieval

A fundamental property of human memory, one that is highly familiar to all of us, is that the retrieval of information from our memories is a fallible process. Names, numbers, and facts that are recallable without apparent effort on one occasion can be impossible to recall on another occasion. There is something erratic and probabilistic about the processes by means of which we attempt to gain access to items of information that, in fact, exist in our memories.

One source of such variation is that retrieval processes are cue-dependent: what we can and cannot recall at a given point in time is strongly influenced by the cues available to us, where such "cues" include not only stimuli bearing an associative relationship to particular items in memory, but also aspects of one's current environmental, emotional, interpersonal or body-state context. As Smith (1988) has pointed out, such contextual cues can be so powerful that we can be virtually a different person in different contexts--at a class reunion, for example, or a place of worship, or attending a little-league baseball game.

It is tempting to consider the fallible nature of retrieval processes as simply a weakness of the human memory system. When viewed in the context of the other characteristics of human memory we summarize below, however, and in terms of the real-world demands on our memories, the retrieval failures that are so typical of human memory are but one reflection of a system that is, overall, adaptive.

Storage

In contrast to the limitations on gaining access to stored information in memory, there appears to be essentially no limit on storage per se. Storing new information in long-term memory appears to be a process of interpretation--of relating the new information to existing knowledge. Items are stored in terms of their meaning, as defined by their semantic relationships to other items. For all practical purposes, there appears to be no limit on how much information can be stored via this process. In fact, rather than thinking of long-term memory as any kind of container, which would imply that there would be less room for new information the greater the amount of information already stored, it is more accurate to think of prior knowledge as creating additional capacity; The more that is already known in a given knowledge domain, the more ways there are to store additional information in that domain.

There is another sense in which the capacity of human memory is essentially unlimited: Once information is successfully embedded within the knowledge network that defines long-term memory, it appears to remain in storage essentially forever. Even the most overlearned and heavily used item of information, such as a prior home phone number or street address one may have had, eventually become non-recallable with a long enough period of disuse, but such forgetting is a matter of loss of retrieval access to such items, not a loss of their representation in memory per se. Such items can typically be recognized at a rate that greatly exceeds chance levels, can be relearned at an accelerated rate, and can often be recalled in special circumstances that reinstate certain cues from the past--all of which constitute evidence that such items have not been lost from memory in any absolute sense.

The storage and retrieval dynamics described thus far illustrate that it is inappropriate to think of memory representations as varying on a unidimensional strength dimension. In a so-called "New Theory of Disuse" Bjork and Bjork (in press) have argued that an item's *storage strength* (how well it has been learned or interrelated with other items in memory) must be distinguished from its *retrieval strength* (how accessible or activated the item's representation is at a given point in time). The retrieval strength of a given item can wax and wane as a function of events involving that item or its competitors.

RETRIEVAL DYNAMICS IN HUMAN MEMORY

Retrieval as a Learning Event

In devices such as a tape recorder and computer memories, retrieving stored items leaves those items in the same state they were in prior to being retrieved. In human memory, on the other hand, the act of retrieval is itself a potent event: The information retrieved becomes more retrievable in the future, and other items bearing certain types of similarity relationships to the retrieved items become less retrievable in the future. The successful retrieval of an item from memory is, in fact, considerably more potent as a learning event than is a presentation of that item for study, and the potency of an act of retrieval increases with how difficult or involved the process of retrieval is (see, e.g., Gardiner, Craik and Bleasdale, 1973, and Landauer and Bjork, 1978).

As certain members of a set of items associated to a given cue are made more accessible--that is, have their retrieval strength increased by virtue of further study or retrieval practice-- other items in that set become less recallable. Providing some members of a set of items to be recalled, for example, impairs rather than helps the recall of the remaining. Such "inhibition from part-set cuing" (Nickerson, 1984) has been demonstrated with brand names in product categories (see below) as well as with the members of natural categories and lists learned in the laboratory. Retrieval practice on certain items associated to a given episodic or semantic cue impairs subsequent

recall of other items associated with that cue (see Anderson and Bjork 1990, and Bjork and Geiselman 1978). There is also evidence that the process of recall itself is a "self-limiting process" (Roediger, 1978); that is, in the process of recalling a set of items, the items recalled earlier become more accessible at the expense of yet-to-be-recalled items.

Retrieval Inhibition in the Updating of Memory

In assessing our own memory performance, we tend to think of remembering as good and forgetting as bad. Efficient use of our memories, however, depends, in a sense, as much on efficient forgetting as on efficient remembering. In a variety of different ways, on a range of time scales, we must update our memories. We need to remember our *current* phone number, where we left the car *today*, and how *this* word-processing program works, and so forth; it is not helpful to remember, instead, our old phone number, where we left the car yesterday, and how an old word processor worked. That is, we need some means to erase, set aside, or inhibit out-of-date information.

In man-made memory devices, we typically replace out-of-date information by an over-writing process that is efficient from one perspective (the out-of-date information cannot intrude if it has been obliterated), but is less than optimal from another perspective (what if we happen to need that information again?). In human memory, the primary updating mechanism appears to be retrieval inhibition. As we learn new information to replace old information, retrieval access to the old information becomes inhibited. Because recall of that old information is inhibited, it does not interfere with the recall of the new information, but the old information remains in memory to be recognized or relearned (at an accelerated rate), should that be necessary.

The foregoing characterization of the updating process in humans emerges from research on interference processes carried out decades ago (for a thorough review, see Crowder 1976), and from research on "directed forgetting" carried out more recently (see, e.g. Bjork, 1989, and Geiselman, Bjork and Fishman 1983). The typical procedure in the interference tradition involves having a subject learn a new response (e.g., words) to each of a set of stimuli (e.g., nonsense syllables) after having learned other responses to those stimuli. There is a clear, but implicit, instruction to subjects that they should suppress the original responses once the new learning phase begins. In the directed forgetting paradigm, subjects are typically signalled, at some point in learning a list of items, that they should forget the items they have tried to learn thus far--that these items were the wrong list, or practice list--and that they should memorize the upcoming list instead. In addition to the evidence from such procedures that implicit or explicit instructions to forget inhibit subsequent retrieval access to the to-be-forgotten items, there is also evidence that with time and intervening events there is a recovery of access to those items.

Regression and Recovery

A type of regression effect appears to be fundamental to human memory. When there are alternative or competing memory representations, one constructed more recently than the other, a period of disuse of either representation results in an increase in retrieval access to the earlier representation at the expense of the most recent representation. Thus, having known a woman friend by her maiden name prior to learning her married name, one may get to the point of recalling her married name without apparent competition from her maiden name, but after an extended period of being away from that friend it will tend to be her maiden name, not her married name, that is most recallable. The memory representations underlying motor skills are also subject to such regression. One may have practiced a new and different golf swing, for example, but after a period of not playing it is one's original swing that will be most dominant. The full dynamics of such regression effects are not completely understood. They show up in many types of behavior, in animals as well as humans, and are more pronounced under conditions of stress (for a more thorough discussion of such effects, see Bjork and Bjork, in press). It is also clear that the nature of the situational context cues--and their overlap with the conditions present at the time the earlier or later memory representation were constructed--plays a role. One factor that clearly contributes to memory regression, however, is recovery from retrieval inhibition. As a consequence of constructing and using a newer representation, access to the older representation is inhibited, but with disuse of either representation--and a loss (possibly rapid) of retrieval access to the newer representation--the dominance relationships will change, especially if the older representation was better learned and more highly practiced initially.

ADAPTIVE ASPECTS OF THE SYSTEM

Looked at in isolation, each of the characteristics of human memory discussed above seems unusual or peculiar when compared to the characteristics of man-made recording devices. Taken in combination, however, and viewed in terms of the memory problems the world poses for us, there are some clear adaptive features of such a system.

If we take as a starting point that humans are remarkable as storage devices, and that there are obvious advantages of having virtually unlimited capacity in that domain, the limitations on retrieval access can be viewed as a necessary filter. In the interest of speed, accuracy and avoiding confusion, we do not *want* every item in our memories to be accessible. When asked for our current home phone number, for example, we retrieve that number without entertaining alternatives, even though prior home phone numbers exist in our memories. We could, as certain computer routines might do, retrieve all the numbers with a home phone tag in our memories and then engage a decision process to decide which one is our current number. Such a process would be slower certainly, and more error prone as well.

The fact that retrieval access is heavily cue-dependent, and that retrieving an item makes that item more retrievable in the future, means that, in general, the most accessible items are those we need in our current situation. On the one hand, cues of various types will tend to enhance access to memory representations that are most relevant to the current context. On the other hand, the most accessible items in memory will tend to be those we have been accessing the most in the recent past, which--statistically--will tend to be those we need the most in the near future as well.

The fact that it is retrieval access, not the item's representation in memory per se, that is lost as a function of subsequent learning has adaptive aspects as well. Because the item remains in memory, it will often be recognized and identified as an old item, which can be useful in various ways. Should that old item become pertinent again (the hypothetical woman friend of yours referred to earlier gets divorced, e.g., and returns to her maiden name), regaining full retrieval access to the item is a very rapid process.

Finally, the regression and recovery phenomena referred to above can have adaptive aspects as well. What will it tend to mean if one stops using the more recent of two competing memory representations? Suppose, for example, to pick quite multifaceted memory representations, that you have spent a year in England driving a leased automobile. To drive successfully during that year, and to stay alive, there are many aspects of your earlier habits (corresponding to driving your own car in the United States) that you need to inhibit. When you stop driving in England, however--which we can presume means that you have returned to the United States--it will be very useful if those inhibited habits recover in strength. As that example illustrates the conditions that result in our ceasing to use more recent representations will often also result in less recent representations becoming relevant. It will be adaptive, therefore, if access to those representations recover.

IMPLICATIONS FOR CONSUMER RESEARCH

Marketing

Several recent studies suggest how marketers can use advertising and point-of-purchase displays to activate inhibitory mechanisms in memory. This may help them gain a competitive advantage in situations where recall is a major determinant of consumers' choices, such as when none of the alternatives are physically present (e.g., when writing down a shopping list or choosing a restaurant) or when not all competitors can be found at the same location. Having subjects think about one or more particular brands not only increases the salience in memory of these brands, and the likelihood they are considered for purchase, but also can inhibit the recall of other product category members that otherwise would be candidates for purchase (Alba and Chattopadyay 1985a, 1986; Miniard, Unnava and Bhatla 1990). This retrieval inhibition phenomenon--referred to earlier as the part-set or part-category cuing effect--has also been demonstrated for recall of product attributes (Alba and Chattopadyay 1985b). Marketers apparently can choose the product dimensions on which they want to be judged *and*, at the same time, inhibit consideration of alternative dimensions on which their competitors are superior.

In a similar vein, Keller (1991a, 1991b) shows how recall of the communication effects for a particular advertisement--that is the content of the advertisement and the responses to this content--can be impaired by the presentation of advertisements for competing brands in the same product category (see also Burke and Srull 1988). This inhibition effect even occurred within a group of advertisements of the same valence, presented in the same experimental session (Keller 1991b).

Because successful retrieval of an item strengthens the representation of that item in memory, a marketing campaign that initially influenced recall may have prolonged effects. From a memory perspective, each new purchase and usage of a brand further inhibits consideration of its competitors. Because retrieval of an item is a more potent learning event than the mere exposure and processing of that item, advertisers may want to trigger retrieval attempts in their audience during the presentation of commercial information. A campaign with a series of consecutive commercials in which each, implicitly, refers to the previous "episode" of the series can stimulate recall activities. Similarly, radio messages may contain cues that trigger the recall of the visual elements of a television commercial in the same campaign. These synergistic effects should enhance memory retrieval of the focal brand and inhibition of its competitors.

Consumer Memory

As explained above, memory inhibition may be considered as a fundamental weakness of our memory systems, making us vulnerable to marketing influences that lead to suboptimal consumer decision making. From a more general perspective these effects can be looked upon as an--unfortunate--by-product of a complex of mechanisms that, given the constraints of our memory structure, serves our overall needs. The global advantages of the combined mechanisms of activation and inhibition are most apparent when one follows the memory representation of interrelated sets of knowledge across an extended period of time. Unfortunately, memory researchers have little hard evidence to offer to enhance our understanding of storage and retrieval of complex information in a long-term perspective. Traditional memory research methods (in particular the proverbial memory experiment with a study trial, distractor task and memory test in a single session with simple materials, such as nonsense syllables, to be remembered) do not address these dimensions. It is more important to examine the acquisition of knowledge on the basis of experiences which are distributed in time. During intervals between these exposures, access to the knowledge of interest wil be impaired as a consequence of previous and new

presentations of related information. An interesting and unique attempt to follow these cycles of acquisition, loss, and reacquisition over time can be found in Bahrick (1979).

To illustrate our general claim about the adaptive features of inhibition, we have to resort to the description of a hypothetical case, which the reader probably can link to personal anecdotal evidence. Consider an individual's history of experiences with a frequently purchased branded grocery product such as breakfast cereals. Most of us have already tried out multiple offerings in this product category. Promotions and special pricing entice us into trying previously unknown brands, satiation with known brands and the desire for variation may cause periodic switching between brands, and our mother, or spouse, or friend, having invited us for breakfast, may urge us to try a particular brand, either because they like that brand or because they think it is exactly what we need. Ideally, the complete set of experiences with each of the alternatives should be available at each purchase occasion to allow us to make an optimal choice. Time constraints evidently prohibit consideration of all this information, and the processing costs would outweigh the expected benefits. Some of the product knowledge may even be completely irrelevant, for instance, because an alternative may have disappeared from the market. Even a random draw from the pool of currently available alternatives will not be maximally informative: preferences and tastes tend to change with time and aging, and social forces also have an impact on how appropriate certain choices are. In many product categories there is therefore no absolute best choice for a particular person across all purchase occasions. Time and context dictate the best choice. Someone on a diet now would probably like to suppress recall of his or her once favorite Chocolate Sugar Crunch cereal. One may be praised as a beer connoisseur in this country, for ordering Heineken, while the second author's Belgian friends would certainly frown upon this choice.

Within certain constraints, recently acquired or activated information will be most relevant to our current decisions and choices *and* will be most easily recalled. Products and brands that we can recall now without any effort, for instance when writing down our shopping list, are those that we retrieved from memory, purchased or encountered in the recent past. Those are the ones which best serve our needs, given our current taste, social status, and dietary needs, and given this season's fashion and the current state of technology. (A recent disappointing product trial will also be salient. The product will first be consciously avoided and then gradually lose its salience.)

Activation mechanisms, without inhibition being involved, could produce most, if not all, of these desirable effects. A change in context may, however, make highly active information completely irrelevant for present purposes. The retrieval of recently activated, but now irrelevant, information would not only slow down our performance but could also lead to suboptimal choices. Fortunately, the new set of memory cues that becomes available with a change in context not only activates a new set of knowledge, but also inhibits possibly competing, but now obsolete, information.

People who regularly spend time in a different country can experience how easily they can recall the different brands of a product that are unavailable in the U.S., given the proper retrieval cues, and how little interference there is from American brands in the same product category that are not distributed in that country. Similarly, current middle-aged shoppers for a television set will not search for one of the many American brands that were available before Japanese electronic companies started dominating the market. Even without conscious learning attempts, our knowledge about market evolutions is constantly updated by the dual mechanisms of activation and inhibition. On the other hand, the features of our first, now almost historic, television set can be retrieved when recollecting personal experiences and anecdotes. Interestingly, our discussion about inhibition also illustrates that recognition may be a less relevant criterion for advertising effectiveness than some authors (e.g., Singh, Rothschild and Churchill 1988) claim. Relying on recognition alone to make a choice would be too time-consuming and overwhelming in today's complex choice environment, and would generate too large a consideration set. So even when all alternatives are visually present, recall (and inhibition of recall) play an important role that is functional in satisfying our needs, with a minimum of cognitive effort.

CONCLUDING COMMENT

There is within human memory a complex interplay of storage and retrieval processes. The pattern of items that are accessible and non-accessible shifts and fluctuates as a consequence of new learning, retrieval practice, and changing contextual cues of multiple types. We have attempted to argue herein that inhibition and competition are as important in the dynamics of such shifting patterns of access as are processes of activation and association.

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