# THE DYNAMICS OF LEARNING AND FORGETTING: A NEW MODEL AND ITS APPLICATION TO ADVERTISING

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## Abstract

Learning and forgetting of brand names and brand-related information is a function of how presentations of this information are distributed in time. Eventually, memory traces of (or elements of) an advertisement become inaccessible, however many times the ad was presented before. This loss of access is not a consequence of mere passage of time, but a result of the presentation and retrieval of other items that bear certain relationships to the ad or its elements. We develop a model that explains the cumulative effect of advertising as a function of time and interfering information. This model accounts in a parsimonious way for the basic characteristics of the storage and retrieval processes in the human memory sytem.

## INTRODUCTION

Memory tests are a standard component of many consumer behavior studies, and models of advertising effectiveness are often based on assumptions about the human memory system (e.g. Little 1979, Mahajan and Muller 1986). Consumer researchers have, however, only recently become interested in the complex dynamics of human memory (e.g. Alba and Chattopadhyay 1985, 1986; Burke and Srull 1988; see Shimp 1990 for citations of the relatively few early studies). Findings in the specialized memory literature have only slowly become adopted in the consumer behavior field. The relevance for consumer behavior of basic research in cognitive psychology is not always obvious, and important findings are often not easily translated to a marketing context.

In this article we review a theory (see Bjork and Bjork 1988, 1990) and present a model that captures the important dynamics of the human memory system. We think the model is particularly relevant to and readily applicable within an advertising context.

## STIMULUS ASSOCIATIONS AND RETRIEVAL INHIBITION

Advertisements have one or more of the following aims:
(1) to increase the awareness for a brand name; (2) to link the brand name to a (product) need; and (3) to associate the brand name with other information (e.g. product/brand attributes, situations in which the brand/product can be used, feelings associated with the use of the brand or product, etc.). Advertisers try to maximize the memorability of the brand name and its associations (consumer attitudes are part of such associations, to the extent

that they are based on advertising messages). Increasing brand awareness is particularly important when consumer choice is memory-based (Lynch and Srull 1982), such as in making a grocery shopping list, or choosing an industrial supplier, retail outlet, or restaurant). In this paper we focus on brand-name recall, but our model also applies to stimulus-based decision making where the brand names are available - in the yellow pages for instance, or in package information in a store - but brand-relevant information has to be retrieved from memory.

From a learning perspective, a good strategy is to relate the brand meaningfully to concepts already stored in memory. A rich set of memory traces will enhance the accessibility of the brand name. So the brand name with the most elaborate or richest encoding will have the highest probability of retrieval when a memory-based product choice has to be made. In terms of the associative-network theories of memory (e.g. Anderson 1983; Collins and Loftus 1975), such a strategy involves making as many links from the brand name to other concepts as strong as possible.

Another body of research and literature suggests an almost opposite strategy. In a series of experiments, Alba and Chattopadhyay (1985, 1986) showed that having subjects think about a (set of) particular brand(s) inhibits the recall of competing brands in the same product category. Also, thinking about a particular product (e.g. deodorant sprays) suppresses the retrieval of competing products (e.g. deodorant soaps). The phenomenon is more generally known in the memory literature as retrieval inhibition owing to part-set cuing (see Nickerson 1985, for a review). The authors' explanation of their results refers to Rundus's salience hypothesis (1973). The probability of retrieval of a brand name is determined by the strength of association between the product category and brand name, divided by the summed strengths of all associations between the product category and brand names. The presentation of a brand name causes an increase in this associative strength, which enhances this brand's salience and retrieval probability at the expense of the unpresented brand names. During memory search this brand therefore comes to mind continually and inhibits recall of its competitors.

Alba and Chattopadhyay's studies look at memory inhibition caused by stimuli presented at the time of retrieval. Retrieval interference is more general and more often occurring than their work might suggest. In current memory theories interference is the primary mechanism behind forgetting. Stimulus associations are more likely to be forgotten if new associations to these stimuli are learned (retroactive interference). Similarly, previously learned associations interfere with and inhibit retrieval of new information (proactive interference). Both effects were recently demonstrated for advertisements for different brands in the same product class (Burke and Srull 1988). The dependent variable in this case was not brand recall, but ad information recall in general. An interesting feature of their experiments was that the content of the ads did not overlap, so the only relation between the ads was the common product class. One of the experiments used three levels of repetition and, as expected found a cumulative interference effect.

The retrieval competition phenomena (part-set cueing and interference) described here probably apply to brand name recall and recall of brand associations. We expect that the more the attributes and image of brands overlap, the more important memory competition effects will be. In some markets (e.g. cosmetics) it is hard to create a distinct memory position for a brand, because, at least from the perspective of the consumer, real product differences can hardly be discriminated and/or because the product does not lend itself to many associations.

We try to get more insight into the dynamics of these processes over time and over a number of different learning and retrieval occasions for different brands. Our attempts are based on a more explicit theory of memory processes. In the next section we start with the basic assumption of the theory and then discuss its elements in terms of the more specific model. For a systematic overview from a more general perspective we refer to the original formulations (Bjork and Bjork 1988, 1990).

## THE DYNAMICS OF LEARNING AND FORGETTING

### Storage and Retrieval Strength

The theory is built on the conceptual distinction between an item's storage strength and its retrieval strength in long-term memory. These strengths are latent constructs. Storage strength reflects how well learned an item is. Learning is used here in a broad sense and can be the result of the presentation of information (e.g. an advertisement) or of a successful retrieval attempt (e.g. when writing down a shopping list). The basic characteristic of storage strength is that it is a monotonic function of learning. It accumulates over time and never drops back to a previous level. This assumption reflects the general finding that information successfully encoded in long-term memory remains there virtually forever (see Solso 1988 for a review).

Retrieval strength is a measure of the current accessibility of an item in response to a given cue, and completely determines the probability of recall of an item. It is the equivalent of what other researchers refer to as activation or salience (Alba and Chattopadhyay 1986) of an item. In contrast to storage strength, retrieval strength can be lost, and is subject to capacity limitations - that is, there is a limit on the number of items that can be retrieved in response to a retrieval cue at a given moment in time. Although there is no direct effect of storage strength on recall probability, the important characteristics of the theory and model are a result of the interaction of the two memory strengths. The specific functional forms presented in the next section were chosen to accommodate general findings in experimental research. For a more detailed motivation we refer to Bjork and Bjork (1990).

**Learning and forgetting**

Treating time as a discrete variable, the gist of the model can be represented in two linear difference equations. We choose the time intervals such that only one learning event can take place in each time increment. Without loss of generality, storage and retrieval strength can be scaled between zero and one.

For storage strength we have:

$$S_{t+1,i} = S_{t,i} + L_{t,i} \{ \alpha \ (1 - S_{t,i}) \ (1 - R_{t,i}) \} \qquad 0 < \alpha < 1 \qquad [1]$$

Storage strength of item i at time t+1 is the storage strength at time t plus the effect of (re)learning the item at some moment in between t and t+1.

$L_{t+1,i}$ is a dummy variable indicating whether a learning event took place or not and A is the effect parameter. The effect is a decreasing function of current storage strength and a decreasing function of current retrieval strength, as both retrieval and storage strength have an asymptote of one.

Unlike storage strength, retrieval strength is volatile; it can decrease as well as increase. In any time interval, item i or another item j can be (re)learned. These learning opportunities are again represented as dummy variables, $L_{t,i}$ and $L_{t,j}$ respectively. In each time increment only one learning event can take place, which puts a restriction on the values of the dummy variables.

$$
\begin{aligned}
R_{t+1,i} = R_{t,i} &+ L_{t,i}\,\{(\beta + (1-\beta)\,S_{t,i})\,(1 - R_{t,i})\} \\
&- L_{t,j}\,\{\gamma\, a_{ij}\,(1 - S_{t,i})\,R_{t,i}\} \qquad [2] \\
&\qquad 0 < \beta,\gamma < 1 \\
&\qquad L_{t,i} + L_{t,j} = 0 \text{ or } 1
\end{aligned}
$$

The effect of (re)learning item i on retrieval strength is an increasing function of storage strength. Items which were well learned in the past, and therefore have a higher storage strength, can more easily regain retrieval strength than less well learned items. A new item will start from a storage strength and retrieval strength of zero, so the total effect of the first learning event is equal to B. The effect of further learning is then mediated by a more complex function of ß. Successive learning events have a decreasing marginal impact on retrieval strength.

The last term of equation [2] captures inhibition effects from competing items. The probability that a given cue leads to the retrieval of an item decreases as other associations to the same cue are learned subsequently.

Learning of a new item ($L_{t,j}$) is therefore represented as leading to a decrease in retrieval strength. The effect is a function of how much the items have in common, more specifically of the number of potential memory cues they share, and/or whether or not they are members of the same category. This similarity is denoted by $a_{ij}$, a measure between zero and one. $\Gamma$ is the forgetting rate, and the higher the current retrieval strength of an item, the more it will suffer from the interference of other items. On the other hand, storage strength acts as a buffer against interference.

The observable response of interest is the probability of retrieval. In the current version of our model, the probability of retrieval is simply equal to the retrieval strength.

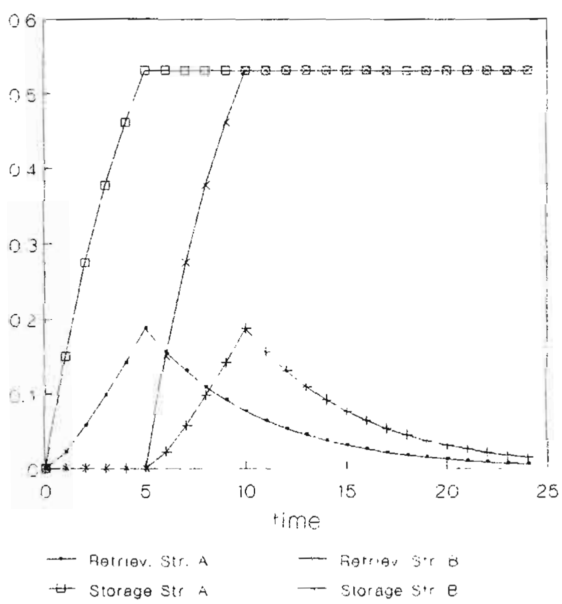
## ILLUSTRATION

In this section we show how the model can account for some peculiar human- memory phenomena and explore its implications in an advertising context.

### Memory dynamics

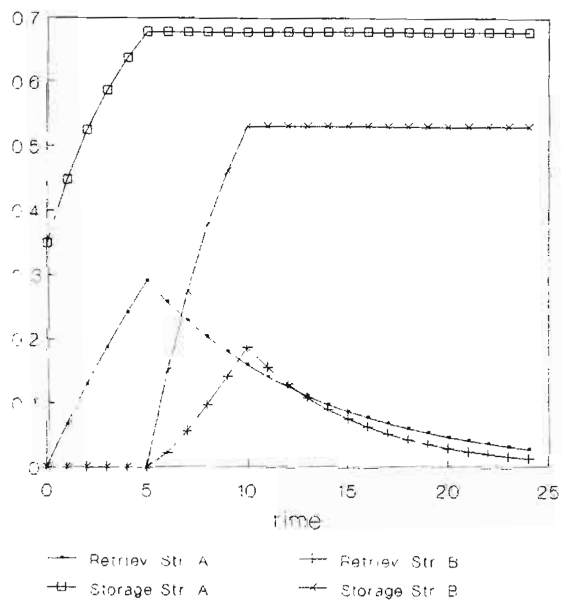
*Relative and absolute recovery.* One of the classics in memory research is the unlearning-plus-spontaneous-recovery phenomenon (Melton and Irwin 1940, Postman et al. 1968). Learning a list A of paired associates (s-r) can be undone by studying a new list of associates B in which the stimuli (s) are the same as in A but the responses (r) different. In our model, increasing the accessibility of second-list responses makes first-list responses less accessible. As time passes, however, list A responses recover relative to list B responses. Figure 1 shows retrieval and storage strengths across 24 time intervals. In the first five periods list A is learned, and B is learned in the next five. With the passage of time, new information is encountered which has some relation to A and B, and this leads to retrieval loss of both lists. We obtain relative recovery of list A because the loss of retrieval strength is negatively accelerated.

**Fig 1. Relative recovery**
**List A and B**



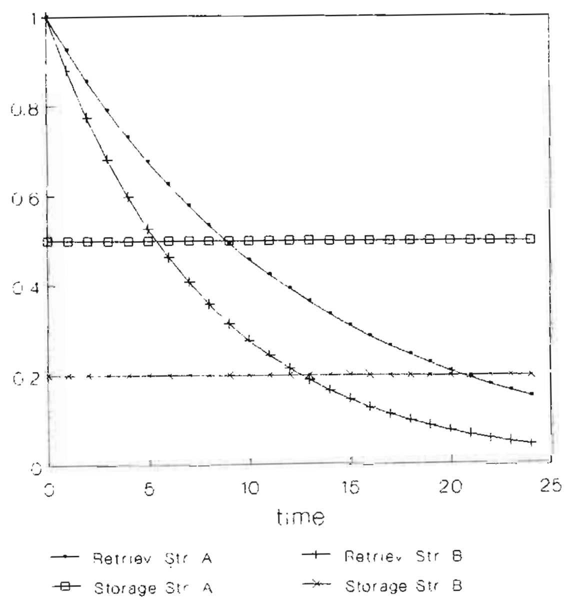

Recall of list A after a delay is sometimes also better than recall of the later learned list B in absolute terms. This outcome is predicted when A's storage strength is higher than B's storage strength, as in figure 2. Such a result illustrates how storage strength, although it has no direct influence on performance, still has an important latent impact. Real-world applications of unlearning and recovery are discussed in Bjork and Bjork (1990).

**Fig 2. Absolute Recovery**
**List A and B**




*Overlearning.* Another robust result in the learning literature is that additional learning trials after perfect performance has been achieved still are effective in the sense that they slow the rate of subsequent forgetting. In figure 3, list A and B have been learned to perfection, but A has been given additional learning trials after a period of delay. This additional practice resulted in a further increase in storage strength, which buffers the item against subsequent interference from other items.

Fig 3. Overlearning
List A and B



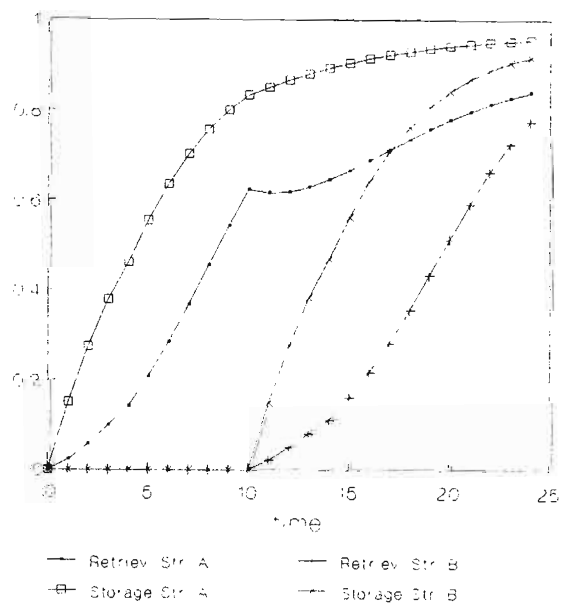

**An advertising scenario**

We look at learning and forgetting of one consumer who goes through a fixed weekly shopping routine. Storage and retrieval strength of brand names, in response to a product category cue, are influenced by two possible events: (a) advertising during the week and (b) retrieval at the moment the weekly shopping list is made. Both are learning events and retrieval is assumed to have a stronger impact. When the preferred brand cannot be recalled, the product category is written on the list. The brand decision is then made in the store, by comparison of brands or by recognition (if storage strength is larger than zero). The current version of the model ignores the possible effect of recognition on memory strengths. Another simplification is that events follow a fixed repetitive sequence. Each retrieval attempt/shopping event takes place at the beginning of the week and our consumer goes shopping every week. During the week, he/she can be exposed to advertising messages for two competing brands. Each brand can only advertise once per period. So, storage and retrieval strength in period t+1 are first of all updated for the effect of the retrieval attempt in t, at least if retrieval was successful, and next for the impact of advertising. Our model therefore consists of four difference equations. Also the asymmetrical effects of advertising are included in the model. Brands that in the eyes of the consumer are more similar to each other will affect each other's retrieval strength more heavily than less similar brands. These similarities are the $a_{ij}$ in the model. Finally, we also include the interference effect of other, weakly related information to which the consumer is exposed during the week.

In the context of this article we found a simple, nonstochastic version of the model more insightful. To simplify the present exposition, we assume that brands with nonzero retrieval strength are always retrieved (this drastic assumption does not alter the properties of the model we want to illustrate here). Since our model has not yet been parameterized on memory data, we based the assignment of parameter values on qualitative considerations. We started by modeling simple scenarios for one brand and increased the complexity step by step. The model for instance had to exhibit decreasing returns to scale and this limits the range of the parameter values. Some decisions were arbitrary. Retrieval is for instance a more potent learning event, but how it compares to advertising is unknown. The retrieval parameters were set at three times the value of the corresponding advertising parameters.

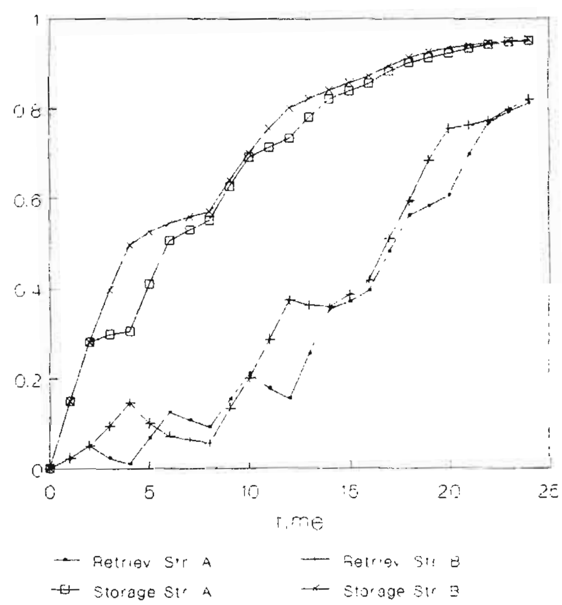
Because the results are to some extent a function of arbitrary decisions, we restrict this illustration to a few scenarios. Our main aim is to give an idea of the potential of the model. In figure 4 brand A is launched in week 1 with a 10 period advertising campaign. Its competitor B is introduced in week 10 with a campaign which on itself is as effective as A's, and which lasts for 14 weeks. An important observation is that retrieval strength for A is an S-shaped function of learning. The introduction of B interrupts this pattern. We first get a small drop in A's retrieval strength, but the continuous effective retrieval attempts and the high storage strength insulate the brand against B's competitive actions.

**Fig 4. Two Brand Market**
**Introduction B in period 10**



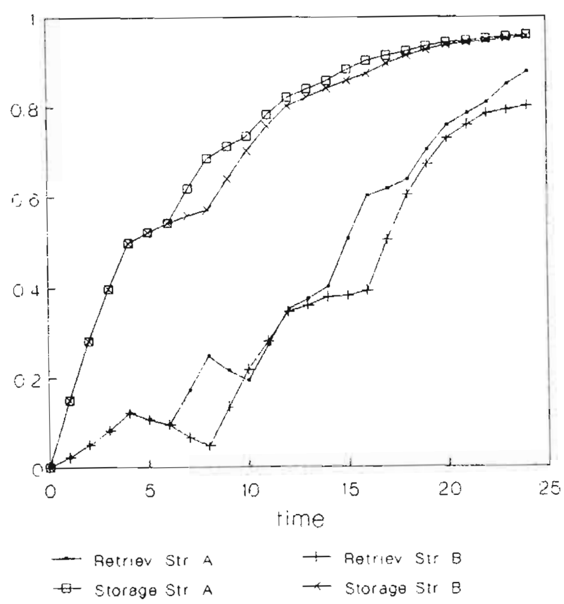
In figure 5, A and B simultaneously enter the market, advertise for an equal number of weeks during our observation period, but schedule their ad campaign differently. A starts with 2 weeks of advertising, discontinues the campaign for 2 periods, advertises again for 2 periods, etc. B also uses this pulsing pattern but with a 4 week cycle. Retrieval strength of A first follows a regular sawtooth pattern which corresponds to the advertising pattern. In later periods this response curve is smoother. The higher levels of all the variables involved give the interactions among these variables more weight, and the direct effect of advertising is less pronounced than in the first periods. After period 15, effective retrieval attempts in each period keep on pushing storage and retrieval strength to higher levels, even in periods where A does not advertise.

Fig 5. Pulsed Advertising
Scenario 1



Overall, B has a more effective strategy than A in scenario 1, although the advertising expenses are the same for the two brands. In figure 6, brand A has a slightly different schedule. The product launch is supported by a four-week instead of two-week campaign. For the next periods the two-week pulsing pattern of scenario 1 is used. B's actions are exactly the same as in figure 5. Using the same parameters as for scenario 1, we evaluate the response of our consumer to this sequence of advertising messages. Ignoring the two last periods, A and B again use the same number of ads. Nevertheless, the small change in A's strategy now gives it an edge over B in terms of retrieval strength.

Fig 6. Pulsed Advertising
Scenario 2



## Conclusion

Because the parameter values are to some extent arbitrary, the scenarios in the previous section are only a first exploration of the face validity of our model. They were also intended as an illustration of the potential of the model for advertising research. We believe that the distinction between storage and retrieval strength and the complex interaction between these variables in our model provide a new and promising way to study the cumulative effect of advertising.

We are currently simulating different scenarios with a probabilistic version of the model to examine its implications in more detail. Results of memory experiments are used as a benchmark. Parallel to this, we started working on the calibration of the model. The parameters are a function of the nature of stimuli and of the time intervals in the experiments. Different datasets will therefore lead to different parameter estimates. On the other hand, some patterns in the parameters should remain constant, reflecting the general properties of the memory system. In this respect even the parameters for the learning and forgetting of simple stimuli should tell something about memory for advertising messages. A next step in our project will then be the calibration of the model on advertising data.

# REFERENCES


Alba, Joseph W. and Amitava Chattopadhyay (1985), "The effects of context and part-category cues on the recall of competing brands," *Journal of Marketing Research*, 22 (August), 340-349.

Alba, Joseph W. and Amitava Chattopadhyay (1986), "Salience effects in brand recall," *Journal of Marketing Research*, 23 (November), 363-369.

Anderson, John R. (1983), "A Spreading Activation Theory of Memory," *Journal of Verbal Learning and Behavior*, 22 (June), 261-295.

Bjork, Robert A. and Elizabeth L. Bjork (1990), "A new theory of disuse and an old theory of stimulus fluctuation," in *Festschrift for W.K. Estes*, ed. A. Healy, S. Kosslyn and R. Shiffrin, Hillsdale, NJ: Erlbaum.

Bjork, Elizabeth L. and Bjork, Robert A. (1988), "On the Adaptive Aspects of Retrieval Failure in Autobiographical Memory," in *Practical Aspects of Memory: Current Research and Isuues: Vol. 1; Memory in Everyday Life*, ed. M.M. Grueneberg, P.E. Morris and R.N. Sykes, New York: Wiley, 283-288.

Burke, Raymond R. and Thomas K. Srull (1988), "Competitive Interference and Consumer Memory for Advertising", *Journal of Consumer Research*, 15 (June), 55-68.

Collins, Allan M. and Elizabeth F. Loftus (1975), "A Spreading Activation Theory of Semantic Processing," *Psychological Review*, 82 (November), 407-428.

Little, John D.C. (1979), "Aggregate Advertising Models: The State of the Art," *Operations Research*, 27 (July-August), 629-667.

Mahajan, Vijay and Eitan Muller (1986), "Advertising Pulsing Policies for Generating Awareness for New Products," *Marketing Science*, 5 (Spring), 89-106.

Melton, A.W. and J.M. Irwin (1940) "The influence of degree of interpolated learning on retroactive inhibition and the overt transfer of specific responses," *American Journal of Psychology*, 53, 173-203.

Nickerson, Raymond S. (1984), "Retrieval inhibition from part-set cuing: A persistent enigma in memory research", *Memory & Cognition*, 12 (6), 531-552.

Postman, L., Stark, K, and Fraser J. (1968), "Temporal Changes in Interference," *Journal of Verbal Learning and Verbal Behavior*, 7, 672-694.

Rundus, Dewey (1973), "Negative effects of using list items as recall cues," *Journal of Verbal Learning and Verbal Behavior*, 12, 43-50.

Shimp, Terence A. (1991), "Neo-Pavlovian conditioning and its implications for consumer theory and research," in *Handbook of Consumer Behavior*, ed. Thomas R. Robertson and Harold H. Kassarjian, Englewood Cliffs, NJ: Prentice Hall, 162-187.

Solso, R.L. (1988), *Cognitive Psychology* (Chapter 6, Memory: Structures and Processes), Newton, MA: Allyn & Bacon.