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Priming in a Distributed Memory System: Implications for Models of Implicit Memory

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ABSTRACT

Schacter (1987) reviews three different approaches that explain dissociations between 'explicit' and 'implicit' memory task performance: the activation view, the processing view, and the multiple memory system view. These theoretical distinctions have maximum explanatory power only when implemented in an operational process-level model of memory performance. As suggested by Schacter, the three 'views' or 'loci of effect' may not be mutually exclusive. This presentation starts with the most parsimonious assumption, a single memory system, modeled using Murdock's (1982) distributed memory model TODAM. We assess the degree to which this single system can account for a selection of both implicit memory phenomena (i.e., priming effects) and explicit memory performance and suggest necessary extensions or modifications of the model. Most implicit memory phenomena involve redintegration of partial cues (e.g., word fragment completion), a task which is handled easily and naturally by distributed memory models. Throughout, we discuss how the assumptions about encoding, storage, and retrieval processes made by TODAM to account for the data can be interpreted in light of current theoretical explanations of explicit/implicit memory differences.

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INTRODUCTION

If counterintuitive results are the mainstay of successful social psychologists, dissociation results make for good press in cognitive psychology. One distinction that has gained in popularity over the last several years is that between explicit memory, or conscious recollection, and implicit memory, defined as facilitation of test performance without conscious recollection as, for example, in priming. Dissociations occur at several different levels. Variables such as processing differences at encoding or modality changes between study and test have differential effects on the two types of memory tasks. Furthermore, amnesics who perform poorly at explicit memory tasks function virtually normally at implicit memory tasks.

Schacter (1987) reviews three classes of theories that have been suggested to account for these phenomena. According to the *activation view*, implicit memory effects are due to the temporary activation of pre-existing representations or logogens (e.g., Graf & Mandler, 1984) whereas explicit memory involves the creation of new memory traces. This hypothesis, which can be considered 'explanatory' only in a weak, metaphorical, sense, however has been empirically discounted (Graf & Schacter, 1985).

According to the *processing view*, implicit and explicit memory differ in their encoding and retrieval processes. Jacoby (1983b) and Roediger, Weldon, and Challis (1989a), among others, explain differences in implicit and explicit memory performance by attributing them to data-driven and conceptually-driven processing, respectively. However, in the absence of independent ways of assessing data-driven vs. conceptually-driven processing, this distinction adds little more than a different label to the phenomena. Dunn and Kirsner (1988) argue furthermore, that even double dissociations are logically inconclusive with respect to the question of single vs. multiple processes.

The *multiple-memory system view* assumes that implicit and explicit memory reflect separate underlying memory systems, for example Squire and Cohen's (1984) declarative memory vs. procedural memory distinction, or Tulving's (1972, 1983) episodic vs. semantic memory distinction. Sherry and Schacter (1987) provide a guide to the wide variety of current uses of the term 'multiple memory systems'. Humphreys, Bain, and Pike (1988), on the other hand, argue convincingly that the postulation of separate memory systems is little more than a renaming of the phenomena of interest.

Two recent developments suggest a different approach from the three discussed above. The first one is the advent of explicit process models of memory over the last decade. Examples of such models are Gillund and Shiffrin's (1984) Search of Associative Memory model (SAM) or Murdock's (1982,1985) Theory of Distributed Associative Memory model (TODAM). Models that explicitly instantiate hypothesized memory representations and processes (for example, as computer simulations) have to pay equal attention to similarities and dependencies in performance on different memory tasks as to performance dissociations, since their goal is to model memory performance in its entirety. This is especially true for the area of implicit and explicit memory, where few 'facts' are cast in stone. For example, early evidence that implicit memory does not depend on elaborative processing and decays over time coexists with studies showing an effect of elaborative processing on implicit memory and little change in performance over a 7 day span. (For a comprehensive review of the literature see Schacter, 1987, or Shimamura, 1986). Thus, an explanation or model of implicit and explicit memory must account for changes in outcomes as the function of seemingly insignificant task or procedural changes. Examples of the type of modeling that is capable of making a variety of predictions with a small set of representation and processing assumptions and careful task analysis can be found in Humphreys, Bain, & Pike (1989), Lewandowsky and Murdock (1988), and Weber (1988).

The second development is an increasing awareness of people's ability to make strategic use of available information and instructions in a variety of task environments [e.g., in inference (Klayman & Ho, 1987), decision making (Payne, Bettman, & Johnson, 1988), or memory tasks (Humphreys et al., 1989)]. That is, people are seen as active, adaptive, and goal-directed organisms who tailor their processing to the information, constraints, and task at hand.

In combination, these two trends suggest that differences in memory task performances may be fruitfully modeled with a common set of representations and processing mechanisms which are strategically and selectively applied as required.

The goal of this paper is to suggest how a variety of experimental results centered around the 'implicit vs. explicit' memory distinction can be modeled by one such process model; namely, Murdock's (1982, 1983) parallel, associative, and distributed TODAM. One of the most important advantages of a single-store distributed system over other models is its ability to reconstitute or *redintegrate* complete stimuli from only partial information or fragments. Redintegration is a natural consequence of TODAM's encoding and retrieval processes outlined below. This model feature is particularly important to handle the large range of implicit memory tasks involving redintegration, such as word or picture fragment completion.

When a model attempts to account for an ever larger range of phenomena and data, necessary changes or extensions in the model often become apparent. TODAM has gone through some of these changes since it first appeared in the scene in 1982, and some additional changes that may be required to handle implicit and explicit memory phenomena are suggested in this chapter. Some of these suggestions may turn out to be dead ends, but if only one of them turns out to be useful, the purpose of this chapter will be fulfilled. While some of the details described below depend at least partially on the particular representation and processing assumptions made by TODAM, some of the suggestions are quite general, and the basic logic of the approach could be generalized to other models at the same level of specificity (e.g., Pike's, 1984, matrix model).

GENERAL ISSUES

Locus of Implicit and Explicit Memory Effects

A pervasive assumption in current discussions of dissociations between implicit and explicit memory performance is that the effects arise at either the encoding stage (different stores or different encoding processes), at the memory retrieval stage, or as the result of mismatches between the two (Roediger et al.'s, 1989a, application of Tulving's notion of encoding specificity). Another possibility that has been largely ignored is that the effect occurs at the stage at which memory process output is converted into an overt response. It is possible that poor performance on a memory test may tell us nothing about memory because it may be due to criterion effects. In the case of recognition performance, for example, the output from the memory system—matching strength—needs to be interpreted by a decision system as sufficient to either identify or reject the item as old (see Hockley and Murdock, 1987, for details).

Hockley (1989) provides a convincing demonstration that differences in criterion values of the decision stage can account for a memory performance impairment (specifically, frequency discrimination in frontal lobe patients) without having to postulate any impairment in encoding or memory comparison processes. Snodgrass and Corwin (1988) provide further evidence that different memory pathologies, such as dementia, may manifest themselves mainly in criterion differences. Ratcliff and McKoon (1988) suggest a criterion model of 'perceptual' bias changes to account for long-term priming in such implicit memory tasks as perceptual identification or word fragment completion. As an explanation for the explicit memory deficit of amnesics, however, the criterion hypothesis may not suffice, since Snodgrass and Corwin (1988) found recognition memory impairments in amnesics to be mainly due to changes in discrimination (d') relative to normals rather than due to differences in criteria.

Need for Task Analysis

The collection of different memory tasks under the label 'implicit memory' on such grounds as that they all show preserved learning in amnesics or that they all require no 'conscious awareness' may falsely combine disparate phenomena and blind us to important differences. Thus, Ratcliff and McKoon (1988) argue against the existence of a unitary framework or process theory to explain all phenomena that have been labeled as 'priming'. Similar to our argument above, they emphasize the necessity for specific and explicit models of memory in order to evaluate claims about the similarities or differences between priming effects in different paradigms.

In addition to assuming a particular structural memory framework, a detailed analysis of a particular memory task will provide information or at least hypotheses about the following task components: (1) Given the experimental instructions, the stimulus material, and the presentation format, what did subjects encode? For example, was it more efficient to pay attention to item information, or rather relational information? (2) Were subjects aware of the subsequent memory task or tasks to be performed? Could they adjust their encoding to maximize performance on the subsequent task or did they have to use some 'general purpose' encoding strategy? (3) How did subjects use the retrieval instructions and cues? (4) How did the encoding and retrieval operations match or interact?

Depending on the experimental paradigm, differences between implicit or explicit memory performance, for example, may have to explained purely by differences in retrieval and response operations, if the instructions subjects received at study were neutral to the memory task at test or identical (e.g., Jacoby, 1983b). In other cases, subjects may receive different instructions during study, and thus performance differences could be modeled by different encoding operations as well. At any rate, implicit in these questions is the assumption that subjects have a flexible set of encoding and retrieval strategies that is adaptively applied given stimulus material and task context. Answers to these questions will, of course, only be useful to the extent that a memory process model is in place that can predict differences in memory performance as a function of encoding or retrieval content or process differences.

TODAM as a Structural Framework for Memory

Encoding, retrieval, and response processes in TODAM. Following J. A. Anderson (1969, 1973), TODAM represents information (items or events) as a vector of component attributes or features. Anderson's assumptions stem from attempts to provide a plausible neural information processing model, where items and events are represented as vectors of the firing frequency of neurons. Similarly, the features of TODAM should be thought of more as quasi 'neural' micro features than as aspects of an item or event that would be identified as 'features' by a human observer. However, TODAM makes no claim to being a neural model, but is rather an abstract mathematical model.

A common memory vector **M** stores item information as well as auto-associative and relational information. For item information, each item vector is simply added to the memory vector. The formation of an auto-association of an item with itself or of a relation between two items, **A** and **B**, is represented by the mathematical operation of *convolution* of the appropriate item vectors (see Murdock, 1982). A convolution of two or more vectors also results in a vector. Thus, item, auto-associative, and relational information are all simply vectors and can be superimposed in the same memory vector. To avoid saturation of M and to model forgetting, the current vector M is discounted by a constant $0 \le \alpha \le 1$, the forgetting parameter, every time new information is added. Other model parameters are the relative weights given to different types of information in a particular situation, where the weights sum to unity to represent limited attention or finite processing capacity. To store the j'th pair of items presented in a paired associate learning task, for example, the memory vector would be updated as follows:

$$\mathbf{M}_j = \alpha \mathbf{M}_{j-1} + b_1 \mathbf{A}_j + b_2 \mathbf{B}_j + c_1(\mathbf{A}_j * \mathbf{A}_j) + c_2(\mathbf{B}_j * \mathbf{B}_j) + d(\mathbf{A}_j * \mathbf{B}_j) \qquad (1)$$

where the sum of the weights $(b_1 + b_2 + c_1 + c_2 + d)$ is one. TODAM provides for three types of retrieval. The first is recognition, the process by which a present item is compared with information in memory, resulting in a yes-no response. The second is cued recall, where an item must be generated in response to a question or a cue word. Lastly, redintegration is the process that reconstructs a complete item from a partial list of its features.

Recognition is modeled by the dot-product of probe item A and memory vector M (i.e., A.M). The resulting value, which reflects the similarity between A and M, is fed into a two-criterion decision system very similar to the one proposed by Swets and Green (1961). More details can be found in Murdock (1982, 1983), with extensions that allow the system to make latency predictions in Hockley and Murdock (1987). To derive predictions for the decision stage of the model, one needs to know the variance of the dot-product similarity between probe and memory vector both for old (i.e., previously studied) and new probes. Analytic derivations for these moments can be found in Weber (1988).

The generative processes of recall and redintegration are modeled by the *correlation* operation. For associative recall, the cue A is correlated with the memory vectorM (i.e., A#M) where M contains, among other components, the convolution A*B established at study. In Murdock (1982), all contributions to the memory vector are mutually independent, which means that the correlation of A with M can be treated as the sum of the correlations of A with the components of M. The only non-zero correlation component is A#(A*B), which results in B′, an approximation to B. The degree of similarity between B′ and B is measured by the dot-product, such that B.B′ = B.(A#(A*B)). Redintegration uses the same operations as cued recall, with auto-associations as the crucial associative information in the memory vector M. That is, the correlation A#(A*A) has output A′ which is similar to A to the extent A.(A#(A*A)).

Conversion of the retrieved vector A′ or B′ into overt responses requires an additional stage of processing outside of the scope of TODAM. Murdock (1987) discusses several existing algorithms for this stage that he calls 'deblurring'. While TODAM does not model the deblurring process, it does predict its probability of success. To predict recall or redintegrative performance, TODAM computes the probability that the vector retrieved by the correlation operation (B′) is more similar to the target item B than to any other item and that the retrieved information B′ is within the critical range of the target. (For exact mathematical expressions, see Murdock, 1982).

Differences in performance for the explicit cued recall task and the implicit fragment completion task by amnesics (Graf & Schacter, 1985) suggest that TODAM would be well advised to show some response generation differences for these two tasks, even though both of them are 'generation' rather than 'matching' tasks in the sense of Humphreys et al. (1989). The suggestion made in this paper is that item generation in cued recall differs from item generation in redintegration tasks to the extent that the latter make no requirement for a familiarity match. Thus it is hypothesized that in cued recall tasks a response is generated, but that it is subjected to a dot-product recognition check with the memory vector M and that it is only emitted if the dot -product similarity exceeds a criterion. In redintegration generation tasks, no such additional similarity check is required.

This assumption helps in explaining the amnesic memory deficit of poor cued recall and recognition performance, which co-exists with virtually normal redintegrative memory performance (word fragment completion tasks or perceptual identification tasks), in a parsimonious way. One only has to assume that amnesics have lost the ability to perform (or utilize the results of) the dot- product similarity computation operation to explain the dissociation pattern. Generation tasks which do not require this operation, on the other hand, will show undiminished performance. The exact nature of this deficit would have to be further explored to see whether it is due to changes in criterion values at the decision stage or whether it occurs earlier during the memory match, manifesting itself as changes in d'. (The latter could, for example, arise if amnesics failed to encode item information, restricting themselves to auto-associative and relational information.)

As an aside, it is instructive to note that Ratcliff and McKoon's (1988, p. 405) contrast between retrieval and matching tasks, which require changes in d' to model performance differences, and production tasks, which require changes in criterion values instead, holds true only in their process model of memory, being a version of Morton's (1979) logogen model. As outlined in the previous paragraph, in TODAM it is possible to model performance differences in either type of task with either sensitivity or criterion changes.

As Schacter (1987) notes, despite frequent dissociations, there are many cases where implicit and explicit memory performance covaries. Thus the situation is similar to the relationship between recall and recognition performance, which are sometimes independent and sometimes not (Flexser & Tulving, 1978). The theoretical problem is to explain the whole pattern of results, not just the more dramatic experimental dissociations.

Murdock's (1982, 1983) model TODAM has allowed for possible dissociations between recognition and cued recall by assuming independent memory representations of item information and associative information, the latter being the convolution of the item vectors involved. Even though the two types of information are stored in the same memory store, M, thus eliminating search or homunculus problems, the information is independent in the sense that item information will not contribute signal strength in a cued recall task or vice versa. Different tasks or strategic considerations will encourage the selective encoding of different types of information (item vs. associative). For a detailed exposition of the model as well as applications, see Lewandowsky & Murdock (1989), Murdock (1982, 1983, 1989), and Weber (1988).

From its conception in the early 1980's, TODAM has become increasingly sophisticated. Elaborations of the model were largely 'data-driven', to account for a body of experimental results hierarchically increasing in complexity and scope. Thus, TODAM models forgetting (and serial position effects) by the joint operation of the model parameter, $\alpha < 1$ (representing decay of the existing compound memory vector every time new information is added) as well as output interference (the addition of recalled items back into the memory store). Learning (i.e., the phenomenon that by memory performance improves with repeated presentations of the stimulus) has been modeled by either a 'closed-loop' version of TODAM (Murdock & Lamon, 1988) in which information gets encoded only to the degree to which it is not already represented in memory or by the probabilistic encoding of item features (Murdock, 1987; Weber, 1988) where the probability of encoding a particular feature is a function of presentation duration. Another elaboration of TODAM has been the introduction of correlated as opposed to independent item vectors (modeled by a parameter, ρ, reflecting the correlation coefficient between item features) to represent similarity between items (Murdock, 1989).

Possible or necessary changes in TODAM. Redintegration or the ability to reconstruct an item from only partial cues (e.g., word stem completion or the identification of a degraded stimulus) was modeled by Eich (1985) by adding auto-associations of items ($A*A$) to the memory vector. (For details on the encoding and retrieval processes that thus allow redintegration, see Eich, 1985, and Weber, 1988). Redintegration clearly is an important process mediating implicit memory performance. Word or picture fragment completion tasks are prototypically redintegrative, and the ability to redintegrate seems to be largely preserved in amnesics (e.g., Warrington & Weiskrantz, 1968, 1970).

Performance in cued recall (mediated by $A*B$ memory components) and fragment completion (mediated by $A*A$ memory components) can, in fact, be statistically independent (Tulving,Schacter & Stark, 1982). This presents a problem for TODAM in its current form. Mathematically, $A*A$ and $A*B$ present in the same memory vector, M, will not be independent, because of the existence of nonzero covariance terms in the determination of responses. An additional argument against using the simple convolution of two item vectors, $A*B$, to represent the association of the two items A and B, are Humphreys et al.'s (1989) cross-associates paradigm data. As these authors point out, TODAM in its current form cannot account for people's ability to overcome strong pre-existing associations (e.g., *king—queen*, *bread—butter*) in order to identify such list-associates as *king—bread* or *queen—butter*. They suggest, instead, the incorporation of 'context' as an 'item' in its own right, into a three-way association. A different possibility is advocated in this chapter, namely to represent different relations explicitly as a triple associations between two items (**A** and **B**) and a relation connecting them ($\mathbf{R}_i$) to form $\mathbf{A}*\mathbf{R}_i*\mathbf{B}$.

This representation solves both of the previous problems. Strong pre-existing associations are usually the result of semantic relations, such as "Queen is married to King" ($\mathbf{Q}*\mathbf{R}_m*\mathbf{K}$), whereas experimental associations are generally of the type "Queen is contiguous to Butter" ($\mathbf{Q}*\mathbf{R}_c*\mathbf{B}$). Cued recall in TODAM of "What was the word Queen contiguous to?" (i.e., $(\mathbf{Q}*\mathbf{R}_c)\#\mathbf{M}$) will result in an answer similar to **B** or Butter, while at the same time cued recall of "Who are Queens married to?" (i.e., $((\mathbf{Q}*\mathbf{R}_m)\#\mathbf{M}$) will result in an answer similar to **K** or King. By the same token, associative or relational triplets will be mathematically independent from the auto-associative digrams, thus allowing for independent performance on tasks (e.g., recall vs. fragment completion) that involve one or the other.

Other changes to TODAM may be necessary to account for the whole range of implicit and explicit memory performance data. For example, it may be necessary to assume that different features of items get encoded for the different memory components, possibly in a hierarchical way. For example, auto-associative encoding, $\mathbf{A}*\mathbf{A}$, may focus on surface (i.e., perceptual features) of the stimulus, as the primary function of the auto-associative component is the redintegration of the stimulus from partial information. (This would explain the sensitivity of implicit memory tasks dependent on auto-associative information to modality differences or other surface feature changes). Item or relational encoding, in contrast, may focus on higher-level semantic features (including, perhaps, 'context'), in such a way that although surface features get encoded first, if time or task allows (i.e., this is where the levels of processing effects come in) then higher order features get encoded as well.

This explanation of modality effects and levels of processing effects in terms of different features entering into the memory representation of an item, depending on whether the item is encoded as an auto-association, as an item by itself, or in a relation, is a radical but maybe necessary departure from previous versions of TODAM. This distinction between types of features (modality-specific surface features vs. higher-level or semantic features) which are employed (more or less automatically) in different memory representations can be seen as an operationalization or process-model interpretation of Roediger et al.'s (1989a) distinction between conceptual and data-driven processing. It gives meaning to their general idea that a match between encoding and retrieval requirements is necessary for optimal performance (along the lines of Tulving's encoding specificity principle).

Ratcliff and McKoon (1988, p. 405) interpret differences in the decay rate of memory effects as reflecting the involvement of different but possibly overlapping kinds of information for different tasks. In the context of TODAM, some more specific interpretations are possible. Differences in decay rate of memory effects in different tasks may be due to different degrees of output interference of the different memory components. Alternatively they may be due to differential vector length when stimuli get encoded as items, auto-associations, or in relational structures, or as the result of levels-of-processing manipulations.

Memory Dissociations in Amnesics

Early interest in differences between implicit and explicit memory performance was sparked by dissociations of performance on tasks in these two classes by amnesics. This raises the question of how to model the amnesic memory deficit in a model like TODAM, in such a way as to account for the body of data. Parallel to the question whether implicit vs. explicit memory differences are a homogeneous phenomenon, it is at least questionable whether amnesics' memory performance can be explained by postulating a single deficit.

Hypothesized deficits will depend on the particular memory model employed. Thus Humphreys et al. (1989) assume that amnesics may be deficient in encoding 'context'. Memory systems explanations would hold that amnesics may be missing a particular memory system (e.g., episodic memory). In the context of TODAM, the amnesic deficit could be a particular encoding operation or more likely a particular retrieval or response operation (see below).

Illustrative Examples

As a final demonstration of how task specific shifts in encoding and retrieval operations may bring about functional dissociations, we will provide a qualitative interpretation, using TODAM, for the results of Jacoby's (1983b) study. This is meant to be only illustrative of the modeling approaches discussed above. No claim is made that these approaches could account for all the data in this large and complex body of literature.

In this study, subjects studied antonyms under three conditions. They were either presented with the pair *hot–cold* with the instruction to read it out loud (the *context* condition), with the display *hot–?* with the instruction to generate the antonym and say it out loud (the *generate* condition), or with the display *xxx–cold* with the instruction to read the second word out loud (the *no-context* condition). At test, subjects were assigned to one of two conditions, involving a recognition (explicit or matching) task or a perceptual identification (implicit or generation) task. The main result of the study which is also discussed at length in Roediger et al. (1989a), was that relative performance on the recognition task increases from the *no-context* to the *context* to the *generate* condition, whereas the opposite is true for the perceptual identification task.

How would TODAM account for this pattern of results? For the recognition task, performance in the *no-context* condition is mediated only by the item information ("cold") as the only information encoded in the memory vector. In the *context* condition, item information is utilized just as in the *no-context* condition, but in addition subjects can use the relational component of the memory vector ("cold*R*hot"). To the extent that the recognition cue *cold* retrieves an antonym that is also recognized as 'old' (*hot* in this case), *cold* itself is more likely to be an old item. Finally, in the *generate* condition, subjects can also take advantage of both item and relational information. The small performance advantage of the *generate* over the *context* condition may be due to relational or antonym information getting a larger attentional weight under 'generate' instructions than under 'read' instructions, leading perhaps to a longer item or relational vector which would lead to superior performance in a task where the strength of the overall match determines performance.

In contrast, for the perceptual identification task, it is the previous encoding of the item's surface features that determines relative performance. Thus, one would expect performance to be worst in the *generate* conditions, where subjects never saw the word *cold* and thus never encoded the visual surface features. In the *context* as well as the *no-context* conditions, subjects see the stimulus and thus get to encode its surface features as auto-associations. However, in the *context* condition, subjects see twice as many items as in the *no-context* condition. Thus, on the basis of greater output interference, one would expect worse performance in the *context* condition.

CONCLUSIONS AND INTERPRETATIONS

Dissociation of memory functions in normals has been modeled by assuming different and independent components in the memory vector for item, auto-associative, and relational information. The more usual dependencies of memory performance can be modeled by assuming that under favorable conditions all three components are equally well (or equally badly) encoded. However, instructions, presentation format, or study conditions can lead to asymmetric and/or independent encoding of components. One could, presumably, label these different memory vector components as different 'memory systems.' This would however lose the interpretation usually given to that label, namely spatially distinct storage locations. Certainly, the different components suggested here do not coincide with any memory system division previously suggested.

It was suggested that amnesic explicit memory deficits may occur not at the storage or retrieval stage, but at the subsequent decision stage. A defect in performing TODAM's familiarity match (dot-product) operation would explain the amnesics' deficit in tasks that require this operation (mainly explicit memory tasks) and their virtually normal performance in those tasks that do not (mainly implicit memory tasks). The exact nature of such a defect (e.g., a d' or a criterion effect) needs to be explored further.

In conclusion, the attempts at explanations of implicit vs. explicit memory performance differences in terms of a unified memory model like TODAM should be seen not so much as competitors to other explanations, but as ways to implement these explanations in a process account (while reaping some of the benefits of a distributed representation at the same time). To do so in a systematic and comprehensive way will still require a lot of work. Several issues concerning explicit vs. implicit memory were hardly addressed here—for example, the modality sensitivity of implicit memory tasks compared with the levels of processing sensitivity of explicit memory tasks. These may necessitate the introduction of different (or only partially overlapping) feature vectors when encoding item, auto- associative, or relational information, as briefly discussed earlier.

The chapter argued for the importance of a task analysis, in addition to having an explicit process-model of memory like TODAM, to explain the effects of stimulus manipulations and task context on memory performance. One example of such an analysis was provided, but in a post-dictive fashion (i.e., inferring what must have been encoded and retrieved at time of study or test to produce the obtained pattern of responses). The argument for task analysis will be all the more strengthened if, in the future, encoding and retrieval assumptions will be made predictively and in a unified fashion across a range of experimental conditions and paradigms.