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STRUCTURE AND PROCESS OF HUMAN LONG-TERM MEMORY

A Dissertation Presented

By

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ABSTRACT

This dissertation, using the methodology of cognitive psychology, addressed several questions about the structure and process of human long-term memory (LTM). First, several arguments were presented for viewing LTM as a dynamic network structure.

Within this framework, the major structural question addressed in this dissertation is whether there are isolable LTM sub-structures. Several possible partitions of LTM were considered, and a specific multilayered LTM hypothesis was developed. An assumption of this hypothesis which was tested is that there are isolable lexical (word) and semantic (concept) memories. Previous work relevant to this issue was reviewed.

While associative retrieval is a natural type of processing in a network structure, whether there are more complex, constructive, but still automatic retrieval processes (i.e. procedural retrieval) was the major processing question addressed in this dissertation. Two types of associative retrieval processes--intersection and generate-test--were described, and several notions about procedural retrieval were outlined. Previous experimental work addressed at related questions was reviewed.

The approach used to address these issues was to require subjects to make simple timed responses to experimentally presented material. They retrieved one of several types of information about one of several words on each of several hundred randomly sequenced trials. A general process model was constructed which was assumed to reflect the flow of information processing required to complete the task, and reaction time (RT) data were used to analyze the retrieval stage. Of special interest was the pattern of sequential effects. How does RT to retrieve a fact vary as a function of the relationship between to-be-retrieved and recently-retrieved information? What does this imply about the structure and process of LTM? Sequential predictions concerning the multi-layered LTM and procedural retrieval hypotheses were derived.

The major purpose of Experiment I was to address the processing question. Interesting sequential effects which could be assigned to the retrieval stage of processing were observed. Among other things, faster RT to retrieve the same type of information about different concepts on pairs of successive trials was inconsistent with purely associative retrieval models but was consistent with procedural retrieval.

Experiment II, using different stimulus materials, replicated the findings of Experiment I, and also addressed the major structural question. In particular, different patterns of sequential effects were obtained for pairs of successive trials hypothesized to involve retrieiving information from the same versus a different LTM layer, a result consistent with the multi-layered notion. However, the exact nature of these results were not easily accounted for by purely associative multi-layered models.

Experiment III using different stimulus materials, replicated the major findings of Experiments I and II. A modification of associative multi-layered models was introduced to account for the structural results of Experiments II and III, and was further tested in Experiment IV. In addition, Experiment III examined the special role that semantic relations (i.e. CATEGORY, INSTANCE, and PROPERTY) may play in retrieval of semantic facts by looking at sequential effects among these three types of retrieval. While such effects were present, they were not accounted for by purely associative models, but were explained in terms of a procedurally-oriented LTM.

Experiment IV re-examined the structural question and found that even the modified associative model was inadequate. The results were also explained in terms of a procedurally-oriented LTM.

Finally, several comments about the nature of a procedurally-oriented LTM were made. Specifically, the ambiguity of the distinction between structure and process is emphasized in such models, as is the constructive property of LTM. However, such a notion should not be viewed as antithetical to network models which emphasize the associative property of LTM. Rather, further work is required to better understand the coordination of these important properties of LTM.

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CHAPTER I

INTRODUCTION

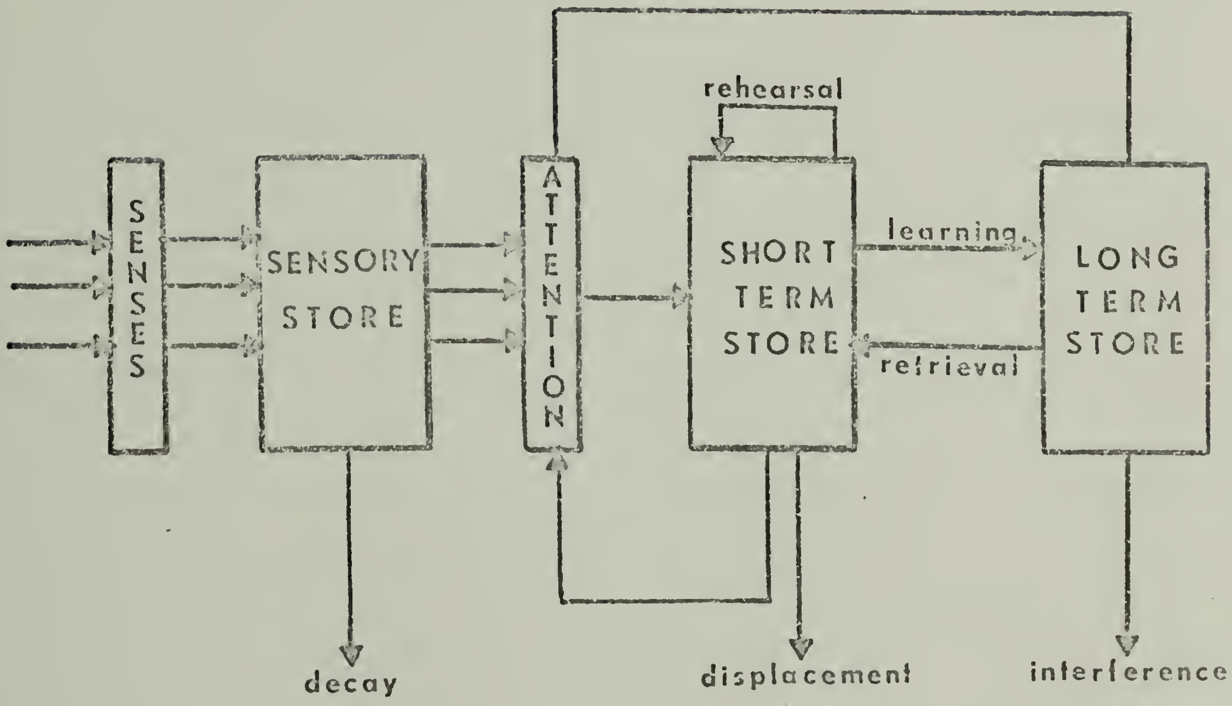
From classical philosophers to modern neuroscientists, students of the mind have attempted to delineate a set of isolable cognitive structures and processes which are both necessary and sufficient to account for the variety of intellectual functions humans are capable of. By viewing the mind as an information processing system and by examining the behavior of the system when different information and/or task demands are imposed upon it, cognitive psychologists have recently made considerable progress toward a structuralist description of the mind.

Figure 1, adapted from Broadbent (1958), presents a generally accepted schematization of the human information processing system. Cognitive processing is viewed as a series of transformations of information, each influenced by previous experience and knowledge and by limiting properties of relevant parts of the system. This dissertation is concerned with the long-term memory (LTM) component, the store for the variety of knowledge we have and for the processes which allow us to use that knowledge in interesting ways.

In this chapter, several arguments will be presented for viewing LTM as a network, and three processing assumptions which follow from previous experimental work will be described; these notions about LTM structure and process provide the theoretical framework in which the questions addressed in this dissertation will be posed. The next two chapters will discuss a number of general issues about ways to refine

Figure 1

An Information Processing Model of the Mind



the dynamic LTM network described in the introduction. First, various proposals about a more differentiated LTM will be discussed, and experimental attempts to validate some of these notions will be reviewed. Then several types of LTM processes will be contrasted, and relevant experimental work will also be reviewed. Finally, the last six chapters will present the logic, results, and conclusions of a series of experiments designed to test hypotheses about structure and process raised in earlier chapters.

Structural Assumptions

An increasingly popular, but by no means new, way to conceptualize LTM is as a network--a set of nodes interconnected by arcs. This view does not constitute a strong predictive model, but is rather a weak heuristic, flexible enough to represent both simple and complex types of knowledge necessary to account for human cognitive processing. Before summarizing some of the advantages of a network conceptualization, two alternative views of LTM, sequential data structures and feature models, will be briefly discussed, and their inadequacies pointed out.

Alternative conceptualizations. The first alternative LTM representation, sequential data structures, has its origins in metaphors to computer memories. The important property of these memories is that they are not content addressable, but rather must be searched serially. While this idea has been useful as a model of short-term memory (c.f. Sternberg, 1969; Theios, 1973), it is probably inadequate to capture important properties of LTM for which network models are well-suited. Specifically, we know that previous experience influences cognitive processing in ways not easily accounted for by models which postulate storage of memories in isolated memory stacks (Perlmutter, Harsip, and Myers, in press; Perlmutter, Sorce, and Myers, 1976).

Feature models (c.f. Smith, Rips, and Shoben, 1974; Smith, Shoben, and Rips, 1974) are another possible approach to representation of information in LTM. A major difficulty of these models is specifying a psychologically acceptable set of features. While on the one hand, it has been demonstrated that a sufficient feature analysis may not be available for all concepts (c.f. Wittgenstein, 1958), on the other hand, Taylor (1976) has demonstrated the serious consequences of deriving predictions from feature models with incorrect identification of features. Since there are difficulties in deciding on an appropriate set of features, and since feature models are a special case of network models (see Hollan, 1975), it seems appropriate to work with the weaker class; we will thus return to discussion of network models.

Philosophical considerations. Three broad and converging investigations of cognition provide positive support for a network conceptualization of LTM. First, the associative nature of the human mind has been a dominant and recurring epistomological claim. Thus, since networks are abstract associative structures, we might conclude that they are well-suited as models of memory. However, it is important to consider a recent controversy between psychologists who believe that memory is primarily constructive and should not be represented by networks (c.f. Anderson and Ortony, 1975; Jenkins, 1974), and those who emphasize its associative property (e.g. Anderson and Bower, 1973). The present position is that it should be clear that memory is both associative and constructive, but that both properties can be incorporated into complex memory networks. There are several recent sources of support for this claim. First, Foss and Harwood (1975) have described how configural information can be encoded in memory networks. Second, existing artificial intelligence (AI) programs which attempt to process natural language (e.g. Schank, 1972; 1973), do in fact, represent knowledge generated by their constructive processes in associative networks. Finally, also within the domain of AI, a number of investigators (e.g. Winograd, 1972, 1973; Norman and Rumelhart, 1975) embed procedural knowledge within associative networks which has the consequence of making them constructive memories.

Biological considerations. A second reason for preferring network models is that they are naturally occurring biological structures. The fact that the brain is built from networks of neurons and that low level behavior can be modeled in terms of neural networks, makes the network metaphor of LTM somewhat more appealing than less natural structures (e.g. stacks). Of course, this argument is extremely weak since the level of analysis of cognitive theories is so distant from biological considerations.

AI considerations. The third source of support for the claim that network models might be able to capture the richness of the human information processing system comes from work which attempts to program computers to behave intelligently, AI. Following Quillian's (1968; 1969) seminal work on the use of semantic networks in a natural language processing system, virtually all AI projects which represent diversified bodies of real world knowledge do so in network data structures. A defining property of these structures is that pointers (arcs in the network) are used to divorce the logical organization from the physical organization. This leads to flexible retrieval since the subset of memory examined for any particular problem can be limited by tracing only logically relevant pointers. Also, efficiency of storage is obtained because information units need be represented only once; pointers, rather than copies of memories, may then be used to reference or modify memory. The relevance of this point to human LTM can be seen by noting that while we sometimes have the capacity to analyze complex concepts into their component features, to have to do so in the context of storing or retrieving each memory of a complex concept is not always possible and would be wasteful of storage and processing resources. Rather, the more fundamental property of human memory seems to be its ability to recognize the identity of complex concepts in different contexts, as well as the similarity of related complex concepts.

A final point about work in AI is that most recent ideas about representation of knowledge (e.g. Arbib's schemes, 1975; Hewitt's actors, 1973; Minsky's frames, 1975; Schank's scripts, 1975; or Winograd's frames, 1975) while much more sophisticated than Quillian's (1968) original ideas, can be viewed as extensions of, rather than alternatives to, semantic networks.

Summary. To summarize, the present work assumes that it is useful to conceptualize LTM as a network. Several arguments for this position were presented. Further, while this theoretical perspective is weak, it raises interesting questions about the nature of LTM. The purpose of the present dissertation is to address some of these questions.

The first set of questions which grow out of this framework deal with further specification of the organization of LTM. Should the LTM network be viewed as one homgeneous knowledge store, or is it more useful to view LTM as a layered network, or as some other heterogeneous structure? Further, what are the isolable substructures of LTM, and what type of experimental evidence can confirm or disconfirm the existence of a particular hypothesized LTM structure?

In addition to specifying the structure of LTM, it is important to understand what types of fundamental cognitive processes allow us to make use of our stored knowledge. One natural type of processing in a network simply involves traversing pathways to obtain relevant information, associative retrieval. A second focus of this dissertation will be to begin to isolate more complex cognitive processes.

Before dealing with these questions in more detail, it is important to specify three assumptions about the dynamics of the LTM network. These assumptions are derived from experimental work which will be briefly summarized. Their relevance is due to the fact that the present methodology relies on viewing LTM as a dynamic network. Inferences about LTM structure and process are based on experimentally-induced changes in cognitive behavior as a function of recent processing.

Processing Assumptions

Strength assumption. An important point in the present formulation of LTM is that associations in the network have strength values which influence processing times: High strength associations are processed faster than low strength associations. Support for this assumption is found in the results of several recent experiments dealing with semantic memory. For example, Wilkins (1971) found that time to decide whether or not a word is a member of a semantic category depends on the conjoint frequency of category and instance. Conrad (1972) found that time to verify the relationship between a subject and predicate decreases as associative strength between them increases. Consistent with these findings, Rips, Shoben, and Smith (1973) found that time to verify propositions decreases as a function of rated distance between subject and predicate. Also, Sanford and Seymour (1974) found that time to produce the correct superset of a category instance is less for "close" than for "far" instances.

A series of experiments which investigated retrieval processes in episodic memory (Perlmutter, Sorce, and Myers, 1976) indicated that strength directs episodic retrieval as well. Further, these experiments led us to conclude that strength varies both as a function of processing which occurs in the laboratory and as a function of pre-experimental conditions. Subjects memorized lists of from three to twenty-four pairs of words. Then reaction time (RT) to recall a response to a visually presented cue was measured on each of several hundred randomly sequenced trials. RT increased as a negatively accelerated function of list length, both the slope and intercept of this function decreased with practice, and RT increased with lag (number of items intervening since the current item was last probed) but decreased with consecutive repetitions of a single cue. These findings were accounted for by a model which assumed that strength increases when an association is retrieved but decreases at other times and that RT is an inverse function of strength. Further, the influence of pre-experimental strength was accounted for by viewing it as a minimum strength level, specific to each association. These assumptions about the dynamics of strength fluctuations will be adopted in the present work.

Competitive search assumption. The second processing assumption is that associative retrieval involves a competitive search among associations from a starting node, and amount of competition is related to strength of other associations. Our own work with memorized pairs of words (Perlmutter, Harsip, and Myers, in press) indicates that semantic associations of words interfere with the retrieval of memorized associations. A complementary finding by Lewis and Anderson (1976) is that RT to verify a pre-experimentally known fact about a famous person increases as number of experimentally memorized facts about the person increases. Also, King and Anderson (1975) have found that number of experimentally memorized facts about a concept predicts recognition time to any one of them, and Hayes-Roth and Hayes-Roth (1975) obtained equivalent results and also showed that amount of competition can be experimentally manipulated by practice of selected associations. Thus, there seems to be ample evidence that both pre-experimental and experimentally learned associations compete for processing when any type of information is retrieved. It should be noted that the competitive search notion is consistent with various formulations of interference theory (c.f. Postman and Underwood, 1973), and with several recently proposed models in which retrieval is based on a ratio-of-strength rule (Rundus, 1973; Shiffrin, 1970).

Spreading activation assumption. The previous two conclusions: (1) that strength of associations increases during processing and decreases at other times; and (2) that other associations from a node are processed during retrieval, suggest that these other associations may also fluctuate in strength. This conjecture finds support in experiments which have demonstrated that recent processing in LTM has consequences for subsequent processing. In a variety of tasks, there is evidence for the belief that activation persists for several seconds.

Meyer and his co-workers (Meyer and Schvaneveldt, 1971; Meyer, Schvanveldt, and Ruddy, 1974; Schvanveldt and Meyer, 1973) found that time to decide that two letter strings are both English words is shorter for associated words (e.g. BREAD-BUTTER) than for nonassociated words (e.g. NURSE-BUTTER). Following a series of experiments employing this lexical decision task, they concluded that facilitation of the second lexical decision was attributable to a spread of activation, that the encoding stage was facilitated, and that activation decays within a few seconds.

Spreading activation may also facilitate the retrieval stage of processing. Collins and Loftus (1975) recently interpreted a large body of results within the context of spreading activation. They reviewed several experiments in which subjects were required to produce an instance of a category (e.g. FRUIT) which began with a specified letter (e.g. A) or had a specified property (e.g. RED). Shorter RT was observed when the category was supplied before the restriction (Freedman and Loftus, 1971), when category and instance were highly associated (Loftus, 1973), and when the same category had been presented on the preceding trial (Loftus and Loftus, 1974). The authors argue that in all conditions in which responses are facilitated, activation from a concept node is spread over a more restricted set of paths. Assuming a fixed amount of activation, more activation on each path under these conditions than under conditions in which activation is spread more diffusely, should result in faster retrieval. A similar interpretation is applicable to results of a study by Collins and Quillian (1970). Employing a verification task, they found shorter RT when pre-specified categories were narrower.

That spreading activation can interfere with response retrieval is suggested by a study reported by Gorfein and Jacobson (1973). They used the Brown-Peterson paradigm in which subjects are presented with a word, required to recall it approximately 10 seconds later, and then presented with the next study word after a rest interval of about 5 seconds. In the Gorfein and Jacobson (1973) experiment, each successive set of six words was from the same semantic category. Time to recall increased with serial position within a semantic set and decreased when a word from a new category was presented. These data suggest that search for a word is slowed by increased activation on paths to related and recently processed words.

Results from our recall task (Perlmutter and Myers, 1974, in preparation) may also be interpreted in this way. Recall of memorized associates was significantly slower when all cue words were from the same semantic category than when they were all from different categories. Our interpretation is that presentation of any one cue sets up patterns of activation which provides competition to the correct response for other, related cues.

Warren (1972; 1974) presented subjects with a list of one or more items for later recall, then measured time to name the color in which a word was printed. Color naming required more time when the color word (word printed in color) was a member of the to-be-remembered list, a category label for items in that list, or an associate of items in the list. In the case of uni-directional associates, the interference effect occurred only when the memory word elicited the color word. Warren interpreted these results as support for the hypothesis that encoding a word entails activation of its associates. Attempts to determine the time course of such activation produced conflicting results but it appears that interference can be obtained with lags of at least 15 second between presentation of memory and color word.

Summary. To summarize, three LTM processing constraints were presented. First, associations in the LTM network are assumed to have strength values. The magnitude of these strengths is both a function of long-term semantic knowledge and recent processing. When associations are processed their strength increases and at other times it decreases to its semantic base rate. Second, search through this network is directed by current strength values, and is competitive among associations from the starting node. Third, a spreading activation process serves to increase strength on pathways recently processed and their neighbors in the LTM network.

CHAPTER II

STRUCTURAL ISSUES

Thus far, arguments for viewing LTM as a network were presented and evidence for three assumptions about processing within that network was reviewed. A major focus of the present dissertation is to consider the possibility that LTM can be best viewed as consisting of several isolable, but interconnected memories. Noting the many different classes of information which are apparently represented in human LTM, many memory theorists have postulated the existence of "functionally distinct" sub-structures, with LTM being partitioned along the same lines as the knowledge which is represented within it. While the potential advantages of this "divide and conquer" strategy are apparent enough, it should be equally clear that such an epistomological approach toward understanding memory must be viewed with caution. While a theory of knowledge can provide hypotheses about useful ways to conceptualize LTM, independent criteria must be established for verifying these ideas.

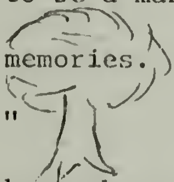
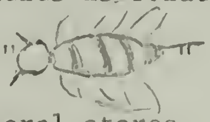
One reason to hypothesize the existence of more than one LTM sub-structure is that some information is best represented in one type of data structure, while other information is better represented in another type of data structure. A second reason for hypothesizing the existence of multiple LTM sub-structures is if different bodies of knowledge are better organized along different dimensions. In this section several LTM distinctions will be discussed with respect to these two coding criteria and related considerations. This will result in the presentation of one hypothesis about the organization of LTM. The experiments to be reported are, in part, attempts to validate several details of this conceptualization.

Memory Distinctions

Conceptual and peripheral memories. One reason the human information processing system is both so fascinating and difficult to study is that it operates in three very different modes. It directly interprets information from its five senses (sensory mode); it interprets and generates symbolic information through the use of language (linguistic mode); and it interprets and generates information of an even more abstract form when it thinks (conceptual mode). The important point is that while there are systematic relationships among the contents of all three of these information modes, the appropriate way to capture them in a cognitive theory is by no means obvious.

One way to deal with this problem is to assume that the information mode of thought (the conceptual mode) is the fundamental mode of the human information processing system, perhaps analogous to a computer's machine language. Then linguistic and sensory information requires translation into the conceptual form. An LTM model can capture this notion by postulating that one component, a conceptual store, retains general knowledge and specific memories, while additional LTM components (peripheral memories) retain modality specific information. It should be emphasized that what are being referred to here as linguistic and sensory stores are, in fact, components of LTM because they retain the knowledge necessary to interpret external stimuli and to transform that information into conceptual memories.

Drawing a gross distinction between a single conceptual memory and a number of mode specific peripheral memories seems well-founded on a number of grounds. First, with respect to the second coding criterion, a conceptual store should be organized along semantic dimensions, whereas a linguistic store might be better organized along phonemic and/or orthographic dimensions, and each sensory modality might have its own best organizing principle (e.g. visual memories are probably temporally organized).

The second major reason for hypothesizing several modality specific peripheral memories and a single conceptual memory is that there seems to be a many-to-one mapping of peripheral representations to conceptual memories. So, for example, the memory representation for "TREE" and "" probably map into a single conceptual memory. That we know about the commonality between these two stimuli leads to hypothesizing a single conceptual store. That we know about the differences between them (e.g. that the first stimulus is related to "BEE", but the second stimulus is not related to " in the same way) leads to hypothesizing multiple peripheral stores.

<u>Sensory and linguistic memories</u>. A number of memory theorists, most notably Paivio (1974), focus on the clear differences among inputs to the human information processing system and postulate memory distinctions along the same lines. Since so much of our non-linguistic sensory input is visual, virtually all such theories consist of visual

and verbal memories, but presumably there are equivalent memories for other senses. On the other hand, some theorists (e.g. Anderson and Bower, 1973; Pylyshyn, 1973; 1975) focus on the conceptual equivalence of modality specific inputs and argue for a single LTM. By summarizing arguments of the former theorists, advantages of hypothesizing multiple peripheral memories should be apparent. By summarizing arguments of the latter theorists, on the other hand, advantages of hypothesizing a single modality independent store at a more central level (the conceptual level) should also be apparent.

The four types of evidence which have led Paivio to the dual-store position are: (1) that there are individual differences in human abilities for independent symbolic systems (Guilford, 1967; DiVesta, Ingersoll, and Sunshine, 1971); (2) that a perceptual task can interfere with performance on a memory task, or vice versa, if the two involve the same perceptual-motor systems (Brooks, 1968; Bryne, 1974; Klee and Eysenck, 1973); (3) that imagery and verbal encoding instructions affect recall in memory experiments (Paivio and Csapo, 1973); and (4) that visual information appears to be processed in an analogue fashion (Cooper and Shepard, 1973; Kosslyn, 1975). These points are well-taken; however, they could all be accounted for by a model which makes the visual-verbal distinction at a peripheral level only.

Pylyshyn (1973; 1975) has, in fact, presented convincing arguments that any visual information, including that used in mental rotation or relative size judgement experiments, could be represented in the same types of data structures as verbal information (i.e. propositions). In fact, he suggests that believing that analogical representations are more natural solutions is simply sweeping the problem under the rug. Whether a discrete or analogue data structure is used, the theorist must account for how information about physical laws which govern non-linguistic stimuli is encoded. To believe that these issues are automatically resolved in analogical representations is naive. Pylyshyn's position, then, is that propositional data structures, about which we know more than analogical data structures, should be further explored for solutions to representing visual knowledge.

To summarize, it is suggested here that LTM be viewed as several modality specific peripheral memories (including visual and verbal stores), and a single conceptual memory. We will now turn to discussion of one issue which has led to a sub-division of conceptual memory.

Universal and particular memories. One dimension along which conceptual information has often been classified is its degree of generality. At one extreme is analytic knowledge--what we know, by definition, to be true of all possible worlds (e.g. All bachelors are unmarried). Another type of knowledge, synthetic knowledge, we apparently know by induction to be true in this world (e.g. All milk is white). However, even synthetic knowledge is quite general compared to a third type of knowledge, knowledge we have of specific events (e.g. The milk I drank this morning was white). That humans can distinguish among these classes of knowledge and that most people share the same intuitions about how to classify any given fact, indicate that the LTM in which they are all represented encodes information about generality of memories.

Many memory theorists have been sensitive to issues about generality of knowledge, and several different solutions to the question of precisely where it is theoretically important to draw distinctions between classes of knowledge have been offered. The present position is that it is important to distinguish between universal memories which conserve generalized knowledge (both analytic and synthetic) in an abstracted or schematized form, and particular memories which conserve experiences. This distinction is consistent with Tulving's (1972) "pretheoretical" distinction between semantic and episodic memory. The major distinguishing features between these two memories are that while episodic memories are more or less faithful records of a person's experiences which can be described in terms of perceptual properties and temporal-spatial relationships to other events, semantic memories are much less literal and do not require storage of temporal-spatial information. Further, episodic memories have autobiographical references and are susceptible to transformation and loss, whereas semantic memories have cognitive references and are stable.

Theorists who have proposed more specific LTM models than Tulving (1972), especially computer modelers, have also found it useful to draw a distinction between universal and particular knowledge. While these theories differ in detail, the universal-particular dichotomy seems to be a common theme among the LTM distinctions summarized in Table 1. Quillian's (1968) work on semantic networks introduced the distinction between type (universal) and token (particular) nodes to information

Table 1

Representation of Universal and Particular Knowledge

THEORY	UNIVERSAL	PARTICULAR
Anderson & Bower (1973)	Concept node	Individual node
Atkinson and Juola (1973)	Lexicon	Event/knowledge store
Fiksel and Bower (1973)	Semantic store	Propositional store
Quiillian (1969)	Type node	Token node
Rumelhart, Lindsay, & Norman (1972)	Primary node	Secondary node
Schank (1975)	Scripts	Episodes
Tulving (1972)	Semantic store	Episodic store

processing modelers. Similar distinctions are seen in Anderson and Bower's (1973) concept versus individual nodes, and in Rumelhart, Lindsay, and Norman's (1972) primary versus secondary node. The type-token node distinction has afforded semantic network models considerable efficiency of storage because universal knowledge can be stored once at type nodes and thereby holds implicitly for token nodes which point to types. There is also a good deal of flexibility for retrieving related memories in such a system, because the type nodes serve as a complex cross-reference system. Furthermore, that a single token node may reference an arbitrarily complex structure, gives semantic network models considerably more flexibility to account for complex cognitive phenomena than previously believed possible of fundamentally associative structures.

One major difference among the models summarized in Table 1 is whether lexical knowledge (knowledge about words) is retained in the universal store or in a separate peripheral memory as proposed here. Anderson and Bower (1973) and Schank (1975) are most explicit about retaining word information separately from conceptual information, whereas the other theorists mentioned in Table 1 seem to believe that information about the word that stands for a concept is one type of universal knowledge. On the other hand, a recent model proposed by Collins and Loftus (1975) distinguishes between lexical and semantic memories, but is not explicit about how particular memories are encoded.

In addition to the facts that we seem to be able to classify information on a generality continuum, and that computer modelers have found the universal-particular distinction useful, there is at least one other reason for including this distinction in an LTM model. The first coding criterion mentioned above indicates that one reason to hypothesize distinct LTM stores is that the knowledge retained in each is best represented in different types of data structures. Since a good deal of universal knowledge seems to be abstracted, procedural representations are well-suited data structures. On the other hand, particular memories seem to be adequately represented in declarative data structures. This suggestion is realized in Schank's (1975) model in which universal knowledge is encoded in what he calls scripts which are stereotyped procedures, whereas particular memories are encoded in propositions. Further discussion of viewing memory of universal knowledge, at least in part, as a set of procedures which use particular memories as data will be presented in the next chapter on LTM processing. At this point, the present position on the three structural distinctions discussed in this section will be summarized by introducing one hypothesis about the organization of LTM.

Three-layered LTM network. It was previously suggested that a useful way to view LTM is as consisting of a conceptual store and several peripheral stores. Since the present work will focus on processing of linguistic material, the relevant peripheral store will be referred to as the lexicon; other peripheral stores may be thought of as being in the same memory level since they also map into conceptual representations.

For the present purposes, it is hypothesized that there are three distinct levels of memory: (1) lexical memory where information about words is conserved; (2) semantic memory where universal knowledge about concepts is conserved; and (3) episodic memory where particular knowledge about episodes is conserved. The latter two memories are both components, but at different levels, of conceptual memory; lexical memory, on the other hand, is one of a number of peripheral memories which share a single LTM level. The notion of level captures the fact that there is a one-to-many mapping of nodes from lexical to semantic and from semantic to episodic memory, although some episodic nodes have no semantic correlates and some semantic nodes have no lexical correlates.

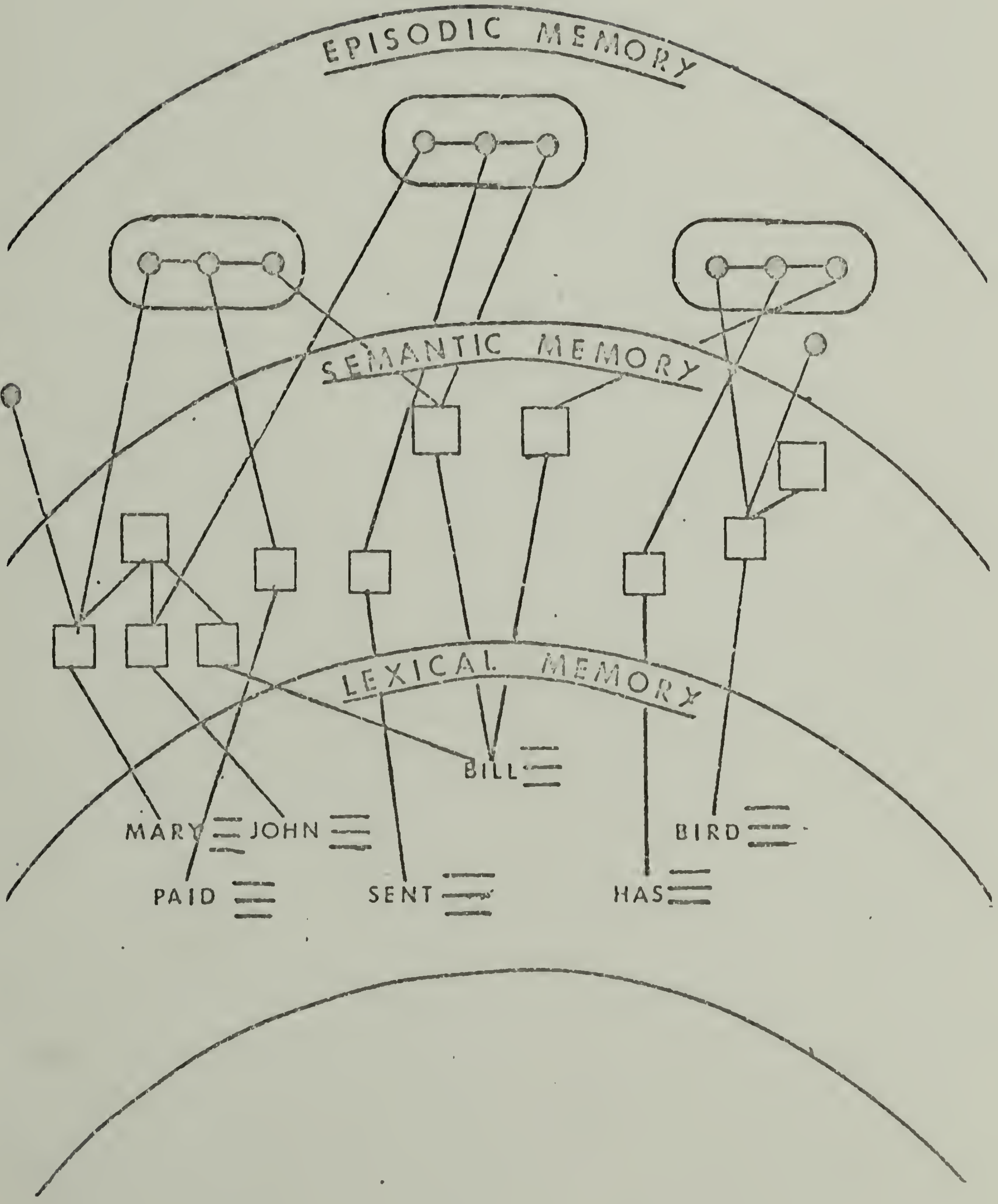
In line with the first coding criterion, there seem to be prior reasons to believe that different data structures might be better suited to representing these three classes of knowledge, and AI work in natural language processing supports this claim. While lexical memory could easily be represented by a look-up table of phonemic, orthographic, and possibly syntactic features, the conceptual stores must be much more associative. In fact, a number of investigators have shown that declarative representations are well-suited for encoding episodic knowledge. On the other hand, abstractions of particular memories, that is semantic knowledge, may be better encoded in procedural representations. Such representations may actually encode a good deal of knowledge about the concept, or may simply be a set of procedures for examining corresponding episodic memories. The models of Anderson (in press), Norman and Rumelhart (1975), and Schank (1975) are most consistent with this position. In line with the second coding criterion, organization of lexical memory should be along phonemic and/or orthographic dimensions, semantic memory along conceptual dimensions, and episodic memory along temporal-spatial dimensions.

Figure 2 is an example of part of this three-layered memory which encodes the sentences "Mary paid a bill," "John sent a bill," and "The bird has a bill." The important points to note are that: (1) literal lexical information is not available in conceptual memory; (2) there are one-to-many mappings from lexical to semantic, and from semantic to episodic memory; (3) some semantic nodes have no lexical equivalents, and similarly some episodic nodes have no semantic equivalents (in this example, the overall propositions); and (4) semantic nodes can be associated to other semantic nodes and episodic nodes can be associated to other episodic nodes. Perhaps the most important point about the layered network perspective of LTM is that while there seem to be good prior reasons to draw a number of distinctions about types of knowledge in LTM, each layer is connected to other layers. We use universal knowledge to understand particular events; we use particular events to infer universal knowledge; and we understand the meaning of words by the episodes they have been used in.

A further point about this network is that the three processing assumptions discussed previously--strength valued associations, competitive search, and spreading activation--are all hypothesized to hold throughout the network. While the simple associative retrieval implied by these assumptions is certainly a fundamental type of processing which is involved in a good deal of cognitive processing, one

Figure 2

Three-Layered Memory



goal of the present work was to find support for the existence of more complex, but non-strategic, LTM processes. Since the type of processes investigated make use of semantic information, hypothesized to be represented procedurally, their isolation may be taken as support for the notion of a procedurally represented semantic memory. Further discussion of this will be postponed until the next chapter. At this point, since a major goal of the present work is to provide experimental support for the notion of distinct lexical and conceptual memories, several previous approaches to investigating this issue will be reviewed.

Empirical Evidence

Four types of empirical evidence provide some support for the notion of a multi-layered LTM. All of these classes of evidence are weaker than would be desired. However, the package as a whole lends some credence to the issues of interest, and the experiments to be reported in subsequent chapters provide converging evidence for the conclusions derived from the empirical work reviewed here.

Physiological evidence. Perhaps the strongest type of evidence which can be used to isolate an LTM component is physiological. One example is that when we find patients with selective memory deficits, we might want to conclude that the type of knowledge they are lacking is analogous to an isolable type of memory. So, for example, the very existence of patients with alexicas, auditory agnosias, and digraphias may be taken as support of the notion of an isolable lexicon. While a number of theorists (c.f. Luria, 1973) would like to use this type of evidence to draw much more detailed pictures of the relationship between parts of the brain and cognitive functioning, there seems to be enough confusion in the relevant literature (c.f. Geschwind, 1969) to suggest that such an endeavor might be best postponed.

Another source of physiological evidence, which at least weakly supports the notion of an isolable lexicon, is work done on hemispheric specialization (see Dimond and Beaumont, 1974 for an interesting collection of papers on this topic). While older work suggested a neat distinction between linguistic functioning in the dominant (left) hemisphere, and non-linguistic functioning in the other hemisphere, more recent work indicates that this conclusion is premature. However, an emerging picture now seems to support the notion that both hemispheres have access to a conceptual memory, whereas only the left hemisphere has access to lexical knowledge. That the right hemisphere does not process at the lexical level seems most clear in the domain of speech production, but appears likely to hold for word recognition as well.

Same-different RT experiments. A second approach to isolating LTM sub-structures is exemplified by the notion of levels of processing which has provided a major thrust to an extensive research program by Posner and his co-workers (c.f. Posner, 1969, 1973; Posner and Mitchell, 1967; Posner, Lewis, and Conrad, 1972). They measure subjects' RT to make same-different judgements to pairs of simultaneously presented stimuli; the same-different rule is based on physical (e.g. A A), name (e.g. A a), vowel versus consonant (e.g. A E), or category (e.g.

Dog Cat) identity rules.

Two types of evidence from these experiments can be used to confirm a levels of processing analysis. First, if RT remains constant to make same decisions to a given stimulus pair while varying the decision rule, different levels of processing must be involved. For example, the finding that RT to make same judgements to physically identical stimuli (e.g. A A) was equal under physical and name identity decision rules, implies that there are distinct physical and name codes. This is because if both decisions were based on a single measure of similarity, a less stringent criterion could be used to say same under name than physical identity instructions. Contrary to the observed result, this would lead to faster RT under name than physical identity instructions. Second, if RT remains constant to make different decisions while varying amount of irrelevant similarities in pairs, but holding the decision rule constant, different levels of processing must be involved. For example, the finding that RT was equal to make different judgements to same (e.g. A a) and different (e.g. A b) name pairs under a physical identity decision rule also implies that there are distinct physical and name codes. This is because if decisions were based on a single measure of similarity, a different response could be arrived at more quickly for less globally similar different name pairs (e.g. A b) than for more globally similar same name pairs (e.g. A a), again a finding disconfirmed by the data.

A difficulty for the levels analysis, however, became apparent in an experiment in which Eichelman (1970) required subjects to name letters as quickly as possible. He found that RT decreased when the same letter was repeated on successive trials. That this repetition effect was greater for physically identical letters than for those having only their name in common is not naturally accounted for by the levels of processing notion. Rather, Posner and Snyder (1975) have recently appended a general spreading activation notion to their theory. They argue that:

> In a naming experiment subjects appear to benefit from automatic activation primarily. In simultaneous matching tasks the levels of processing component seems to dominate. In successive matching, both factors may be involved.

This additional complication suggests that the same-different paradigm may not be very useful for distinguishing among more complex levels of knowledge. The next experimental approach, examining the effect of various orienting tasks on incidental learning, on the other hand, has the potential to be more appropriate to such an endeavor.

Incidental learning experiments. Craik and his co-workers (Craik, 1973; Craik and Lockhart, 1972; Craik and Tulving, 1975) have also proposed a levels of processing analysis of memory. However, the major focus of their work is considerably different from Posner's. Their basic idea is that it is useful to view an LTM trace as a consequence of the perceptual analysis which encoded the initial stimulus. Further, they believe that trace persistence is a function of the depth of perceptual analysis. Shallow analyses are concerned with less persistent physical features while deeper analyses are concerned with more persistent, more abstract, meaningful features.

The experimental work most relevant to this theoretical position are studies which measure incidental memory as a function of type of orienting task. Shallow orienting tasks generally deal with the stimulus words on a physical level (e.g. Is there an e in the word? or produce a rhyme); on the other hand, deeper orienting tasks generally deal with the stimulus words on a meaningful level (e.g. Is the word pleasant or not? or produce an associate). When orienting tasks are either scaled by experimenters, or on the basis of time to make discriminations, "deeper" orienting tasks lead to better incidental recall (e.g. Hyde and Jenkins, 1969; 1973; Johnston and Jenkins, 1971; Till and Jenkins, 1973; Walsh and Jenkins, 1973) and incidental recognition (Craik and Tulving, 1975).

Unfortunately, it is not clear that this line of investigation could lead to the identification of isolable memory codes or levels of processing. Rather, it might simply demonstrate that "meaningful events are well-remembered." While Craik and Tulving (page 270) entertain this possibility, they reject it (I am not clear why). That their most recent experiments (Craik and Tulving, 1975, especially Experiment 8) led them to conclude that it is more useful to think of enduring LTM traces as resulting from elaborative, rather than deeper processing, seems to support the suggestion that their approach will not lead to a precise specification of isolable levels of processing. At the same time, it does not rule out the possibility that such a goal is achievable.

Priming experiments. The final experimental approach to the identification of isolable LTM sub-structures, priming studies, rests on the assumption that there is a spreading activation process in LTM. Further, retrieval is conceptualized as resulting from the intersection of several strength directed search processes (see Collins and Loftus, 1975). A number of experiments in this domain by Loftus and her coworkers(e.g., Freedman and Loftus, 1971; Grober and Loftus, 1974; Loftus and Cole, 1974) have led Loftus (1973) to postulate a lexicon, distinct from semantic memory.

Freedman and Loftus (1971) had subjects produce an instance of a category that began with a given letter (e.g. A-Fruit) or was characterized by a given adjective (e.g. Red-Fruit). That subjects were faster when the category was given first than when either the letter or adjective were given first was explained by the fact that spreading activation would be restricted to a less diffuse area of LTM and would thus be stronger when the category name was seen first. Grober and Loftus (1974) used the same task, but category names always came first. They ran one condition which blocked letter and adjective trials separately, and one which randomly mixed both trial types. While blocking facilitated letter trial RT, it had no effect on adjective trial RT. Collins and Loftus (1975) interpreted these results as support for the notion of distinct lexical and semantic memories which can be separately primed. Another relevant experiment which Collins and Loftus (1975) explain in terms of their model was reported by Loftus and Cole (1974). In this experiment, subjects' RT to produce an appropriate instance to noun, adjective, letter triples (e.g. Animal, Small, M) was measured. That subjects were faster when the adjective was presented before the letter was explained as follows:

> When the adjective appears before the letter, activation will spread from a small set of instances in the semantic network to the lexical network where the intersection occurs, since the letter can be expected. When the letter is presented before the adjective, activation will spread from a small set of instances in the lexical network back to semantic network where an intersection with the adjective will occur. Then the subject must return again to the lexical network to retrieve the name, so there is an extra transit necessary in this condition.

Thus, the results of these experiments seem consistent with a model which postulates separate lexical and conceptual memories. The experiments to be presented here represent an alternative application of the priming methodology to examine the same LTM layers. Before turning to a discussion of these experiments, some general questions about the nature of processing in LTM will be raised.

CHAPTER III

PROCESSING ISSUES

The previous section discussed questions about how the variety of knowledge we have may be organized in LTM. The present section will consider questions about the processes which allow us to make use of that knowledge. It is important to realize, however, that any neat dichotomy between cognitive structure and process is more apparent than real. In fact, Anderson (in press) has recently proved that there are systematic trade-offs between cognitive structures and processes of a theory of LTM. Behavioral data which can be predicted by any particular theory could be equivalently predicted by an infinite number of theories which hypothesize different cognitive structures, but simultaneously compensate by modifying the postulated cognitive processes. For the present purposes, this leaves us in the position of looking for cognitive processes which complement the network model of LTM previously argued for.

This section will consider three classes of retrieval processes--intersection, generate-test, and procedural. The first two are most familiar in the psychological literature on memory. There are well-defined models of each which have been explored both theoretically and empirically. The notion of procedural retrieval, on the other hand, is less precise. While one could unearth many historical roots, including ideas from Gestalt, motor, and schema-oriented theories, applications of these ideas to memory have not yet been precisely modeled. Nor have conditions for empirical validation of procedural retrieval been well-defined. The present discussion of this class of retrieval processes will focus on more current theoretical developments which come from AI. As presented in the next chapter, a major goal of this dissertation was to define experimental conditions in which the notion of procedural retrieval could be investigated. The second part of this chapter will review some possibly relevant empirical work.

Retrieval Processes

Intersection retrieval. The network view of LTM claims that the meaning of a concept is, at least in part, encoded by the set of associations which intersect at its LTM node. Thus, a fundamental type of process which can make use of this type of knowledge is associative retrieval, traversing arcs in the LTM network. The first type of associative retrieval to be considered is intersection retrieval. The basic idea is that a response is available at the intersection of two or more associative chains. Precisely how such a process can solve cognitive problems depends upon the specific task involved, as well as structural details of the network. However, a number of models in the literature (e.g. Anderson, in press; Collins and Quillian, 1972; Collins and Loftus, 1975; Fiksel and Bower, 1976) indicate that such a retrieval process is, in fact, capable of: (1) retrieving facts; (2) recognizing which facts have been previously encoded in LTM; and (3) computing simple inferences. A more detailed discussion of perhaps the most formally precise model, Fiksel and Bower's (1976), should serve to support the claim that intersection retrieval is capable of a good deal of the cognitive processing people seem capable of, and indicate how such a process works.

An interesting point about Fiksel and Bower's model is that each node in their LTM network is a finite state automaton, which has a finite number of labeled limbs connected to other nodes in the network, thus encoding associative relationships. When a particular problem is posed to this LTM, a control process establishes the task requirements in terms of a sequence of relational types (limb labelings). Associative retrieval is accomplished by propagating activation through the network in a manner sensitive to the relational structure, while keeping track of what the memory is searching for, and how far it has preceded.

Given this representation, Fiksel and Bower have proven that a finite solution to any well-specified fact retrieval problem can be found. (By well-specified it is meant that the relationship between the cued and required concept can be established in terms of the relational types.) This fact retrieval is accomplished by propagating activation from the cued node along appropriately labeled limbs until the entire relational sequence is satisfied. Also, Fiksel and Bower have proven that their system can determine whether any well-specified relationship between two LTM concepts is already encoded in memory. This is accomplished by simultaneously propagating activation from the two LTM nodes. In one case the relational sequence is traced in a forward manner; in the other case it is traced in a reverse order, using inverse relations. If an intersection is achieved between these two processes at precisely the point when the relational sequence is exhausted, the fact was previously encoded in LTM. Finally, by including production operators which make use of logical information such as "A property of a superset of a concept is a property of the concept", Fiksel and Bower's LTM network is also able to compute simple inferences. This is accomplished, using the inference rule mentioned as follows: When a property relation occurs in the relational sequence, appropriately encoded activation is propagated along property <u>and</u> superset limbs; in the case of the superset limbs, an additional property relation is inserted in the relational sequence.

To summarize, by way of example it was argued that intersection retrieval processes could make use of a good deal of knowledge stored in LTM networks. Specifically, fact retrieval, recognition memory, and simple inference can be accomplished by such a simple process. Further, it is suggested that assumptions about the dynamics of network, such as those presented in the introduction (i.e., strength valued arcs, competitive search, and spreading activation) can serve to make the LTM network context sensitive and account for quantitative aspects of a number of experimental results.

<u>Generate-test retrieval</u>. A second type of associative retrieval process which has been explored in network models of LTM is generate-test retrieval. This type of process is best conceptualized as consisting of two sub-stages. During the first sub-stage associations related to a cued concept are generated; during the second sub-stage they are tested for correctness. Precise mathematical models of many varia-

tions of each of these sub-stages exist in the literature on memory, perception, and sensation. Such analyses will not, however, be discussed here because aspects of generate-test retrieval relevant to the present work are not dependent upon these finer grain considerations. Rather, they hinge on the basic assumption that there are two sub-stages of retrieval, the first of which is directed from a single cued concept.

As with intersection retrieval, one well-specified decision retrieval model of LTM (Anderson and Bower, 1972; 1973) will be described with the goal of indicating how such a process can accomplish a number of simple cognitive tasks. In Anderson and Bower's model, each node in the LTM network has a set of relation-specific GETLISTS which encode associative relationships. When a particular problem is posed to this LTM, the cued concept is accessed. Then, possible solutions are generated by scanning the properly-labeled GETLIST. The test sub-stage involves checking that an appropriate associative configuration can be traced from a particular GETLIST entry.

In many ways, this type of processing is similar to intersection retrieval. In fact, Anderson and Bower have demonstrated that their model is capable of the same types of processing that Fiksel and Bower's model is capable of. Both of the retrieval processes are associative in that retrieval involves tracing appropriate associations in search of a pre-specified configuration. In intersection retrieval, more than one requirement of the solution can be simultaneously cued and a solution is defined at the intersection of these search processes. In generate-test retrieval, on the other hand, search is initiated from a single cued element and possible solutions are tested with respect to all other relevant information. This distinction may evaporate when generate-test retrieval processes are allowed to proceed in parallel from several nodes, as they are in Anderson and Bower's model; however, this complication will not be considered in the present work.

To summarize, generate-test retrieval, like intersection retrieval, can be easily incorporated into a dynamic network representation of LTM. It is also capable of accomplishing many of the simple, but fundamental, cognitive tasks human beings are capable of. A distinguishing feature of generate-test retrieval is that there is a single focus from which associations are first generated, and then tested for relevance. At this point we turn from these basically associative retrieval processes to consideration of more complex, but less well-defined, procedural retrieval processes.

Procedural retrieval. While some form of associative retrieval seems to be a fundamental type of cognitive processing, it is interesting to ask whether more complex processes are directly available in LTM. That is, while it is clear that we can solve complex cognitive problems, must we construct appropriate associative chains on line, or are there some types of processing for which there are isolable LTM procedures directly available? For example, is there an isolable LTM procedure which can find a particular class of information (e.g. CATEGORY or COLOR) about any concept? If the answer is yes, what are the types of knowledge for which these procedures are psychologically valid? How may they be incorporated into network models of LTM? How can their existence be experimentally demonstrated? It is suggested here that some insights into all but the last question may be provided by considering ideas about procedural representation which have come out of recent work in AI. The final question about experimental verification of some of these ideas will be postponed to the next section.

As was previously mentioned, much work in AI, particularly natural language processing, has provided cognitive psychologists with a rich source of theoretical ideas. In particular, Quillian's (1969) work on semantic networks indicated how a network structure provided with intersection retrieval processes could accomplish many cognitive tasks. The notion of semantic networks has been further developed in natural language processing systems (c.f. Simmons, 1973) and cognitive theories of LTM (c.f. Collins and Loftus, 1975; Fiksel and Bower, 1976) and has led to a good understanding of declarative (propositional) data structures (c.f. Pylyshyn, 1973; Sandewall, 1970). However, as these notions have been more fully explored and their limits noted, ideas about alternative procedural representations (e.g. Norman and Rumelhart, 1975; Winograd, 1972) have provided an exciting new dimension to second generation AI projects and are particularly relevant to the present discussion of LTM processes.

A better understanding of the distinction between declarative and procedural representations can be attained by noting a parallel philosophical distinction between "knowing that" and "knowing how". Also, Piaget's distinction between figurative and operative memory has the same flavor. The former memories are static structures, while the latter are dynamic processes.

The present suggestion is that just as natural language processing systems found semantic networks to be limited, cognitive theories which do not postulate cognitive processes more complex than associative retrieval may be limited. Rather, isolable cognitive processes in the form of procedures may capture a new dimension of the human information processing system. To the extent that this is true, it will be important to more precisely define these LTM procedures and the control structure which coordinates their computation. For now they may be viewed as knowledge packages which have the capacity to actively derive knowledge from other parts of LTM.

Several advantages of the procedural notion will be mentioned. First, referring to the previously made distinction between representation of universal and particular knowledge, it is interesting to speculate that a procedural memory generates universal knowledge from declarative, particular representations. Second, procedural representations are extremely efficient means of storage, since one rule may generate an infinite amount of information (for example, it can be used to classify an infinite number of stimuli which represent the same concept). Third, procedural representations provide a link between mental representations and action, a link which is missing from purely declarative representations. Fourth, the idea of storing information procedurally negates the structure-process distinction which was previously questioned; in procedural representations, the structure is the process which operates on memory.

It is important to address the question of whether and how these procedural representations may be incorporated into network conceptualizations of LTM since it was previously argued that such a framework was valuable. A number of memory theorists (e.g. Anderson and Ortony, 1975; Jenkins, 1974) have argued that these more complex ideas about process are antithetical to network structures. For example, Jenkins said that:

> ...at rock bottom there is a profound difference in belief between associationism, which presupposes fundamental units and relations out of which all else is constructed, and contextualism, which presupposes that events are primary and that the quality of events determines what the possibilities are for a host of analyses.
>
> (Jenkins, 1974; page 794)

However, it is argued here that the type of network model entertained in the previous section is associative, but does not make the fatal assumptions Jenkins associates all associative theories with. In fact, the third generation of natural language processing systems (e.g. Minsky, 1975; Moore and Newell, 1973; Schank, 1975; Winograd, 1975) have been especially concerned with the problem of finding useful ways of combining declarative and procedural knowledge in usable information packets, and developing appropriate control structures to coordinate processing in these complex systems. As was previously mentioned, these ideas can be viewed as an extension of semantic networks, rather than as alternatives. Yet, it is important to note the change in emphasis to more complex and dynamic memory components in these new models. A parallel change in focus may be warranted in the domain of LTM theories. We will now turn to a discussion of the type of experimental work which might be applicable to investigating these more complex ideas about cognitive processing.

Empirical Evidence

There is probably no disagreement with the claim that humans make use of both simple associative and complex procedural (constructive) processing. At the extremes, neural transmission is associative, while planful behavior is procedural. The present problem is to more clearly delineate the nature of an intermediate level of processing. Specifically, is there evidence for procedural types of processing which can be characterized as non-strategic, automatic, etc.? Two approaches to addressing this issue will be mentioned here and relevant empirical work will be summarized. The experiments to be reported in later chapters provide an alternative approach to the same problem.

Mental arithmetic experiments. Since there may be a large number of heterogeneous LTM procedures, one way to demonstrate their role in retrieval is to carefully investigate the processing involved in a limited and well-specified task domain. Chronometric studies of mental arithmetic and number comparison (e.g. Groen and Parkman, 1972; Parkman, 1971, 1972; Parkman and Groen, 1971; Restle, 1970), provide an example of this approach. The basic idea behind this work is that process models can be developed on the basis of well-defined computational algorithms, and RT predictions can be derived. If the structural variables assumed to influence processing (e.g. minimum number, maximum number, sum, etc.) account for observed RT differences, support for a particular process model of the task, and the general idea of procedural retrieval is obtained.

In this vein, Parkman and Groen (1971) proposed a counting model to account for the finding that mental addition time increases linearly with sum and minimum of two addends. Specifically, in their model a counter is set to the larger number, and then incremented an appropriate number of times. If time to set and increment the counter is constant, the correct RT predictions result. However, alternative associative processes might lead to the same pattern of RTs. For example, Groen and Parkman (1972) suggested that:

> The counting model could easily be reformulated as retrieval algorithms that calculated an index, rather than a sum, with the index being used for a memory retrieval operation. Alternatively, one might reformulate each model in terms of a list structure. The setting operation might then correspond to an operation that accessed a given list, while the incrementing operation might correspond to finding the next element on the list.

In fact, two types of weak evidence have been interpreted as supporting the associative notion.

First, Parkman (1972) has argued that if similar patterns of RT differences are obtained for mental addition and mental multiplication, the associative notion should be preferred. This is because different computational algorithms would be involved in the two arithmetic tasks, but a common structural representation of the number system would direct associative processes. That the same variables affected RTs in both tasks, therefore, was taken as support of associative retrieval.

Second, Groen and Parkman (1972) used a developmental approach to distinguish between procedural and associative explanations of mental arithmetic data. Specifically, they found that the slope of a regression line relating mental addition time to minimum addend was 400 msec for first grade children, but only 20 msec for adults. While they point out that this developmental difference may be indicative of shorter incrementation time in adults, they prefer the alternative conclusion that children use procedural retrieval processes, but adults generally use associative processes.

A considerably different approach toward understanding number processing in particular, and cognitive processing in general, is provided by the work of Shepard, Kilpatrick, and Cunningham (1975). Rather than testing models of simple processing tasks, they attempt to infer the form of the internal representation of numbers by scaling paired comparison ratings. Their relevant point is that:

> ...a satisfactory explanation of the pattern of reaction times from such chronometric experiments may not be possible solely in terms of an information-processing model that takes no account of the structural relationship among the internal representations.

Rather, they argue that if the appropriate non-linear transformation of magnitude is chosen, a single variable could account for a good deal of RT data from mental arithmetic and number comparison studies. If this is true, it may be that chronometric analysis of well-specified task domains cannot provide definitive evidence of procedural retrieval processes. We will now turn to work which has operationally defined this notion in a way which may lead to such evidence.

Automatic versus conscious processing. While human capacity for planful behavior provides clear evidence of constructive information processing, whether such processing is available as unitized, automatic, non-strategic procedural retrieval is the question of present interest. How a number of investigators define automatic processing (e.g. LaBerge and Samuels, 1974; Posner and Synder, 1975), and attempt to empirically demonstrate it, is therefore relevant. Posner and Snyder (1975) provide three operational indicants of automatic processing: (1) it occurs without intention; (2) it occurs without giving rise to conscious awareness; and (3) it occurs without producing interference with other ongoing mental activity. Likewise, LaBerge and Samuels (1974) define automaticity as processing which does not require attention.

Using these criteria, LaBerge (1975) attempted to demonstrate that repeated experience causes perceptual and associative processes to become automatic. Specifically, he measured subjects' RT to match and classify familiar and unfamiliar letters. The relevant trials in his experiment were proceded by invalid cues, and therefore required a switch in attention. A critical assumption is that familiar letters are automatically processed. Then, that an initially large difference in RT for the two sets of letters diminished after five experimental sessions, can be taken as evidence that processing the unfamiliar letters also became automatic. While such experiments clearly demonstrate learning, it is less clear that they provide insight into the nature of automatic processing.

Posner and Snyder (1975), on the other hand, believe that their experiments indicate what type of processing is automatic. Like LaBerge, they examined matching and classification RT but they varied the probability that a priming cue was a valid indicator of the next trial. Assuming that generally invalid cues would not be attended to, priming effects in this condition are examples of automatic processing. On the other hand, since generally valid cues would be attended to, priming effects in this condition would include conscious as well as automatic processing. The relevant findings were: (1) in low cue validity conditions informative cue trials were faster than neutral cue trials which did not differ from mis-informative cue trials; and (2) in high cue validity conditions all three trial types differed (i.e. informative cue trials were faster than neutral cue trials which were faster than mis-informative cue trials). Posner and Snyder (1975) interpreted these results as supporting their theory that automatic priming present in low cue validity conditions is due to pathway activation. Priming in high cue validity conditions, on the other hand, includes conscious allocation of attention as well.

Whether pathway activation is the only type of automatic processing, as implied by Posner and Snyder (1975) and Posner and Rogers (in press), is of interest. The present suggestion is that such purely associative processing may only be one type of automatic processing; retrieval using isolable procedures may be a second example. Kolers (1975) recently argued that this latter type of processing plays a role in perception. The finding which led him to this conclusion was a larger speed advantage for reading second sentences which shared visual features with previously read sentences, than for second sentences which only shared words or meanings with previously read sentences. We will now turn to discussion of the present approach used to investigate automatic procedural processing in a fact retrieval domain.

CHAPTER IV

STATEMENT OF THE PROBLEM

The purpose of the present dissertation is to refine the theoretical view of human LTM developed in previous chapters. More specifically, several questions about the organizational structure and retrieval processes of LTM which follow from viewing it as a dynamic network will be pursued. In particular, two goals of the present work are to obtain experimental support for: (1) the notion of a multi-layered LTM; and (2) the notion of isolable LTM procedures. Several additional questions about details of structure and process will be raised in the context of specific experiments.

The approach used to address these issues was to require subjects to make simple timed responses to experimentally presented material. The experimental task was assumed to necessitate subjects' use of LTM structures and processes which are of particular interest here. A general process model was constructed which was assumed to reflect the flow of information processing required to complete the task, and RT data were used to analyze the retrieval stage.

The axioms of the present argument fall into three classes. First, the assumption that time to produce a response directly reflects the mental operations involved, an assumption shared by most contemporary cognitive psychologists, plays an important role in the current work. The particular use of RT data in the present work requires the assumption that a fixed and finite set of stages is involved in the experimental task. However, additional assumptions about seriality of stages, stage independence, and stochastic independence which have often been employed in RT studies will not be required here. Rather, following Taylor (1976), it will be assumed that corrections to basic stage times required by interdependence or temporal overlap can be expressed as linear functions of the stage times involved.

The second set of assumptions will be made explicit in a general information processing model. In particular, this model will indicate: (1) what stages of processing are assumed to be involved in the experimental task; (2) which experimental variables are assumed to affect specific processing stages; and (3) what aspects of the data can be used to assign the effects of other variables to processing stages.

Finally, the three LTM assumptions discussed in the introduction--strength valued network, competitive search, and spreading activation--will also be employed. More specifically, the competitive search assumption implies that retrieval time varies as a function of current strength of to-be-retrieved associations relative to current strength of neighbor associations. Further, the spreading activation assumption implies that the strength of recently processed associations and their neighbors in the LTM network are temporarily in a high-strength state. Thus, strength, and hence RT, should vary as a function of the structural relationship between to-be-retrieved and recently-retrieved information. By a simple extension of this logic, we might also expect isolable LTM procedures to vary in accessibility or speed of computation, as a function of whether or not they have been recently used, and for this phenomenon to be reflected in RT measures. Prior to presenting a more detailed outline of the specific ways these three sets of assumptions were employed to address the questions posed above, the experimental paradigm will be described and a general process model will be presented.

Experimental Paradigm

In all of the present experiments, subjects' RT to retrieve one of several types of information about one of several words was measured on each of several hundred randomly sequenced trials. Upon entering the laboratory, subjects read detailed instructions about the experiment. This included familiarizing themselves with a matrix of the stimulus material to be used in their session. Each row label of this matrix was one of the ITEM words which subjects retrieved information about, each column label was one of the TASK types of information they retrieved, and each cell entry was an appropriate RESPONSE to a particular ITEM-TASK pair. After the subject read the instructions, the experimenter reviewed the procedure making sure the subject understood exactly what was required.

A PDP-8 computer controlled the sequencing and timing of stimuli, and recorded trial type, response (i.e. correct or error), and RT for all trials. On each trial one TASK word and one ITEM word were randomly and independently sampled for presentation, with the restriction that each ITEM appear equally often in each block of trials. Depending upon the condition, either the ITEM or TASK was displayed on a video screen; following a short DELAY the other word was added several lines below the first. The subject was to vocalize the correct response as quickly as possible; a vocal response caused the words on the screen to be replaced by the correct response and the subject's RT for that trial. The subject then pulled one of two triggers to indicate whether the response was correct or not, and to initiate a new trial.

RT was measured from the onset of the second word until triggering of the voice key. Minimum time between consecutive trials was 3.5 seconds, and each trial was preceded by a .5 second warning tone. Figure 3 schematically presents the sequence of events for one trial. Twelve blocks of 48 trials of data were collected for each subject; the first block of trials was practice and not included in any analyses.

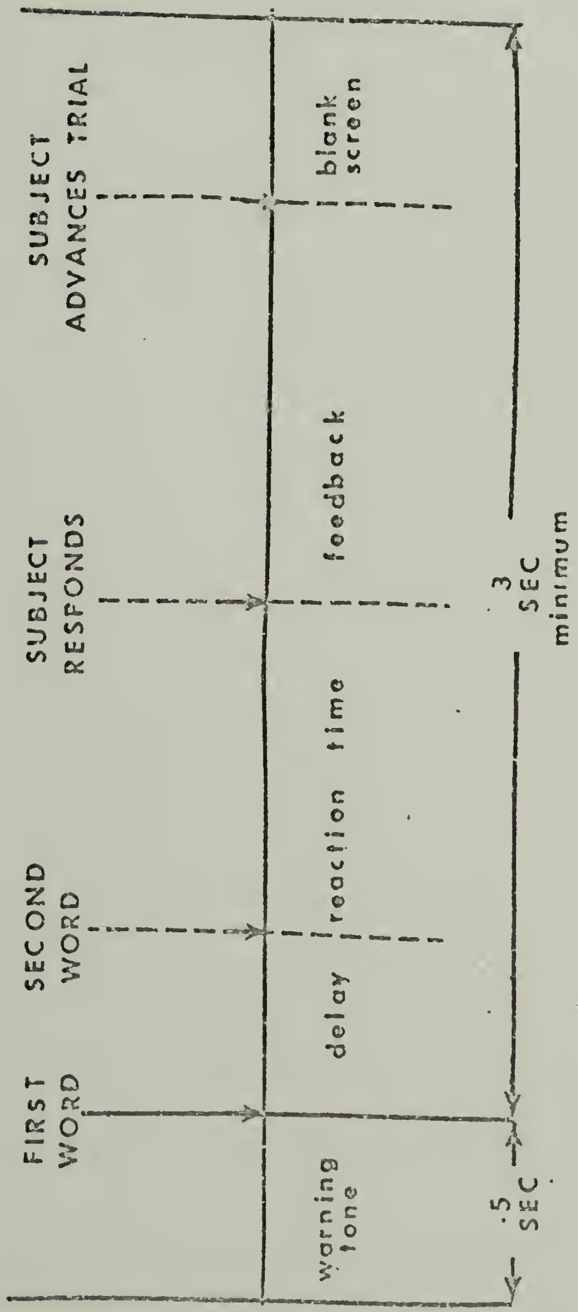
The specific ITEM and TASK words varied between experiments, but were constant for all subjects in any given experiment. One between subjects manipulation was ORDER. For half of the subjects in each experiment, the TASK word always preceded the ITEM word (O(T-I) condition); for the other half of the subjects, the reverse was true (O(I-T) condition). In addition, in Experiment I, the DELAY between onset of the first and second words of the stimulus was a between subjects manipulation; an equal number of subjects had DELAYs of 0, 500, and 1000 msec. In all subsequent experiments, the DELAY was 500 msec for all subjects.

Information Processing Model

The approach used in the present investigation of LTM was to con-

Figure 3

Experimental Paradigm

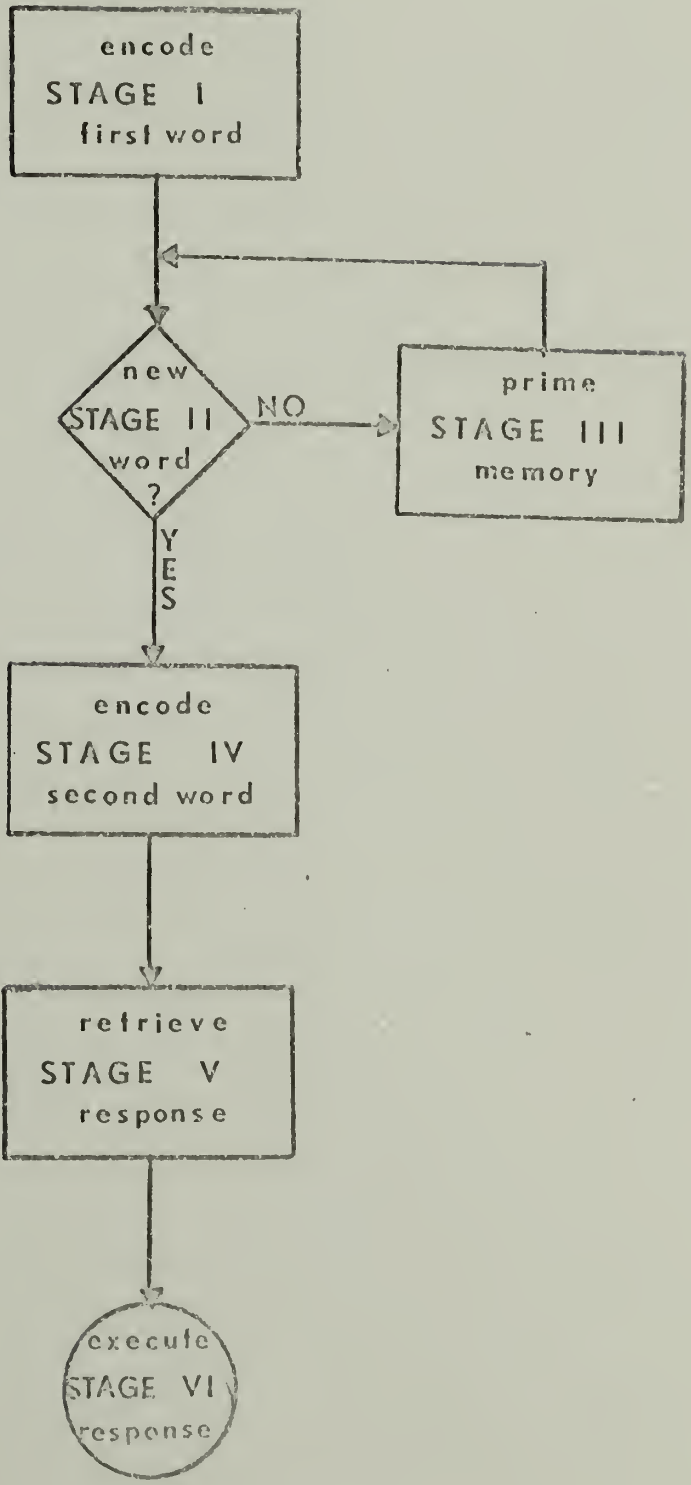


struct a simple model which captures the flow of information processing assumed necessary to complete the experimental task. Then, assumptions about where some experimental variables have their influence were made, and several methods were employed to assign the effects of other variables to appropriate stages. Finally, as will be described in the next three sections of this chapter, the composite picture can be used to analyze the types of structures and processes involved in retrieving information from LTM. At this point, the process model schematically represented in Figure 4 will be briefly described.

It is assumed that subjects begin encoding the first word (Stage I) of the stimulus pair as soon as it appears on the video screen; this assumption seems warranted since a warning tone insures that the subject is aware of the onset of a trial. Next, it is further assumed that subjects become aware of the second word (Stage II) and begin encoding it (Stage IV) as soon as possible; since each subject experiences a constant DELAY between onset of the two words of the stimulus, this strategy is quite natural. Under conditions of a long DELAY between presentation of the two words of the stimulus, it is hypothesized that subjects engage in post-encoding processing of the first word (Stage III). While the exact nature of this processing cannot be specified yet, it will be referred to as "priming". Further, while this term should be interpreted in a theoretically neutral way, it is suggested that it may shorten the retrieval stage, but does not influence encoding or response execution in the present experiments. Following encoding of both words of the stimulus, the retrieval stage (Stage V) is initiated.

Figure 4

A Process Model of the Experimental Paradigm



While the encoding processes are assumed to result in access of memory representations of the stimulus words, the retrieval process is assumed to result in access of a memory representation of the correct response. Since the nature of structures and processes involved in retrieval are of primary interest, they will be further discussed below. Finally, the verbal response is executed in the final stage (Stage VI).

To avoid assuming that stages are non-over-lapping and independent, the procedure suggested by Taylor (1976) was employed to derive RT predictions from this model. In this procedure total RT is viewed as the sum of corrected stage times, where each corrected stage time is a linear function of all basic stage times. Such a correction procedure has enough flexibility to capture many possible types of inter-dependencies among stages. By algebreically recombining terms, RT expressions can be obtained which differ from those derived using more traditional procedures in two ways. Under the present formulation: (1) each basic stage time component has a weighting factor; and (2) the final expression has one extra parameter for correction constants. Inferences drawn from the presence of main or interaction effects on mean RT are consistent with those derived using more traditional procedures. The present procedure, however, underscores the ambiguity inherent in a failure to obtain such effects. Since at the level of corrected stage times, basic stage times may be partially or totally masked by other stages, it is clear that mean RT may not reflect the effect some variable exerts on a particular stage. For this reason, and because of the difficulties generally associated with accepting the null hypothesis, conclusions based on failures to influence RT must remain tentative.

With these points in mind, RT predictions will be derived for the present model. An additional assumption in the present work is that time required to encode a single word is less than or equal to 500 msec. Previous work using a variety of procedures suggests that this assumption is valid. Employing it leads to the following two equations:

$$\mathrm{RT}(\mathrm{DELAY} = 0) = W + t'(\mathrm{I}) + t'(\mathrm{IV}) + t'(\mathrm{V}) + t'(\mathrm{VI}) \tag{1}$$

$$\mathrm{RT}(\mathrm{DELAY} \geq 500) + W + t'(\mathrm{IV}) + t'(\mathrm{V}) + t'(\mathrm{VI}) \tag{2}$$

where $t'(i)$ is the weighted stage time for stage (i), and W is the correction constant.

That is, since RT is measured from onset of the second word, under conditions where the first word was completely encoded prior to presentation of the second word (i.e. DELAY 500), RT is simply a function of the last three processing stages. On the other hand, at zero DELAY, RT includes the time required to encode the first word as well.

The present formulation also suggests that time allotted to priming following presentation of the first word (Stage III) increases with DELAY between the two words. More specifically:

$$t(\mathrm{III}) = \mathrm{DELAY} - t(\mathrm{I}) \qquad \text{when DELAY} \geq t(\mathrm{I}) \tag{3}$$

$$t(\mathrm{III}) = 0 \qquad \text{when DELAY} < t(\mathrm{I}) \tag{4}$$

Also, the nature of Stage III processing may differ for the two ORDERS of stimulus presentation. For example, in the case where the ITEM is presented first, it is likely that Stage III processing involves priming associations of the ITEM. In the case where the TASK is presented first, on the other hand, such priming may have little effect because the class of associates is so diffuse (see Collins and Loftus, 1975). An alternative type of Stage III processing which may occur when the TASK is presented first is priming of a TASK-specific procedure. Further consideration of differential implications of these possibilities will be raised in the final section of this chapter. For now, it is important to summarize the following three assumptions: (1) the effect of Stage III processing may reduce retrieval time, and is thus indirectly observable in overall RT; (2) the quantity of Stage III processing can be experimentally manipulated by varying the DELAY between onset of the first and second stimulus words; and (3) the nature of Stage III processing may be experimentally manipulated by varying the ORDER of onset of the two stimulus words.

To summarize, a general model of the stages involved in the present experimental task was described. The way manipulation of DELAY between onset of the two stimulus words was assumed to influence processing was incorporated into RT predictions. Further, it was suggested that the ORDER manipulation may affect retrieval, but should not influence encoding or response execution stages of processing.

It was previously suggested that viewing LTM as a dynamic network suggests that examination of sequential effects--how RT varies as a function of recent processing--would be useful to drawing inferences about structure and process. It is discussion of this logic to which we will now turn.

Sequential Analyses

A general analysis will be described which allows assignment of sequential effects to several stages of the process model just presented. In addition, two issues of major interest--assessing the notions of a multi-layered LTM and of isolable LTM procedures--can be addressed by examining RT as a function of the relationship between TASKS on pairs of successive trials. Special consideration of these two issues will follow a more general discussion of sequential analyses.

Considering whether or not the ITEM, RESPONSE, and/or TASK have been repeated on pairs of successive trials leads to five possible types of trials in the present experiments. These are outlined with examples in Table 2. Eight contrasts involving these five trial types will be used to assess ITEM, RESPONSE, and TASK repetition effects, as well as an hypothesis about additivity of ITEM and TASK repetition effects. These contrasts are defined in Table 3, and will be briefly described below.

ITEM repeition effects. Contrasts 1 and 2 (see Table 3) provide two independent assessments of ITEM repetition effects. In the first contrast, the difference between RT(1) and RT(2) must be attributed to the effect of ITEM repetition because both trial types involve different TASKS and RESPONSES. Likewise, in the second contrast, the difference between RT(5) and RT(4) must also be attributed to the effect of ITEM repetition; in this case both trial types involve same TASKS and RESPONSES. The presence of ITEM repetition effects may be due to either

Table 2

Five Repetition Trial Types

TRIAL TYPE	ITEM	TASK	RESPONSE	EXAMPLE Trial n-1	EXAMPLE Trial n
1	Diff	Diff	Diff	SUN SYLLABLES ONE	FROG COLOR GREEN
2	Same	Diff	Diff	FROG SYLLABLES ONE	FROG COLOR GREEN
3	Diff	Same	Diff	CORN COLOR YELLOW	FROG COLOR GREEN
4	Same	Same	Same	FROG COLOR GREEN	FROG COLOR GREEN
5	Diff	Same	Same	GRASS COLOR GREEN	FROG COLOR GREEN

Table 3

Repetition Contrasts

ITEM REPETITION	
CONTRAST(1)=RT(1)-RT(2)	(Different TASK; RESPONSE)
CONTRAST(2)=RT(5)-RT(4)	(Same TASK; RESPONSE)
RESPONSE REPETITION	
CONTRAST(3)=RT(3)-RT(5)	(Different ITEM; same TASK)
TASK REPETITION	
CONTRAST(4)=RT(1)-RT(3)	(Different ITEM; RESPONSE)
CONTRAST(5)=RT(1)-RT(5)-35	(Different ITEM; estimated RESPONSE repetition)
CONTRAST(6)=RT(2)-RT(4)-CONTRAST(3)	(Same ITEM; corrected for RESPONSE repetition)
CONTRAST(7)=RT(2)-RT(4)-35	(Same ITEM; estimated RESPONSE repetition)
ADDITIVITY CONTRAST	
CONTRAST(8)=CONTRAST(1)-CONTRAST(2) =CONTRAST(4)-CONTRAST(6) =CONTRAST(5)-CONTRAST(7)	

encoding or retrieval phenomena.

RESPONSE repetition effects. Contrast 3 (see Table 3) provides a single assessment of RESPONSE repetition effects. The difference between RT(3) and RT(5) must be attributed to the effect of RESPONSE repetition because both trial types involve different ITEMS and same TASKS. The presence of RESPONSE repetition effects may be due to either retrieval or response execution phenomena.

TASK repetition effects. TASK repetition effects attributable to the retrieval stage are of major importance in addressing the present questions. Four contrasts (Contrast 4, 5, 6, and 7) which have been devised to assess TASK repetition effects will be described here. The issue of assigning these and other repetition effects to the appropriate processing stage will be considered at the end of this section. Finally, the implications of certain patterns of TASK repetition effects for the questions of major interest will be considered in the last two sections of this chapter.

Analogous to the situation in which we were able to assess ITEM repetition effects in the context of different and same TASKS, we will assess TASK repetition effects in the context of different (Contrasts 4 and 5) and same (Contrasts 6 and 7) ITEMS. The logic behind Contrast 4 is straightforward. In this case, where we compare pairs of successive trials with different ITEMS and different RESPONSES, the difference between RT(1) and RT(3) must be attributed to TASK repetition. The situation is not quite so simple when the same ITEM is presented on pairs of successive trials. In this case, TASK and RESPONSE repetition are confounded (see trial types 2 and 4 in Table 2). Contrast 6, therefore, relies on the subtractive method (Sternberg, 1969) to isolate the effect of TASK repetition. Specifically, Contrast 3 is used as an estimate of the RESPONSE repetition component and is subtracted from the difference between RT(2) and RT(4).

Two additional TASK repetition contrasts, Contrasts 5 and 7, are analogous to Contrasts 4 and 6 respectively. However, both of these contrasts used an alternative procedure for estimating the RESPONSE repetition component which was subtracted from the comparison of trials in which TASK and RESPONSE repetition was confounded. Specifically, the single best estimate of the RESPONSE repetition effect calculated over experiments, ORDERS, DELAYS, and TASKS, 35 msec, was used. This correction was deemed appropriate since there were no consistent effects of any of these variables on the RESPONSE repetition Contrast 3. Further, these contrasts were deemed necessary since for some TASKS in some experiments, Contrast 6, the other measure of TASK repetition in the context of a repeated ITEM, was not directly calculable. This was true for TASKS which required unique RESPONSES for each ITEM. Thus, due to the importance of assessing the TASK repetition effect in the present work, this additional procedure seemed worthy of consideration.

Additivity contrast. Contrast 8 is a test of the hypothesis that ITEM and TASK repetition effects are independent. Specifically, it can be viewed as any of the three algebreically equivalent contrasts presented in Table 3. In the first form, it is clear that Contrast 8 assesses the equivalence of ITEM repetition effects in the context of different versus same TASKS. In the last two forms, on the other hand, it is clear that Contrast 8 assesses the equivalence of TASK repetition effects in the context of different versus same ITEMS.

Assignment to stages. Contrasts 1 through 7 were constructed so that their signs indicate the nature of repetition effects; negative contrasts are indicative of interference, while positive contrasts are indicative of facilitation. Further, the sign of Contrast 8 indicates whether ITEM and TASK repetition effects attenuate or enhance each other; a negative sign is indicative of the former result, while a positive sign is indicative of the latter result. Investigating what types of repetition influence retrieval and whether interference or facilitation result are of primary interest. However, it is possible that effects of ITEM and/or TASK repetition should be attributed to encoding stages while effects of RESPONSE repetition should be attributed to the response execution stage. Several techniques used to assign repetition effects to the retrieval stage of processing will be outlined here.

One rule of inference is that while facilitation could be attributable to any stage of processing, interference must be attributed to the retrieval stage. This is because the competitive search assumption indicates that recently processed associations which are in a high-strength state compete with to-be-retrieved associations and can cause interference. However, the spreading activation assumption indicates that to-be-retrieved associations which are neighbors of recently-retrieved associations may themselves be in a high-strength state and be retrieved more quickly. Thus, previous assumptions about the retrieval stage imply that repetition effects attributable to it could be exhibited as either interference or facilitation at the level of RT. Previous notions about encoding and response execution, on the other hand, predict only facilitatory effects.

Second, examining the RT predictions from Equations 1 and 2 for the two ORDER conditions (see Table 4), we can see that ITEM first-long DELAY RT does not include ITEM encoding time, while TASK first-long DELAY RT does not include TASK encoding time. Presence of ITEM repetition effects in the former conditions or TASK repetition effects in the latter conditions must therefore be attributed to the retrieval stage.

One difficulty with the previous rule is that in TASK first conditions, Stage III processing may mask TASK repetition effects which are most important in the present work. A third rule of inference, an application of the subtractive method (Sternberg, 1969), provides a way to isolate TASK repetition effects attributable to retrieval which may be present in ITEM first conditions. This argument requires the reasonable assumption that encoding repetition effects are approximately equal for ITEM and TASK words. Then, ITEM repetition effects present in TASK first conditions, which may be attributable to the encoding and/or retrieval stage, can be used as upper bound estimates of repetition effects attributable to encoding. Thus, to the extent that TASK repetition effects in ITEM first conditions are larger than ITEM repetition effects in TASK first conditions, the retrieval stage must be implicated. This procedure, however, is only appropriate if there is no ITEM interference in the retrieval stage. Since both theoretically and

Table 4

Stages of Processing Contributing to RT for ORDER by DELAY Conditions

	TASK first	TASK second
DELAY=ZERO	Encode TASK Encode ITEM Retrieve RESPONSE Execute RESPONSE	Encode ITEM Encode TASK Retrieve RESPONSE Execute RESPONSE
DELAY ≥500	Encode ITEM Retrieve RESPONSE Execute RESPONSE	Encode TASK Retrieve RESPONSE Execute RESPONSE

empirically this qualification is met for ITEM repetition in the context of a repeated TASK (i.e. Contrast 2), but may not be in the context of a non-repeated TASK (i.e. Contrast 1), the latter application of the present rule must be viewed with caution.

A fourth rule of inference is an application of the additive factors logic (Sternberg, 1969). That is, variables which interact at the level of mean RT probably affect common stages. Thus, to the extent that we are willing to assume or are able to infer that one of two interacting variables influences retrieval, we should draw the same conclusion about the second variable. Since it seems reasonable to assume that differences in overall RT for the various TASKS used in these experiments should be attributed to different retrieval processes, repetition effects which vary over TASKS should also be assigned to the retrieval stage. In addition, since it was previously assumed that manipulation of DELAY directly affects amount of Stage III processing, and hence indirectly affects retrieval (Stage V), repetition effects which differ for 500 and 1000 msec DELAY conditions should also be assigned to the retrieval stage. Note that RT for these DELAY conditions, but not the zero DELAY, include the same encoding stages (see Table 4).

Finally, a violation of additivity of ITEM and TASK repetition effects, as measured by Contrast 8, is indicative of their common influence on some stage. While the encoding stage may be responsible, the alternative conclusion of common influence on the retrieval stage is more sound. This is because such non-additivity could be naturally incorporated into a retrieval process (see discussion below), but it is more reasonable to assume that encoding of the two stimulus words involves relatively independent processes. Further, only the retrieval conclusion is sensible if the non-additivity of ITEM and RESPONSE repetition holds equally for ORDER by DELAY conditions in which RT reflects encoding of one or both stimulus words.

To summarize, a general sequential analysis which can be used to assess ITEM, RESPONSE, and TASK repetition effects and assign them to appropriate stages of processing was developed. This analysis will be especially helpful for addressing processing questions. Before considering those questions, a more detailed sequential analysis of trials with different TASKS (i.e. RT(1) and RT(2)), which can be used to shed light on the multi-layered LTM hypothesis, will be described; such an analysis was employed in Experiments II-IV.

Structural Analyses

The logic for the present test of the multi-layered LTM hypothesis rests on the strength assumptions. That is, the notion of isolable LTM layers may be defined in terms of the scope of competitive search and spreading activation. Then relative strength, and hence retrieval times, should vary as a function of whether to-be-retrieved information is from the same or different LTM layers as recently-retrieved information.

In terms of the present experiments, a particular hypothesis about LTM layers can be assessed by further analyzing trials with different TASKS on pairs of successive trials (i.e. RT(1) and RT(2) from Table 2).

Specifically, these trials may be partitioned according to whether the TASKS were from the same or different hypothesized LTM layers. If, as in the present experiments, the hypothesis of interest is that there are isolable lexical and semantic LTM layers, two types of support are available. If RT to lexical TASKS varies as a function of whether lexical or semantic information was retrieved on the preceding trial, or if RT to semantic TASKS varies as a function of class of information retrieved on the preceding trial, the hypothesis would be supported. By comparing pairs of trials in which ITEM and TASK repetition have been held constant, we can be assured that such effects are not due to simple repetition effects.

An example of an analysis sufficient to test the hypothesis that COLOR and CATEGORY information are conserved in a semantic memory, isolable from lexical memory which contains NAME information, is presented in Table 5. This three-by-three table would provide RTs for trial n as a function of TASK on trials n and n-1. The important points are that a multi-layered LTM model predicts that NAME RT should be equal when preceded by COLOR and CATEGORY trials because both of these TASKS are from the same non-lexical memory. On the other hand, COLOR RT and CATEGORY RT should vary as a function of whether the preceding trial involved a TASK from the same (RT(COLOR|CATEGORY) and RT(CATEGORY|COLOR)) or different (RT(COLOR|NAME) and RT(CATEGORY|NAME)) memories. In considering these predictions one should bear in mind that models which view LTM as a single homogeneous network have no explicit mechanism which would lead to systematic effects of TASK

Table 5

TASK Sequencing Effects

TASK TRIAL n-1	TASK-TRIAL n NAME	COLOR	CATEGORY
NAME	TASK Repetition	Different Memory	Different Memory
COLOR	Different Memory	TASK Repetition	Same Memory
CATEGORY	Different Memory	Same Memory	TASK Repetition

sequencing.

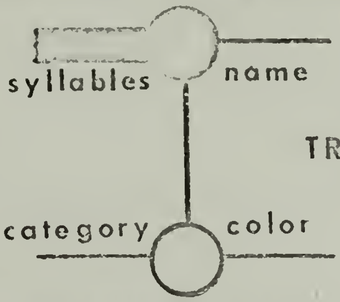
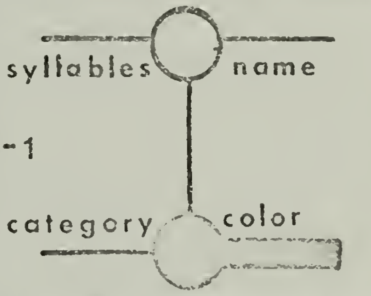
The above analysis relied on the general dynamic property of LTM to test the multi-layered hypothesis. However, no precise mechanism for predicting TASK sequencing effects was offered. The imprecision of this analysis is further attested to by the fact that either facilitation or interference from recently-retrieved, same-layer information could be taken as support of the multi-layered hypothesis. Two more precise models which are especially compatible with associative retrieval processes will be considered here; one which is more compatible with procedural retrieval will be considered in the final chapter.

Direct access model. Both associative multi-layered LTM models make directional predictions about TASK sequencing effects for trials with different TASKS but repeated ITEMS (i.e. RT(2)). However, neither of them have natural ways of accounting for such effects when the ITEM is not repeated (i.e. RT(1)). In the first model, the direct access model, either the lexical or semantic representation of an ITEM is directly accessible as a result of encoding. Figure 5a presents such a two-layered memory representation of a concept with two different lexical (i.e. SYLLABLES and NAME) and two different semantic (i.e. CATEGORY and COLOR) associations. In the left-hand panel, lexical information (i.e. SYLLABLES) was just retrieved; in the right-hand panel, semantic information (i.e. COLOR) was just retrieved. This is indicated by the dark associations, assumed to be in high-strength states. The multi-layered notion is that interference resulting from increased competition from recently processed, high-strength associa-

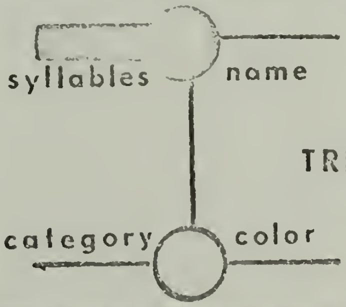
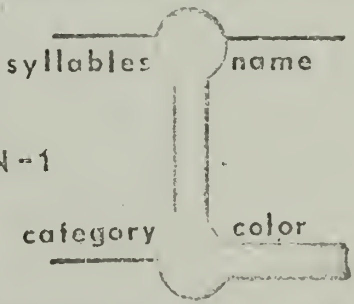
Figure 5

Predicted TASK Sequencing Effects for
Same ITEM - Different TASK Trials

A. DIRECT ACCESS MODEL

		
LEXICAL TRIAL	INTERFERENCE	NO EFFECT
N SEMANTIC	NO EFFECT	INTERFERENCE

B. LEXICAL ACCESS MODEL

		
LEXICAL TRIAL	SEARCH INTERFERENCE	NO EFFECT
N SEMANTIC	NO EFFECT	ACCESS FACILITATION SEARCH INTERFERENCE

tions is layer-specific. Then both lexical and semantic trials which have been preceded by TASKS from the same memory should be slower than if they were preceded by TASKS from the other memory. Further, this should only hold for trials with repeated ITEMS.

Lexical access model. In the second model, the lexical access model, predictions for semantic trials are more flexible. In this model encoding a word involves accessing its lexical representation. Then retrieving semantic information involves accessing the semantic node and searching for the appropriate semantic information. Retrieving lexical information, on the other hand, requires only the latter type of process. Figure 5b is analogous to Figure 5a, but holds for the lexical access model. Predictions for lexical trials are equivalent to those of the direct access model. Specifically, search interference.is predicted for lexical trials preceded by other lexical TASKS. Therefore, as in the direct access model, RT should be slower for lexical trials preceded by other lexical rather than semantic TASKS; lexical interference is predicted. The two associative multi-layered models should, however, be discriminable on the basis of semantic trials. In the lexical access model sequential effects for semantic trials may be manifest in either the semantic access or semantic search sub-stage of retrieval. Since the relative magnitude of predicted semantic access facilitation and search interference is unknown, RT predictions for semantic trials are ambiguous. Therefore, the presence of semantic facilitation in the present experiments should be taken as support of the lexical access model relative to the direct access model. On the other hand, if both lexical and semantic interference are observed, further research would be required to discriminate between the two associative models. Such experiments should be straightforward since the lexical access model implies that semantic access facilitation and search interference can be independently manipulated. Finally, if neither lexical nor semantic interference are observed, or if there are TASK sequencing effects for trials with non-repeated ITEMS, alternatives to these associative conceptualizations will be required.

To summarize, it was argued that the presence of any semantic effects of sequencing pairs of different TASKS may be taken as support of the notion of a multi-layered LTM. In addition, two multi-layered network models which are compatible with associative retrieval were described and more precise predictions were derived for trials with repeated ITEMS. Finally, it is suggested here that to the extent that support is obtained for the multi-layered network, we might expect the present paradigm to be useful in classifying "levels of information storage". The relationship between such a concept and that of "levels of processing TASKS" will be considered in the final chapter of the present dissertation. At this point, we will turn to consideration of isolating LTM procedures, presumably a pre-requisite to the latter analysis.

Processing Analyses

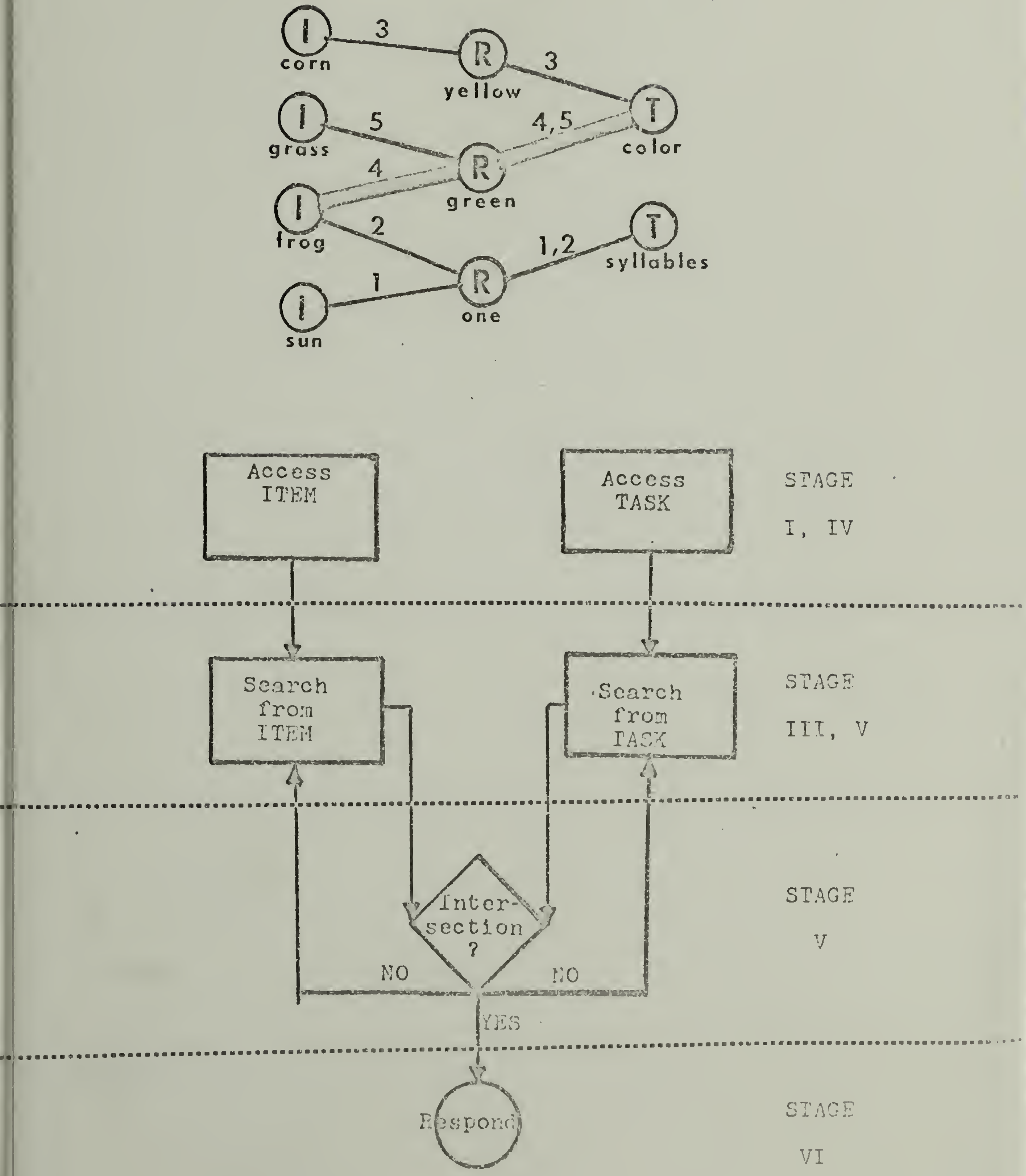
The results of the repetition contrasts discussed in the context of a general sequential analysis, and assignment of their effects to appropriate stages of processing should be of interest, regardless of the theoretical biases one is working in. In this section, however, we will consider the constraints repetition effects assigned to the retrieval stage impose upon the type of processes which grow out of a dynamic network perspective. In the chapter on processing issues three classes of retrieval processes were characterized--intersection, generate-test, and procedural. In this section natural ways these retrieval processes might be brought to bear in the present experimental paradigm will be discussed and several differential predictions will be made. First, a memory representation and process model will be described for each class of retrieval; then, predictions relevant to the present experiments will be outlined.

Intersection retrieval. As described in Chapter III, intersection retrieval involves processes which traverse appropriate pathways in the LTM network. Usually retrieval is accomplished when two such processes intersect at a desired response. In terms of the present experiments, it is reasonable to assume that search emanates from memory representations of the ITEM and TASK, and intersection occurs at the representation for the RESPONSE.

The network in Figure 6 presents a relevant portion of LTM in which the five trial types of the present experiments can be represented. The labels on the nodes and associations in this network correspond to the trial types of Table 2. The lines labeled 4 should be viewed as reference instances of associations retrieved on the preceding trial

Figure 6

Intersection Retrieval



and hence in high-strength states (i.e. same ITEM, TASK, and RESPONSE). The other trial types are indicated in appropriate relationship to the type 4 ITEM, TASK, and RESPONSE. The flow chart in Figure 6 indicates the type of processing which is compatible with an intersection retrieval model.

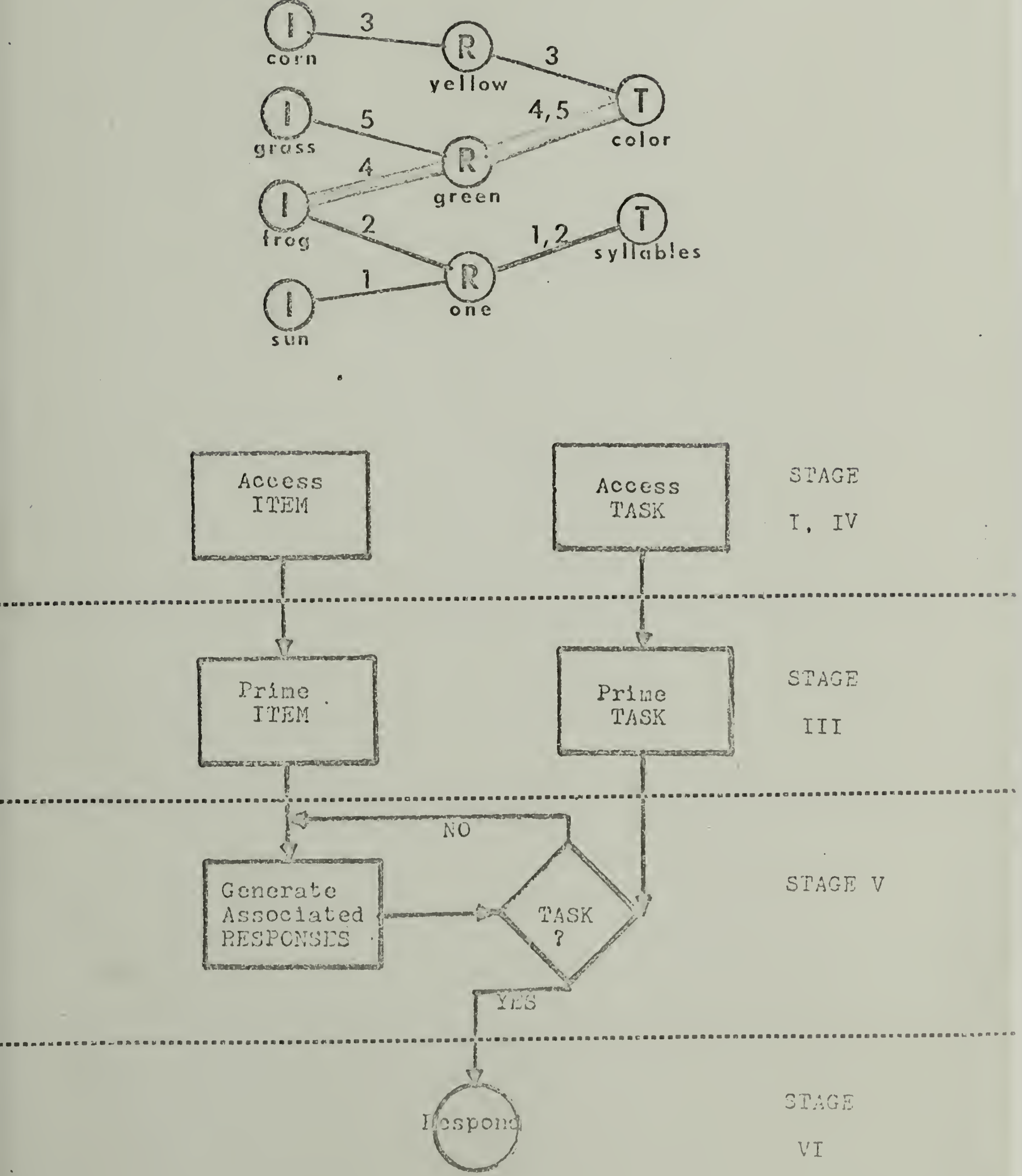
An important aspect of intersection retrieval is that search can proceed from the ITEM or TASK node immediately following their respective encodings. Thus, search from the first word (i.e. TASK for O(T-I) and ITEM for O(I-T)) may be initiated during the DELAY interval. This has the consequence of causing the search process associated with the second word (i.e. ITEM for O(T-I) and TASK for O(I-T)) to dominate RT for long DELAY conditions; on the other hand, both processes should affect RT in zero DELAY conditions. Further, the competitive search and spreading activation principles influence both of these search processes and lead to predictions about repetition effects which will be summarized following discussion of the other two classes of retrieval.

Generate-test retrieval. Generate-test retrieval involves two sub-stages. First, candidate responses are generated; then they are tested for appropriateness. In the context of the present experiments, associated RESPONSES of the ITEM are generated and then tested for relevance to the TASK.

Figure 7 presents a network representation of a portion of LTM which might be used in the present experiments. The labels on the associations correspond to the trial types of Table 2. A process

Figure 7

Generate-Test Retrieval



model of generate-test retrieval is also provided.

An important point about simple versions of this type of retrieval is that the ITEM dominates processing regardless of ORDER. That is, candidate RESPONSES can not be generated until the ITEM is available. Further, the competitive search and spreading activation assumptions which provide repetition effect predictions for intersection retrieval only apply to the generate sub-stage involving search from the ITEM for generate-test retrieval. On the other hand, TASK repetition effects may be expected in the test sub-stage and are analogous to effects predicted for procedural retrieval to which we will now turn.

Procedural retrieval. The basic notion behind procedural retrieval is that LTM has isolable computation devices which are used to access entire classes of information. While it seems clear that associative retrieval is a fundamental process available to LTM, it is suggested here that more complex processing may be available as well. In particular, in the context of the present experiments, it is suggested that the semantic representation of TASK concepts (e.g. NAME, COLOR, or CATEGORY) may be best thought of as isolable procedures which take ITEMS as parameters and return RESPONSES. An important point of this conceptualization is that the procedures are themselves dynamic memory components which vary in accessibility and/or speed of computation. Thus, in the present experiments, a minimal finding to support the procedural retrieval notion is the presence of TASK repetition effects which are attributable to the retrieval stage of processing.

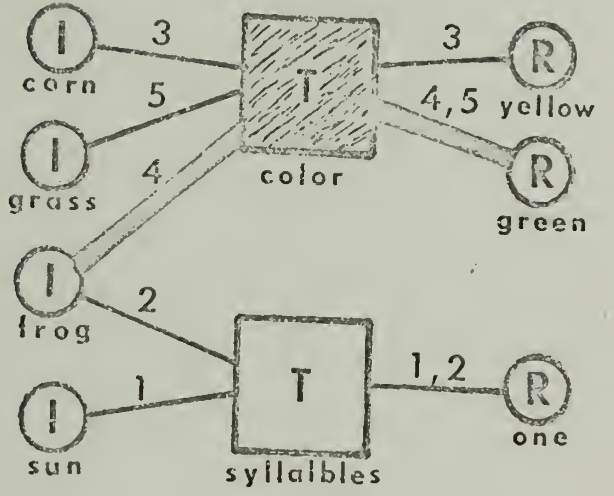
In an attempt to further distinguish, both conceptually and predictively, the notion of procedural retrieval from intersection and generate-test retrieval, a memory representation and a process model which indicate how procedural retrieval could accomplish the present experimental task are presented in Figure 8. Once again, the labels on the associations agree with the trial types of Table 2, and the dark associations and procedure are assumed to be in high-strength states, having just been used.

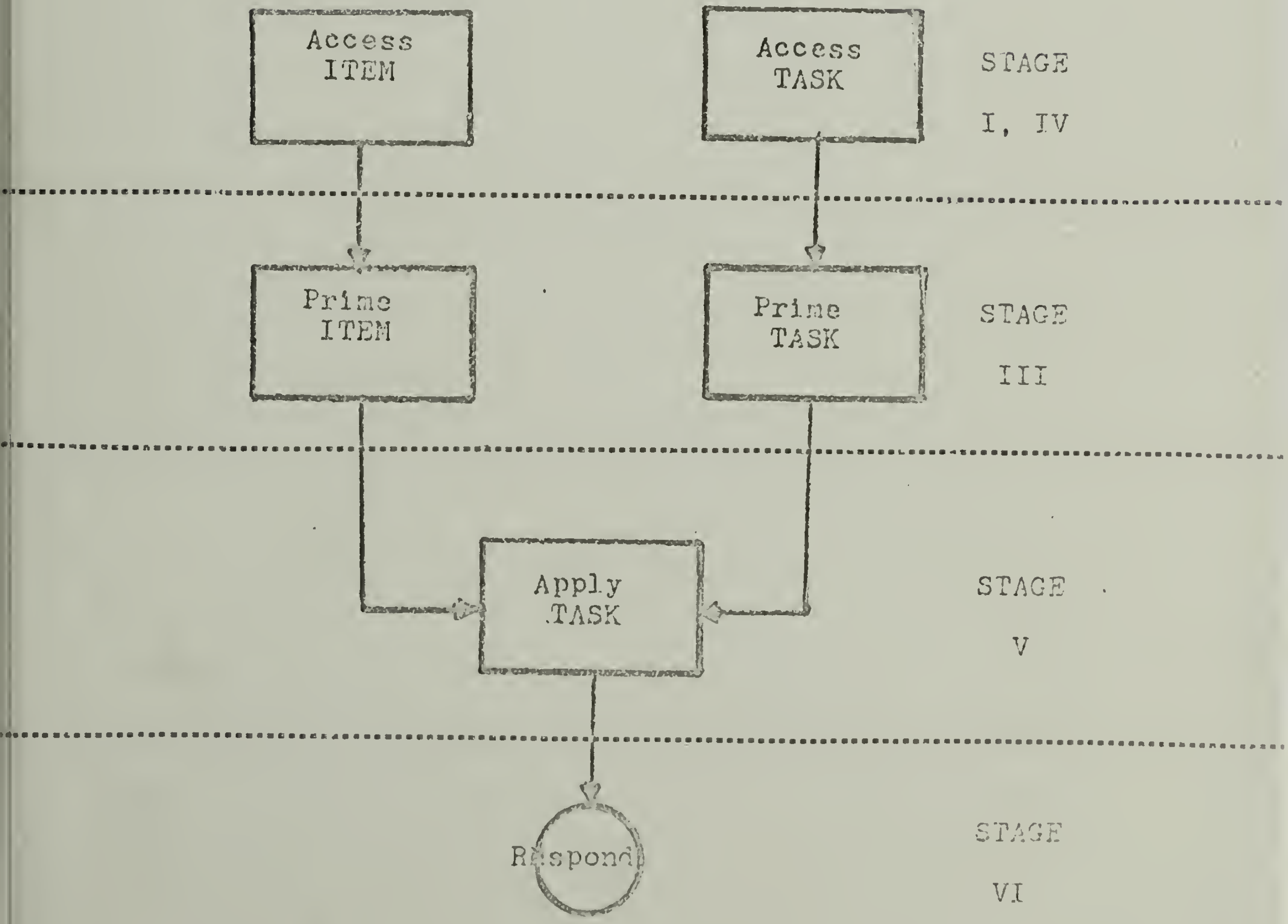
An important point of this type of retrieval is that the TASK plays a central role. Conceptually, the situation is exactly opposite generate-test retrieval. In that case, initiation of processing was contingent upon accessing the relevant ITEM; here the relevant TASK must be accessed for retrieval to begin. This dominance of the TASK in procedural retrieval is also responsible for the fundamental prediction of TASK facilitation. On the other hand, the competitive search and spreading activation assumptions seem less important in procedural, than they were for associative, retrieval. Yet, the dynamic property of LTM is fundamental to the present investigation of LTM. Thus, it is suggested here that, to the extent that procedural retrieval seems to be a useful concept, further research will be required to investigate more precisely how it is coordinated with the strength principles.

<u>Predictions</u>. Simple ways in which three classes of retrieval models might account for processing in the present experimental paradigm were outlined. It should be emphasized that the predictions derived from these models may not be properties of general classes of

Figure 8

Procedural Retrieval





retrieval, but rather of only particular simple interpretations of them. In fact, it is suggested that slight changes in assumptions about the relevant memory structures of the parameters of the spreading activation process may have marked predictive consequences. Nevertheless, failures of the particular models considered here may point to more fundamental inadequacies of the classes of retrieval they are examples of. Also, successes of these models should indicate which classes of retrieval should be more systematically investigated in the future.

Table 6 summarizes predictions about the main effect of ORDER as well as the predicted sign of the repetition contrasts (see Table 3) for each ORDER, for each of the three retrieval processes. The contrast predictions are derived for long DELAY conditions in which Stage III processing is assumed to maximize ORDER effects. At shorter DELAYS (possibily including the longest DELAYS in the present experiments), we might expect both O(T-I) and O(I-T) effects to be present. Thus Table 6 should be viewed as predicting the direction of ORDER, DELAY, and ORDER by DELAY effects on each repetition effect attributable to the retrieval stage. At this point these predictions will be briefly summarized.

Main effect of ORDER: While there is a basic symmetry between the ITEM and TASK in intersection retrieval, generate-test retrieval cannot be initiated until the ITEM is accessed, and procedural retrieval cannot be initiated until the TASK is accessed. Therefore, while no main effect of ORDER is predicted for intersection retrieval, generate-test retrieval

Table 6

Retrieval Predictions

	INTERSECTION		GENERATE-TEST		PROCEDURAL	
	O(T-I)	O(I-T)	O(T-I)	O(I-T)	O(T-I)	O(I-T)
ORDER Main Effect	O(T-I) = O(I-T)		O(T-I) > O(I-T)		O(T-I) < O(I-T)	
ITEM Repetition						
Contrast 1 (different TASK)	< 0	=0	<0	≤0	?	=0
Contrast 2 (same TASK)	>0	=0	>0	≥0	>0	=0
RESPONSE Repetition						
Contrast 3 (same TASK)	=0	>0	>0	>0	>0	>0
TASK Repetition						
Contrasts 4, 5 (different ITEM)	=0	<0	=0	>0	≥0	>0
Contrasts 6, 7 (same ITEM)	=0	>0	=0	>0	≥0	>0

predicts that ITEM first conditions should be fastest while procedural retrieval predicts that TASK first conditions should be fastest.

ITEM repetition contrasts: Since the ITEM dominates RT for the TASK first ORDER under intersection retrieval and for both ORDERS under generate-test retrieval, these are the conditions under which we expect ITEM repetition effects. The predictions are weakest, however, for the ITEM first ORDER of generate-test retrieval because in this case Stage III processing may mask ITEM repetition effects. Predictions rest on two principles derived from the strength assumptions. First, associations which have just been retrieved should be retrieved more rapidly than any other associations on the following trial. Second, other associations emanating from the same starting node as associations just retrieved should be retrieved more slowly than any other associations on the following trials.

In Contrast 1 retrieval of two non-repeated associations is compared (i.e. 1 from SUN and 2 from FROG in Figures 6 and 7). However, the second association emanates from a repeated ITEM and must compete with a high-strength association (i.e. 4 from FROG). In this case RT should be long, and therefore Contrast 1 should be negative. In Contrast 2, on the other hand, retrieval of a repeated association (i.e. 4 from FROG) is compared to retrieval of a non-repeated association (i.e. 5 from GRASS). Retrieval of the former association should be faster, and therefore Contrast 2 should be positive.

Whether the competitive search assumption should be applied to procedural retrieval in the same way as it was for the associative retrieval processes is unclear. Predictions for Contrast 1 are especially ambiguous, although it is likely that Contrast 2 should be positive for procedural retrieval as well.

RESPONSE repetition contrasts: In intersection retrieval (see Figure 6) the RESPONSE repetition Contrast 3 is analogous to the ITEM repetition Contrast 2, but should be operative when retrieval from the TASK dominates RT (i.e. O(I-T)). Retrieving the repeated association (i.e. 5 from COLOR) should be faster than the non-repeated association (i.e. 3 from COLOR) and therefore Contrast 3 should be positive.

For simple versions of generate-test retrieval (see Figure 7) the generate sub-stage should not be influenced by RESPONSE repetition, although the test sub-stage may be facilitated. Since the test sub-stage cannot be initiated during Stage III processing, this facilitation would not be masked and we therefore expect RESPONSE repetition effects in both ORDERS. Finally, in procedural retrieval (see Figure 8), there may also be RESPONSE facilitation, but as in generate-test retrieval, it should not vary with ORDER.

TASK repetition contrasts: Once again the principles operating in intersection retrieval (see Figure 6) follow from the strength assumptions. In this case they hold when retrieval from the TASK dominates RT (i.e. O(I-T)). In Contrast 4 we compare retrieval of two non-repeated associations (i.e. 1 from SYLLABLES and 3 from COLOR). Since the latter association is in the context of a competing high-strength association (i.e. 4 from COLOR), RT should be longer and therefore

Contrast 4 should be negative. Predictions concerning the second set of TASK repetition contrasts, those in the context of a repeated ITEM, are less clear because of the necessary correction for RESPONSE repetition (see discussion in the section on sequential analyses). However, the predictions presented in Table 6 assume that this correction adjusts for response execution stage RESPONSE repetition effects only. Then the relevant comparison is between retrieval for trial types 2 and 4. Under intersection retrieval this is analogous to ITEM repetition Contrast 2, but should be operative in conditions in which the TASK dominates retrieval (i.e. O(I-T)). Retrieving the repeated association (i.e. 4 from COLOR) should be faster than retrieving the non-repeated association (i.e. 2 from SYLLABLES). Therefore, facilitation is predicted.

In generate-test retrieval (see Figure 7) TASK repetition should not influence the generate sub-stage, but may prime the TASK and thus facilitate the test sub-stage. In contrast to intersection retrieval, this facilitation should occur regardless of whether or not the ITEM was repeated. However, like intersection retrieval, this priming may be equivalent to Stage III processing assumed to occur when the TASK is presented first. Therefore, TASK facilitation may not be apparent for that ORDER.

In procedural retrieval (see Figure 8), TASK repetition should increase accessibility and/or computation speed of the TASK regardless of whether or not the ITEM was repeated. However, as in generate-test retrieval, Stage III processing may mask TASK facilitation in

TASK first condition. On the other hand, one possibility is that Stage III processing increases TASK accessibility but not computation speed, while TASK repetition has both effects. If this is true, the TASK repetition contrasts should be positive for both ORDERS, although they may be attenuated for TASK first conditions.

To summarize, the three classes of retrieval make different predictions with respect to the present experiments (see Table 6). Of particular importance are predictions concerning an ORDER main effect and TASK repetition effects in the context of a non-repeated TASK. Specifically, generate-test and procedural retrieval models make strong opposite predictions concerning the former effect; while generate-test retrieval predicts faster RT for ITEM first conditions, procedural retrieval predicts faster RT for TASK first conditions. Intersection retrieval, on the other hand, can be discriminated from both of these on the basis of strong opposite predictions concerning the latter effect; while intersection retrieval predicts TASK interference, the other two types of retrieval predict TASK facilitation in the context of a non-repeated ITEM.

Summary

The purpose of the present section was to develop the logic used to investigate some of the questions about structure and process of human LTM raised in the previous three chapters. The experimental paradigm used in the experiments to be reported was described, and a general model assumed to capture the flow of information processing was presented. In addition, the logic behind the sequential analyses to be used was discussed. Finally, specific ways the results of these experiments could be interpreted with respect to the structure and processing issues of major interest were considered. It is hoped that armed with this development, and especially with the Tables and Figures of this section for fast reference, the implications of the experiments to which we now turn will be apparent.

CHAPTER V

EXPERIMENT I

The main purpose of Experiment 1 was to establish the usefulness of the paradigm introduced in the last chapter for addressing questions about LTM. Would the type of sequential effects previously discussed be apparent in the data? Finding ORDER by DELAY conditions in which TASK repetition effects could be studied was of special interest because support for the notion of isolable LTM procedures is contingent upon such findings. This initial experiment, therefore, included two TASKS, two stimulus ORDERS, and three stimulus DELAY conditions.

Method

The procedure was the same as described in Chapter IV.

Subjects. Seventy-two undergraduates at the University of Massachusetts served as subjects; they received extra credit in their psychology classes for participation.

Design. For half the subjects TASK words appeared above ITEM words on the video display (O(T-I) condition); for the other half of the subjects the reverse was the case (O(I-T) condition). In addition, the DELAY between presentation of the top and bottom words on the display was manipulated as a between subjects variable. Equal groups of subjects had 0, 500, and 1000 msec DELAY intervals. Thus, the overall design of this experiment was a two (O(T-I) versus O(I-T)) by three (0 versus 500 versus 1000) factor completely randomized between subjects design. All other manipulations were varied within subjects.

Materials. Subjects were familiarized with material used in this experiment during the instruction phase. They were asked to retrieve the number of SYLLABLES in an ITEM word, or the COLOR of an ITEM concept. Eight color-specific nouns served as ITEMS (FROG, GRASS, DOLLAR, TURTLE, CORN, SUN, LEMON, and BUTTER). They were chosen so there were two exemplars of each combination of number of SYLLABLES (one or two) and COLOR (yellow or green). Since ITEMS had either one or two SYLLABLES and referred to either yellow or green concepts, and since there were two TASKS, regardless of ORDER, total processing of the first word allowed subjects to narrow the set of possible responses from four to two. For example, if O(T-I) subjects totally processed the TASK word COLOR during the DELAY interval, they could narrow the set of possible RESPONSES to yellow or green; if the TASK word was SYLLABLES, one or two would be required. On the other hand, if O(I-T) subjects totally processed an ITEM word (e.g. TURTLE) during the DELAY interval, they could also narrow the set of possible RESPONSES to two (i.e. two or green). While it is unlikely that subjects in the 0 DELAY condition employed this strategy, it is possible that subjects in the 1000 msec DELAY condition did. The important point is that since ITEMS and TASKS were chosen independently for each trial, the present choice of materials allows us to reject information reduction explanations of ORDER or TASK effects for all DELAY conditions.

Results

All error trials (machine and subject errors) and RTs less than

300 msec or greater than 2000 msec were excluded from all analyses in this and subsequent experiments. Averaged over conditions, this accounted for 6% of the trials. Table 7 presents mean correct RT and error rate for each of the six experimental conditions. As can be seen, RT and error rate are positively correlated, a finding which discredits speed-accuracy trade-off explanations of these data.

The dependent variable entered into all analyses of variance was mean correct RT for each subject for each within subject condition. All variables were treated as fixed effect variables. While this assumption is justified for the between subjects variables, and perhaps to a lesser extent for TASKS, it would be preferable to be able to extend conclusions about ITEMS to a larger set than used in each experiment. However, given the type of sequential analyses of interest and the amount of data available from each subject, conclusions about generality of findings will have to be made across, rather than within, experiments.

ORDER and DELAY. Two manipulations of interest in this experiment are ORDER of presentation of the stimulus words, and DELAY interval between them. The relevant means are plotted in Figure 9. First, it is apparent that TASK first conditions were consistently faster than ITEM first conditions (mean RTs equal 651 and 736 msec for O(T-I) and O(I-T) respectively) ($F(1,66)=12.71$, $p<.01$). Further, there was a significant decrease in RT with increases in DELAY (mean RTs equal 792, 650, and 638 msec for the 0, 500, and 1000 msec DELAY conditions respectively) ($F(2,66)=17.27$, $p<.01$). Closer inspection of the DELAY

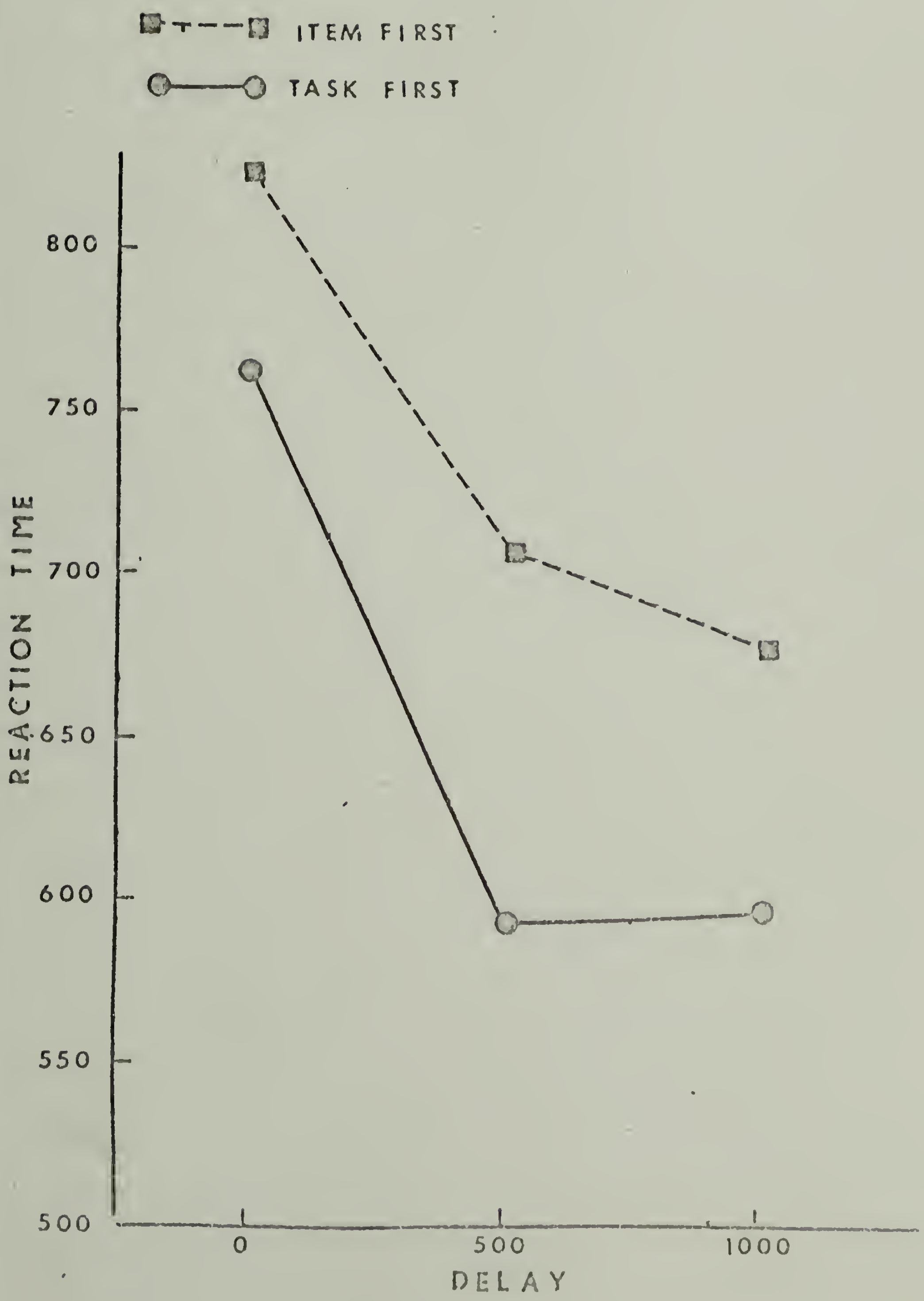
Table 7

Mean RT and Error Rate for ORDER by DELAY Conditions
(Experiment I)

	0 DELAY		500 DELAY		1000 DELAY		MEAN	
	RT	% Error	RT	% Error	RT	% Error	RT	% Error
O(T-I)	763	7%	592	6%	598	5%	651	6%
O(I-T)	822	9%	708	5%	678	7%	736	7%
MEAN	792	8%	650	5%	638	6%	694	6%

Figure 9

Mean RT for ORDER by DELAY Conditions
(Experiment I)



manipulation using the Neuman-Keuls procedure (EW $<$ .01) indicates that while the 0 DELAY condition led to longer RT than either other DELAY, the other two conditions were not reliably different from each other. Finally, the effect of DELAY was the same in both ORDER conditions ($F(2,66) < 1.00$ for the DELAY by ORDER interaction).

Stimulus material. Mean RT for each ITEM by TASK and ORDER by TASK condition is presented in Table 8. Overall, RT to decide how many SYLLABLES in a word is reliably faster than RT to decide the COLOR of the concept (mean RTs equal 680 and 707 msec for SYLLABLE and COLOR TASKS respectively) ($F(1,66)=11.88$, $p < .01$). However, while this difference held in TASK first conditions (mean difference equals 60 msec), it did not hold in ITEM first conditions (mean difference equals -8 msec). A Neuman-Keuls analysis (EW $<$ .01) of the significant interaction between TASK and ORDER ($F(1,66)=19.56$, $p < .01$) attests to the reliability of the TASK effect for O(T-I) but not for O(I-T) conditions.

In addition, there was significant variability among ITEMS ($F(7,464)=27.43$, $p < .01$). Further, the magnitude and direction of the TASK effect varied over ITEMS ($F(7,462)=70.90$, $p < .01$) for the TASK by ITEMS interaction, as did the magnitude but not the direction of the ORDER effect ($F(7,462)=3.14$, $p < .01$ for the ORDER by ITEMS interaction). Finally, the nature of the TASK by ORDER interaction also varied over ITEMS ($F(7,462)=7.62$, $p < .01$ for the three-way interaction). On the other hand, DELAY did not interact with TASKS, ITEMS, their interaction, nor their interactions with ORDER.

Table 8

Mean RT for ITEM by TASK and ORDER by TASK Conditions (Experiment I)

ITEM	SYLLABLES	COLOR
FROG	ONE 687	GREEN 693
GRASS	ONE 749	GREEN 667
DOLLAR	TWO 654	GREEN 790
TURTLE	TWO 644	GREEN 750
CORN	ONE 701	YELLOW 700
SUN	ONE 663	YELLOW 658
LEMON	TWO 698	YELLOW 680
BUTTER	TWO 649	YELLOW 715
TASK FIRST	621	681
ITEM FIRST	740	732
MEAN	680	707

Repetition contrasts. Mean RTs for the five repetition trial types (see Table 2) are presented for DELAY by ORDER conditions in Table 9 and for TASK by ORDER conditions in Table 10. Differences among these trial types will be considered in terms of the repetition contrasts (see Table 3). The magnitude and F-tests associated with each contrast are presented for DELAY by ORDER conditions in Table 11 and Figure 10, and for TASK by ORDER conditions in Table 12. Since, in the entire experiment, only one interaction involving DELAY by TASK was significant, it will be mentioned in the text, but other non-significant effects involving this level of interaction will not be presented. Also, since assessing the absolute and relative magnitude of repetition contrasts for each DELAY by ORDER condition was of primary interest, Neuman-Keuls analyses (EW < .05) were used to compare the contrasts for each condition to other conditions and to zero. Each of the four classes of contrasts (i.e. ITEM repetition, RESPONSE repetition, TASK repetition, and additivity) will now be considered.

ITEM repetition: Contrast 1 examines the effect of ITEM repetition in the context of a non-repeated TASK. Overall, this contrast was not significant, and it was not significantly affected by ORDER, DELAY, nor by their interaction (see Table 11). However, closer inspection of this contrast in Figure 10 indicates several interesting trends which were tested by the Neuman-Keuls analysis. First, this is the only contrast in which there is a suggestion of interference. In particular, there is significant interference in the TASK first-

Table 9

Mean RT for Five Trial Types for ORDER by DELAY Conditions
(Experiment I)

		0 DELAY	500 DELAY	1000 DELAY	MEAN
RT(1)	O(T-I)	774	597	603	658
	O(I-T)	842	733	711	762
	MEAN	808	665	657	710
RT(2)	O(T-I)	803	607	604	671
	O(I-T)	833	747	714	764
	MEAN	818	677	659	718
RT(3)	O(T-I)	743	593	597	644
	O(I-T)	807	693	662	721
	MEAN	775	643	629	682
RT(4)	O(T-I)	709	587	579	625
	O(I-T)	773	650	623	682
	MEAN	741	618	601	654
RT(5)	O(T-I)	736	579	596	637
	O(I-T)	788	676	631	698
	MEAN	762	628	613	668

Table 10

Mean RT for Five Trial Types for ORDER by TASK Conditions

		SYLLABLES	COLOR	MEAN
RT(1)	O(T-I)	692	624	658
	O(I-T)	763	761	762
	MEAN	693	728	710
RT(2)	O(T-I)	697	645	671
	O(I-T)	779	749	764
	MEAN	698	738	718
RT(3)	O(T-I)	676	613	644
	O(I-T)	708	733	721
	MEAN	673	692	682
RT(4)	O(T-I)	644	606	654
	O(I-T)	672	693	682
	MEAN	649	658	654
RT(5)	O(T-I)	669	605	637
	O(I-T)	691	705	698
	MEAN	655	680	668

Table 11

Repetition Contrasts for ORDER by DELAY Conditions
(Experiment I)

		0 DELAY		500 DELAY		1000 DELAY		MEAN		GRAND MEAN
		O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	
Contrast 1 (RT(1)-RT(2))		-28	10	-10	-14	- 1	- 3	-13	- 2	- 8
Contrast	F(1,66)=2.63									
Delay	F(2,66)<1.00									
Order	F(1,66)=1.30									
Delay x Order	F(2,66)=2.08									
Contrast 2 (RT(5)-RT(4))		27	15	- 7	26	17	8	12	16	14
Contrast	F(1,66)=9.16**									
Delay	F(2,66)<1.00									
Order	F(1,66)<1.00									
Delay x Order	F(2,66)=2.43									
Contrast 3 (RT(3)-RT(5))		8	19	14	17	1	31	7	22	15
Contrast	F(1,66)=19.24**									
Delay	F(2,66)<1.00									
Order	F(1,66)=4.86*									
Delay x Order	F(2,66)=1.41									
Contrast 4 (RT(1)-RT(3))		31	36	5	40	6	49	14	42	28
Contrast	F(1,66)=45.41**									
Delay	F(2,66)<1.00									
Order	F(1,66)=11.33**									
Delay x Order	F(2,66)=2.05									
Contrast 5 (RT(1)-RT(5)-35)		3	19	-17	22	-28	45	-14	29	7
Contrast	F(1,66)=3.78									
Delay	F(2,66) <1.00									
Order	F(1,66)=31.13**									
Delay x Order	F(2,66)=4.86**									
Contrast 6 ((RT(2)-RT(4))-(RT(3)-RT(5)))		86	41	7	79	23	59	39	60	49
Contrast	F(1,66)=44.61**									
Delay	F(2,66)<1.00									
Order	F(1,66)=2.06									
Delay x Order	F(2,66)=5.52**									
Contrast 7 (RT(2)-RT(4)-35)		58	25	-15	61	-11	55	11	47	29
Contrast	F(1,66)=18.21**									
Delay	F(2,66)<1.00									
Order	F(1,66)=7.03**									
Delay x Order	F(2,66)=6.64**									
Contrast 8 (Additivity)		-55	- 5	- 2	-39	-18	-10	-30	-18	-22
Contrast	F(1,66)=8.74**									
Delay	F(2,66)<1.00									
Order	F(1,66)<1.00									
Delay x Order	F(2,66)=2.93									

$^{*}p < .05$
$^{**}p < .01$

Figure 10

Repetition Contrasts for ORDER by DELAY Conditions
(Experiment I)

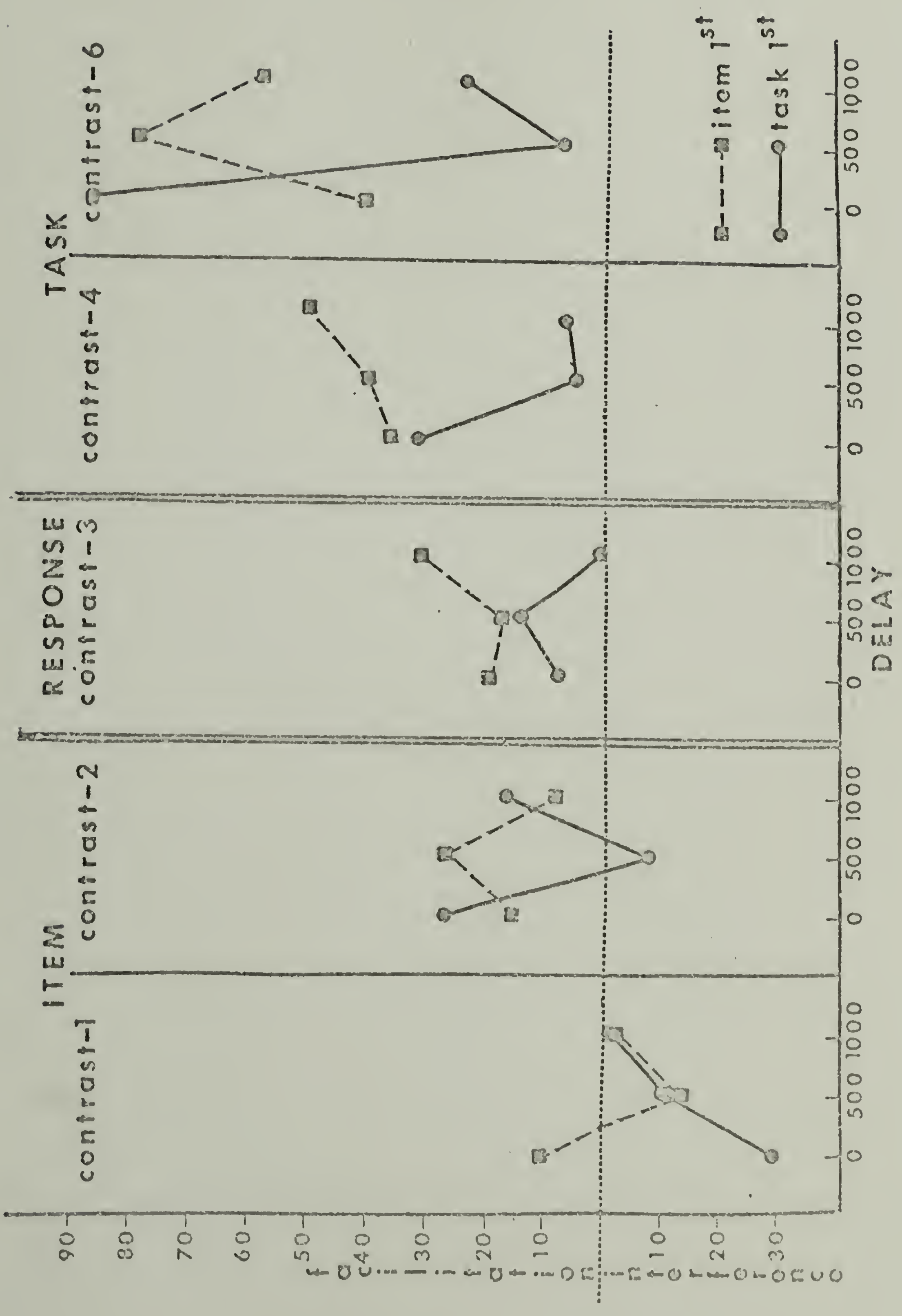


Table 12

Repetition Contrasts for ORDER by TASK Conditions

		SYLLABLES		COLOR		MEAN		GRAND MEAN
		O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	
Contrast 1 (RT(1)-RT(2)		-21	12	-5	-17	-13	-2	-8
Contrast	F(1,66)=2.63							
Task	F(1,66)<1.00							
Order	F(1,66)=1.30							
Task x Order	F(1,66)=7.45**							
Contrast 2 (RT(5)-RT(4))		-1	13	24	19	12	16	14
Contrast	F(1,66)=9.16**							
Task	F(1,66)=4.31*							
Order	F(1,66)<1.00							
Task x Order	F(1,66)=1.41							
Contrast 3 (RT(3)-RT(5))		8	28	7	17	7	22	15
Contrast	F(1,66)=19.24**							
Task	F(1,66)<1.00							
Order	F(1,66)=4.86*							
Task x Order	F(1,66)<1.00							
Contrast 4 (RT(1)-RT(3)		11	28	16	55	14	41	28
Contrast	F(1,66)=45.41**							
Task	F(1,66)=7.63**							
Order	F(1,66)=11.33**							
Task x Order	F(1,66)=3.42							
Contrast 5 (RT(1)-RT(5)-35)		-16	21	-12	36	-14	29	7
Contrast	F(1,66)=3.78							
Task	F(1,66)=3.61							
Order	F(1,66)=31.13**							
Task x Order	F(1,66)=1.09							
Contrast 6 ((RT(2)-RT(4))-(RT(3)-RT(5)))		32	29	46	91	39	60	49
Contrast	F(1,66)=44.61**							
Task	F(1,66)=10.47**							
Order	F(1,66)=2.06							
Task x Order	F(1,66)=4.19*							
Contrast 7 (RT(2)-RT(4)-35)		4	21	18	73	11	47	29
Contrast	F(1,66)=18.21**							
Task	F(1,66)=9.42**							
Order	F(1,66)=7.03**							
Task x Order	F(1,66)=3.26							
Contrast 8 (Additivity)		-20	-1	-29	-36	-25	-18	-22
Contrast	F(1,66)=8.74**							
Task	F(1,66)=4.30							
Order	F(1,66)<1.00							
Task x Order	F(1,66)=1.58							

*p <.05
*p <.01

0 DELAY condition. Further, for TASK first conditions, interference diminishes with increases in DELAY. On the other hand, the situation is less clear for ITEM first conditions, where Contrast 1 was statistically equal for all DELAY conditions and did not differ from zero. Finally, as can be seen in Table 12, while the overall magnitude of Contrast 1 was equivalent for both TASKS, interference was present for SYLLABLE trials in the 0(T-I) but not 0(I-T) conditions and the reverse was true for COLOR trials.

Contrast 2 examines the effect of ITEM repetition in the context of a repeated TASK. In this case there is significant facilitation due to ITEM repetition, and it is not significantly affected by ORDER, DELAY, nor their interaction (see Table 11). However, a Neuman-Keuls analysis supports the impression from Figure 10, that the TASK first-500 DELAY conditions is aberrant; it differs from other conditions, but not from zero. Also, the ITEM first-1000 DELAY contrast is not significantly greater than zero, while other conditions are. Finally, as can be seen in Table 12, Contrast 2 is consistently larger for COLOR than SYLLABLE trials.

RESPONSE repetition: Overall, there is significant RESPONSE facilitation (see Contrast 3 in Table 11). However, in the present experiment, simple effects tests indicate that this effect is only reliable in ITEM first conditiions, a phenomenon consistent with the significant influence of ORDER on Contrast 3. The RESPONSE repetition effect is not, however, influenced by DELAY. Further, while the ORDER by DELAY interaction is not significant, a Neuman-Keuls analysis supports the impression from Figure 10, that the effect of ORDER on RESPONSE repetition is only reliable at the 1000 msec DELAY. Finally, the only RESPONSE repetition effect that varies as a function of whether a SYLLABLE or COLOR trial was involved is the ORDER by DELAY interaction ($\underline{F}(1,66)=8.43$, $\underline{p} <.01$, for the three-way interaction), an interaction not readily interpreted.

TASK repetition: While Contrasts 5 and 7 have been included in Tables 11 and 12 for completeness, only TASK repetition Contrasts 4 and 6 will be discussed with respect to this experiment. The reasons for this omission are threefold. First, an assumption required for Contrasts 5 and 7, that the RESPONSE repetition effect is constant over ORDER, was not met in this experiment (although it was in all subsequent experiments). Second, the 35 msec best estimate of RESPONSE facilitation used in Contrasts 5 and 7 was significantly larger than the effect observed in the present experiment (mean RESPONSE repetition effect equals 22 msec) ($\underline{F}(1,66)=36.08$, $\underline{p} <.01$); this was also not true in any subsequent experiment. Third, while Contrast 6 could not be derived for some TASKS in all other experiments, this was not a problem in the present experiment where no ITEM by TASK conditions had unique RESPONSES. Thus, Contrasts 4 and 6 are sufficient and superior tests of TASK repetition effects here.

Contrast 4 examines the TASK repetition effect in the context of a non-repeated ITEM (see Table 11). Overall, this contrast was significantly larger than zero. Further, while the effect was more marked for ITEM first than TASK first conditions, as evidenced by the significant ORDER effect, simple effects tests found significant facilitation for both ORDERS. Also, while neither the DELAY main effect nor the DELAY by ORDER interaction was significant, closer examination of the six means using Neuman-Keuls procedure (EW $<.01$) is of considerable interest. First, this analysis indicated that the magnitude of Contrast 4 was positive and equal for all DELAY conditions of the ITEM first ORDER. Second, for TASK first conditions, the 0 DELAY contrast was positive and larger than other DELAY conditions which did not differ from each other nor from zero. Finally, as can be seen in Table 12, the TASK repetition effect tested by Contrast 4 was more marked for COLOR than for SYLLABLE trials.

Contrast 6 examines the TASK repetition effect in the context of a repeated ITEM. This contrast was significantly larger than zero and its magnitude was constant over levels of ORDER and DELAY (see Table 11). The interaction of these two variables did, however, affect Contrast 6, and analysis of the six means using the Neuman-Keuls procedure is of interest. First, at 0 DELAY the TASK first effect was larger than the ITEM first effect; however, the reverse was true at the other two DELAY intervals. Second, while all ITEM first conditions exhibited significant TASK facilitation, the contrast for the 0 DELAY condition was smaller than for the other two DELAY conditions, which did not differ from each other. Third, for the TASK first ORDER, the contrast for the 0 DELAY condition was larger than for the other two DELAY conditions which did not differ from each other nor from zero. Finally, as can be seen in Table 12, and consistent with Contrast 4, the TASK repetition effect measured by Contrast 6 was more marked for COLOR than for SYLLABLE trials.

Additivity: Contrast 8 tests the null hypothesis of additivity of ITEM and TASK repetition effects. Is the ITEM repetition effect equivalent in the context of a repeated or non-repeated TASK, or analogously, is the TASK repetition effect equivalent in the context of a repeated or non-repeated ITEM? The answer to these questions is clearly negative (see Table 11). ITEM and TASK repetition effects are more marked in the context of repeating the other stimulus word. Further, this violation is constant over ORDER and DELAY manipulations, but is more marked for COLOR than SYLLABLE trials (see Table 12).

Task sequencing. The analysis of TASK sequencing is of major interest in the remaining experiments which address the issue of a multi-layered LTM. This question cannot, however, be addressed in the present experiment because only two TASKS were used. Therefore, the analyses suggested in Table 5 and Figure 5 are redundant with the repetition contrasts just discussed. Nevertheless, for comparative purposes, means and F-tests derived from the present experiment are presented in this alternative form in Table 13. As in subsequent experiments, variability attributed to between subjects manipulations was partitioned from this analysis but only the relevant within subject means and F-tests are reported. Since discussion of these data in terms of the repetition contrasts is more consistent with the goals of the present experiment, Table 13 will not be considered further.

Table 13

Mean RT as a Function of TASK on Trials n and n-1
(Experiment I)

TRIAL n-1		TRIAL n	
TASK	ITEM	SYLLABLES	COLOR
SYLLABLES	DIFF	665	726
	SAME	651	739
	MEAN	658	733
COLOR	DIFF	691	688
	SAME	697	654
	MEAN	694	671
MEAN	DIFF	678	707
	SAME	674	697
GRAND	MEAN	676	702

Task(n)	F(1,66)=12.75**
Task(n-1)	F(1,66)=17.12**
Item	F(1,66)= 6.34*
Task(n) x Task(n-1)	F(1,66)=162.43**
Task(n) x Item	F(1,66)= 1.05
Task(n-1) x Item	F(1,66)= 5.68
Task(n) x Task(n-1) x Item	F(1,66)=21.56**

* $p < .05$
** $p < .01$

Discussion

The main effects of ORDER and DELAY will first be summarized and interpreted; then the repetition effects will receive equivalent consideration. First, there is an 85 msec speed-advantage for TASK first subjects relative to ITEM first subjects. As discussed in Chapter IV, this is compatible with the notion of procedural retrieval which requires access of a TASK procedure before retrieval can be initiated. On the other hand, it is especially incompatible with generate-test retrieval where access of the ITEM is required to initiate retrieval; in that case an ORDER effect opposite the one observed is predicted.

Second, RT is markedly reduced when a DELAY intervenes between onset of the two stimulus words, but this reduction is not statistically greater for a 1000 than a 500 msec DELAY. As discussed in Chapter IV, decreases in RT with increases in DELAY should be attributed to eliminating encoding time associated with the first stimulus word from measured RT, and priming of memory which reduces retrieval time. Since the 500 and 1000 msec DELAYS had equivalent effects and, since there was not a significant interaction between DELAY and ORDER, the encoding phenomenon is probably largely responsible for the RT reduction with DELAY. However, a non-significantly larger DELAY effect for TASK first conditions (mean DELAY effect equals 168 and 129 msec for the TASK first and ITEM first conditions respectively) suggests that priming the TASK may be more useful than priming the ITEM. This notion is consistent with the previous explanation of the ORDER main effect.

The repetition effects are most apparent in Figure 10 and will be briefly summarized here. First, there is a trend of ITEM interference when we consider ITEM repetition in the context of a non-repeated TASK, but this effect diminishes at long DELAYS. In the context of a repeated TASK, on the other hand, there is clear ITEM facilitation which is more marked for COLOR than for SYLLABLE trials. Second, there is RESPONSE facilitation which is larger for ITEM first conditions. Third, there is a large TASK facilitation effect whether or not the ITEM has been repeated. This effect, however, is markedly diminished (possibly non-existent) when the TASK word precedes the ITEM word by a long DELAY. Also, the TASK facilitation effect is larger for COLOR than for SYLLABLE trials. Fourth, the effects of ITEM and TASK repetition are larger in the context of a repeated second stimulus.

The present TASK is first to assign these repetition effects to appropriate stages of processing and then to consider what constraints they impose upon the retrieval stage. Prior to considering these points, the criteria used to assign repetition effects to the retrieval stage will be briefly reviewed. First, due to previous assumptions about encoding, retrieval, and response execution, interference effects can only be attributed to the retrieval stage. Second, for long DELAYS, RT does not include TASK encoding time for TASK first conditions or ITEM encoding time for ITEM first conditions (see Table 4). Therefore, TASK repetition effects present in the first case and ITEM repetition effects present in the second case must be attributed to the retrieval stage. Third, by application of the subtractive method, TASK repetition effects in ITEM first conditions, which exceed ITEM repetition effects in TASK first conditions, should be attributed, at least in part, to the retrieval stage. However, this rule is of questionable merit when the second stimulus word is not repeated. Fourth, by application of the additive factors logic, repetition effects which vary over TASK or DELAY should be assigned to the retrieval stage. Fifth, non-additivity of ITEM and TASK repetition effects can also be taken as evidence that both affect the retrieval stage.

There is ample evidence that all repetition effects influence the retrieval stage and are thus of value in assessing the three classes of retrieval which are of present interest. The evidence which supports this conclusion with respect to ITEM repetition is: (1) the possibility of ITEM interference in Contrast 1; (2) the presence of ITEM facilitation for ITEM first-long DELAY conditions in Contrast 2; (3) the larger ITEM facilitation effect for COLOR than SYLLABLE trials in Contrast 2; and (4) the non-additivity of ITEM and TASK repetition effects which is stable over ORDER by DELAY conditions. The RESPONSE repetition effect may be attributed, at least in part, to the retrieval stage because it varies over ORDERS. Likewise, several lines of evidence indicate that TASK repetition influences retrieval. They are: (1) that TASK facilitation for ITEM first conditions is larger than ITEM facilitation for TASK first conditions (see Table 11); (2) that TASK facilitation is larger for COLOR than SYLLABLE trials in both Contrasts 4 and 6; and (3) the non-additivity of ITEM and TASK repetition effects which is stable over ORDER by DELAY conditions.

In deciding what the repetition effects tell us about how we retrieve information from LTM, we can refer to Table 6 which outlined the predictions of three classes of retrieval processes. First, the pattern of ITEM repetition effects is generally consistent with all of the retrieval processes, although lack of an ORDER effect in either Contrasts 1 or 2 may be taken as weak support for generate-test retrieval. Second, that RESPONSE repetition effects were larger in ITEM first conditions is most consistent with intersection retrieval. Third, the clear TASK facilitation for ITEM first conditions, both in the context of repeated and non-repeated ITEMS, is consistent with either generate-test or procedural retrieval. On the other hand, this result is inconsistent with intersection retrieval which predicts an interference effect when the TASK but not the ITEM is repeated.

In summary, the results of Experiment I support procedural retrieval and are damaging to both alternatives. While the particular pattern of ITEM and RESPONSE repetition effects are somewhat more consistent with generate-test and intersection retrieval respectively, the relevant contrasts were not incompatible with the procedural model. On the other hand, results relevant to the more fundamental predictions concerning an ORDER main effect, and TASK repetition effects provide strong evidence against generate-test and intersection retrieval respectively, but are consistent with procedural retrieval. While this latter notion is still ill-defined, the idea of isolable LTM procedures which play an important role in retrieving information from LTM seems to be sound. Prior to speculating about the nature of a procedurally oriented LTM, the remaining experiments, among other things, test the reliability of the results which support this notion using a wider variety of TASKS.

CHAPTER VI

EXPERIMENT II

Experiment I established the usefulness of the present paradigm. Of special interest was evidence of TASK facilitation, isolable from ITEM and RESPONSE repetition effects and attributable to the retrieval stage of processing. The purposes of Experiment II are twofold. First, given the results of Experiment I, it is of considerable interest to replicate the findings which were interpreted as supportive of the notion of isolable LTM procedures. Second, Experiment II was designed so the notion of a multi-layered LTM could be assessed.

Specifically, in this experiment, two lexical and two semantic (CATEGORY and COLOR) TASKS were used. The operational distinction between these two classes of TASKS is that the former involves retrieving information about ITEM words, while the latter involves retrieving information about concepts the words refer to. To the extent that RT varies as a function of whether the TASK on the preceding trial involved the same or a different class of information (i.e. lexical versus semantic), we may obtain support for the multi-layer analysis of LTM.

Method

The procedure was the same as described in Chapter IV.

Subjects. Forty-eight undergraduates at the University of Massachusetts served as subjects; they received extra credit in their psychology classes for participation.

Design. For half the subjects TASK words appeared above ITEM words on the video display (O(T-I) condition); for the other half of the subjects the reverse was the case (O(I-T) condition). There was a 500 msec DELAY between onset of the first and second words for all subjects. By assumption, this interval is sufficiently long to eliminate TASK encoding time from TASK first subjects' measured RT and ITEM encoding time from ITEM first subjects' measured RT. Further, the results of Experiment I indicate that longer intervals do not significantly increase the effect of Stage III processing on retrieval.

Materials. Subjects were familiarized with material used in this experiment during the instruction phase. They were asked to NAME the ITEM word, or tell how many SYLLABLES it had (lexical TASKS), or retrieve the CATEGORY or COLOR of the ITEM concept (semantic TASKS). Eight color-specific nouns (PEPPER, PEAS, LEMON, CHEESE, TURTLE, FROG, TIGER, and BEE) served as ITEMS. Each ITEM was uniquely defined by the conjunction of its number of SYLLABLES, CATEGORY, and COLOR. However, ITEMS were chosen so half of them had each of the two RESPONSES associated with each of these three TASKS.

Results

Error trials (machine and subject errors) and RTs less than 300 msec or greater than 2000 msec were excluded from all analyses. This accounted for 6% of the trials. Consistent with Experiment I, RTs from the TASK first condition were significantly faster than those from the ITEM first condition (mean RTs equal 686 and 846 msec for O(T-I) and O(I-T) respectively) ($F(1,46)=25.89$, $p < .01$).

Stimulus material. Mean RT for each ITEM by TASK and ORDER by

TASK condition is presented in Table 14. There was significant variability among TASKS (mean RTs equal 655, 715, 902, and 793 msec for the NAME, SYLLABLE, CATEGORY, and COLOR TASKS respectively) ($F(3,138)= 186.10$, $p <.01$). Further analyses of these means (Bonferroni t tests, EW <.01) indicate that each TASK differs from each of the other three. In addition, while O(T-I) subjects were faster than O(I-T) subjects for all TASKS, the magnitude of this effect varied over TASKS ($F(3,138)= 9.24$, $p <.01$, for the TASK by ORDER interaction). Specifically, as can be seen from Table 14, the ORDER effect was statistically equal and smallest for CATEGORY and COLOR TASKS (mean ORDER effect equals 126 and 117 msec for CATEGORY and COLOR TASKS respectively), but larger for SYLLABLE (mean ORDER effect equals 179 msec) and NAME TASKS (mean ORDER effect equals 218 msec) (Bonferroni t tests, EW <.05).

In addition, there was significant variability among ITEMS ($F(7, 322)=6.37$, $p <.01$). Further, the magnitude (and in one case the direction) of the TASK effect varied over ITEMS ($F(21, 966)=12.61$, $p <.01$, for the TASK by ITEMS interaction). The ORDER effect, however, was stable over ITEMS ($F(7,322)< 1.00$, for the ORDER by ITEMS interaction), as was the TASK by ORDER interaction ($F(21,966)=1.25$ $p >.05$ for the three-way interaction).

Repetition contrasts. RT for the five repetition trial types (see Table 2) are presented for TASK by ORDER conditions in Table 15. Differences among these trial types will be considered in terms of repetition contrasts (see Table 3) which are presented with F-tests

Table 14

Mean RT for ITEM by TASK and ORDER by TASK Conditions
(Experiment II)

ITEM	NAME	SYLLABLES	CATEGORY	COLOR
PEPPER	PEPPER 657	TWO 685	FOOD 940	GREEN 815
PEAS	PEAS 669	ONE 711	FOOD 940	GREEN 778
LEMON	LEMON 671	TWO 748	FOOD 949	YELLOW 748
CHEESE	CHEESE 644	ONE 789	FOOD 922	YELLOW 763
TURTLE	TURTLE 659	TWO 688	ANIMAL 889	GREEN 812
FROG	FROG 653	ONE 715	ANIMAL 856	GREEN 790
TIGER	TIGER 647	TWO 707	ANIMAL 846	YELLOW 821
BEE	BEE 644	ONE 674	ANIMAL 871	YELLOW 820
TASK FIRST	546	625	839	735
ITEM FIRST	764	804	965	852
MEAN	655	715	902	820

Table 15

Mean RT for Five Trial Types for ORDER by TASK Conditions
(Experiment II)

		NAME	SYLLABLES	CATEGORY	COLOR	MEAN
RT(1)	O(T-I)	556	612	840	727	684
	O(I-T)	775	809	966	859	852
	MEAN	665	710	903	793	768
RT(2)	O(T-I)	545	617	818	721	675
	O(I-T)	785	803	998	868	863
	MEAN	665	710	908	795	769
RT(3)	O(T-I)	520	638	888	753	700
	O(I-T)	732	799	982	832	836
	MEAN	626	718	935	792	768
RT(4)	O(T-I)	494	631	724	714	741
	O(I-T)	682	753	832	771	763
	MEAN	588	692	786	742	702
RT(5)	O(T-I)	---	639	780	739	720
	O(I-T)	---	766	868	804	813
	MEAN	---	702	824	772	766

in Table 16. Numbers in parentheses under Contrasts 1, 4, and 7 are means computed for the TASKS for which other contrasts were computed (i.e. SYLLABLE, CATEGORY, and COLOR trials) and are included for comparative purposes. Bonferroni _t_ tests (EW $< .05$) were used to further assess these contrasts when they were significantly influenced by ORDER, TASK, or their interaction.

ITEM repetition: Contrast 1 examines the effect of ITEM repetition in the context of a non-repeated TASK. No such effect was present in any ORDER or TASK condition (see Table 16). Contrast 2, on the other hand, which tests the effect of ITEM repetition in the context of a repeated TASK, was positive and its magnitude did not significantly vary over ORDER or TASK (see Table 16).

RESPONSE repetition: Contrast 3 which tests the RESPONSE repetition effect was also positive and unaffected by ORDER (see Table 16). However, analysis of the significant TASK effect indicates that RESPONSE facilitation is larger for CATEGORY than either SYLLABLE or COLOR trials which did not differ.

TASK repetition: Contrasts 4 and 5 examine the effect of TASK repetition in the context of a non-repeated ITEM. While neither of these contrasts was significant (see Table 16), simple effects analysis of the significant ORDER effect supports the reliability of TASK interference in the O(T-I) condition and TASK facilitation in the O(I-T) condition. The direction and magnitude of Contrasts 4 and 5 also varied over TASK; however, only the NAME TASK led to consistent and reliable facilitation.

Table 16

Repetition Contrasts for ORDER by TASK Conditions
(Experiment II)

		NAME		SYLLABLES		CATEGORY		COLOR		MEAN		GRAND MEAN
		O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	
Contrast 1 (RT(1)-RT(2)) Contrast Task Order Task x Order	 F(1, 46)<1.00 F(3,138)<1.00 F(1, 46)=3.63 F(3,138)=1.82	11	-10	- 6	6	22	-32	6	- 9	9 (8)	-12 (-12)	- 1 (- 2)
Contrast 2 (RT(5)-RT(4)) Contrast Task Order Task x Order	 F(1, 46)=4.73* F(2, 92)<1.00 F(1, 46)<1.00 F(2, 92)<1.00	---	---	8	12	56	21	26	33	30	22	26
Contrast 3 (RT(3)-RT(5)) Contrast Task Order Task x Order	 F(1, 46)=33.50** F(2, 92)=11.20** F(1, 46)=1.13 F(2, 92)<1.00	---	---	- 1	34	108	113	14	28	40	58	49
Contrast 4 (RT(1)-RT(3)) Contrast Task Order Task x Order	 F(1, 46)<1.00 F(3,138)=10.01** F(1, 46)=10.67** F(1,138)=1.05	35	42	-26	10	-48	-16	-26	27	-16 (-33)	16 (7)	0 (-13)
Contrast 5 (RT(1)-RT(5)-35) Contrast Task Order Task x Order	 F(1, 46)<1.00 F(2, 92)=8.53** F(1, 46)=13.10** F(2, 92)<1.00	---	---	-62	8	25	63	-47	20	-28	30	1
Contrast 6 ((RT(2)-RT(4))-(RT(3)-RT(5))) Contrast Task Order Task x Order	 F(1, 46)=1.63 F(2, 92)<1.00 F(1, 46)=4.91* F(2, 92)<1.00	---	---	-12	17	-14	38	- 7	70	-11	41	15
Contrast 7 (RT(2)-RT(4)-35) Contrast Task Order Task x Order	 F(1, 46)=13.36** F(3,138)=7.48** F(1, 46)=13.84** F(3,138)<1.00	15	68	-49	15	59	116	-28	62	- 1 (- 6)	65 (64)	32 (29)
Contrast 8 (Additivity) Contrast Task Order Task x Order	 F(1, 46)=4.63* F(2, 92)<1.00 F(1, 46)<1.00 F(2, 92)<1.00	---	---	-13	- 7	-34	-53	-19	-42	-22	-34	- 28

*$p < .05$
**$p < .01$

Contrasts 6 and 7 examine the effect of TASK repetition in the context of a repeated ITEM. Overall, Contrast 6 is not significant but Contrast 7 is significantly greater than zero (see Table 16). A more consistent picture emerges by simple effects analysis of the significant ORDER effects. There is no TASK repetition effect for the O(T-I) condition, but there is significant TASK facilitation in the O(I-T) condition. Further, in Contrast 6 the TASK repetition effect is larger for NAME and CATEGORY than SYLLABLE and COLOR trials.

Additivity contrast: Consistent with the findings of Experiment I, Contrast 8 is significantly less than zero (see Table 16). This attests to the fact that ITEM and TASK repetition effects are larger in the context of a repeated second stimulus. This non-additivity does not, however, vary with ORDER or TASK.

TASK sequencing. As discussed in Chapter IV, closer examination of TASK sequencing effects can be useful to assessing the multi-layered LTM hypothesis. Specifically, support for this notion is obtained if RT for trials with non-repeated TASKS (i.e. RT(1) and RT(2)) systematically varies as a function of whether the TASK on the previous trial was from the same or different hypothesized LTM layer. Table 17 presents mean trial n RTs and _F_-tests as a function of TASK on trials n and n-1 for trials with repeated and non-repeated ITEMS. The presence of a significant trial n-1 main effect and trial n by trial n-1 interaction (see Table 17) indicates that further analysis is warranted.

The specific hypothesis under consideration is that information about a word (e.g. NAME or SYLLABLES) is conserved in a memory layer

Table 17

Mean RT as a Function of TASK on Trials n and n-1 (Experiment II)

TRIAL n-1		TRIAL n			
TASK	ITEM	NAME	SYLLABLES	CATEGORY	COLOR
NAME	DIFF	628	693	883	782
	SAME	585	693	886	767
	MEAN	607	693	884	774
SYLLABLES	DIFF	654	713	913	797
	SAME	642	693	843	761
	MEAN	648	703	878	779
CATEGORY	DIFF	673	724	886	798
	SAME	649	685	804	770
	MEAN	661	704	845	784
COLOR	DIFF	663	713	911	783
	SAME	669	715	925	744
	MEAN	666	714	918	764
MEAN	DIFF	655	711	898	790
	SAME	636	697	865	760
GRAND	MEAN	645	704	881	775

Task(n)	$\underline{F}(3,138)=140.28^{**}$
Task(n-1)	$\underline{F}(3,138)= 3.74^{*}$
Item	$\underline{F}(1, 46)= 19.50^{**}$
Task(n) x Task(n-1)	$\underline{F}(9,414)= 4.20^{**}$
Task(n) x Item	$\underline{F}(3,138) < 1.00$
Task(n-1) x Item	$\underline{F}(3,138)= 3.09^{*}$
Task(n) x Task(n-1) x Item	$\underline{F}(9,414)= 1.57$

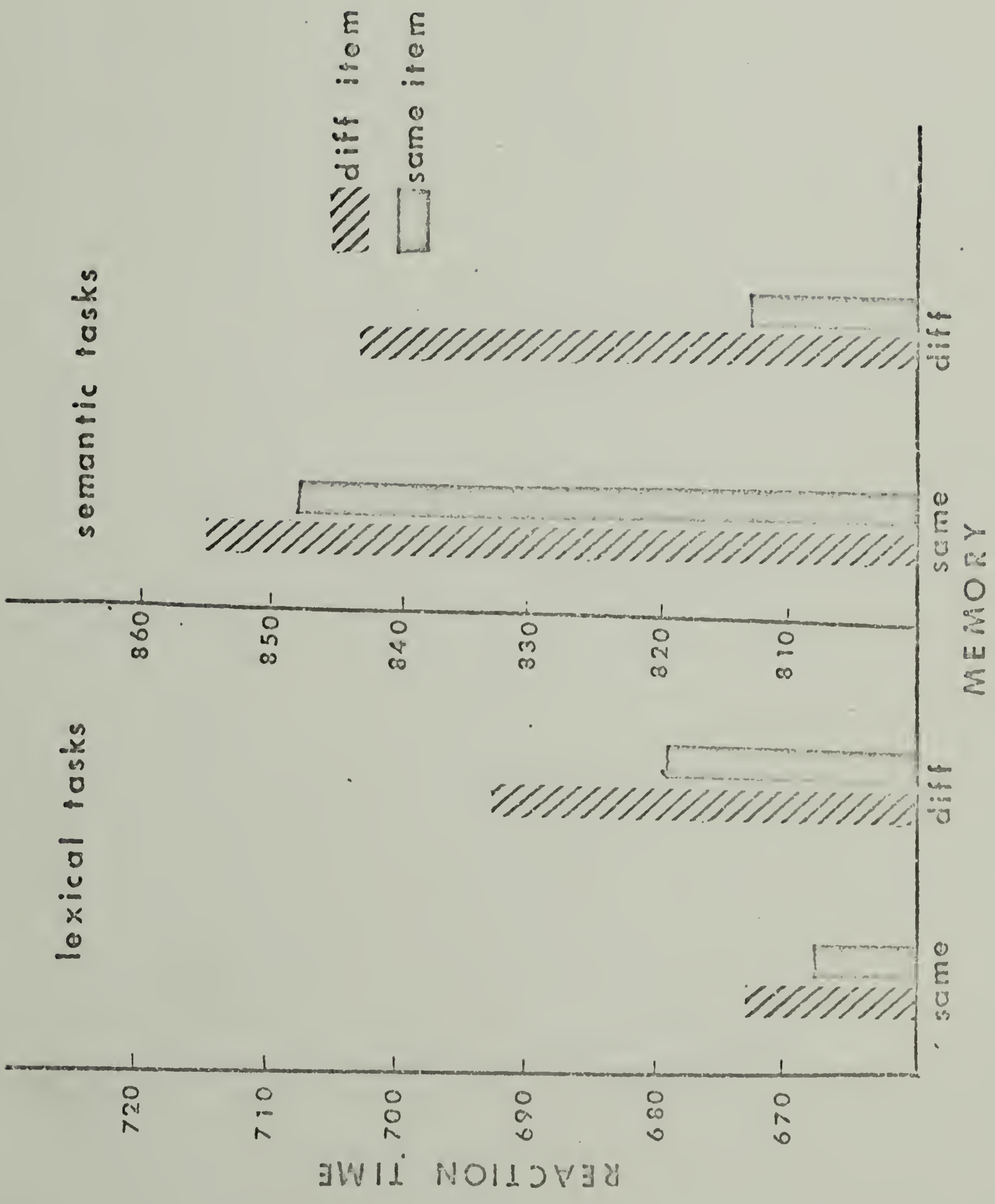
$^{*}\underline{p} < .05$
$^{**}\underline{p} < .01$

(i.e. the lexicon) distinct from where information about concepts (e.g. CATEGORY or COLOR) is conserved (i.e. semantic memory). Since RT varies over TASKS on trial n, the most appropriate way to examine Table 17 is column by column, excluding diagonal cells which represent fast TASK repetition trials. For both NAME and SYLLABLE trials, RT was faster when the preceding trial was a lexical rather than semantic TASK (648 versus 661 and 666 msec for NAME trials and 693 versus 704 and 714 msec for SYLLABLE trials). For CATEGORY and COLOR trials, on the other hand, RT was longer when preceded by a TASK from the same semantic rather than the different lexical memory (918 versus 884 and 878 msec for CATEGORY trials and 784 versus 774 and 779 msec for COLOR trials).

To statistically test these effects, an additional analysis of variance was performed. A mean RT was computed for each subject for each of eight conditions defined by: (1) class of trial n memory TASK (lexical or semantic); (2) memory repetition (same or different); and (3) ITEM repetition (same or different). While variability attributed to the between subjects ORDER factor was partitioned from this analysis, its affect is not relevant to the present consideration and will thus be ignored in this and subsequent experiments. The relevant means are graphically presented in Figure 11. As expected, lexical trials were faster than semantic trials (mean RTs equal 679 and 840 msec for lexical and semantic trials respectively) ($\underline{F}(1,46)=275.70$, $\underline{p} < .01$). Also, trials with repeated ITEMS were faster than trials with non-repeated

Figure 11

TASK Sequencing Effects
(Experiment II)



ITEMS[1] (mean RTs equal 752 and 766 msec for same and different trials respectively) ($\underline{F}(1,46)=7.86$, $\underline{p} < .01$). Specifically, while lexical TASKS were faster when preceded by trials from the same memory (i.e. there was lexical facilitation), the opposite was true of semantic trials (i.e. there was semantic interference). Further, simple effects tests (Bonferroni $\underline{t}$, EW $< .05$) supported the reliability of both of these findings. Finally, none of the interactions with ITEM repetition were significant, although the observed lexical facilitation was somewhat smaller for trials with repeated than non-repeated ITEMS (mean facilitation equals 12 and 20 msec for same and different ITEM trials respectively), while the observed semantic interference was somewhat greater for trials with repeated than non-repeated ITEMS (mean interference equals 34 and 11 msec for same and different ITEM trials respectively).

Discussion

Processing questions. Results of Experiment II which are relevant to the processing questions will be considered first. They are the

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[1] This result is conceptually equivalent to a positive ITEM repetition Contrast 1. The apparent inconsistency between these two measures is due to slightly different weightings of individual RTs for the two partitions of trials. The previous conclusion, that the effect of ITEM repetition in the context of a non-repeated TASK is ambiguous, remains soundest.

ORDER main effect and repetition contrasts. The 160 msec speed advantage for TASK first subjects, relative to ITEM first subjects, replicates Experiment I. The repetition contrasts are also basically compatible with those of Experiment I, although several differences should be noted. First, in the context of a non-repeated TASK there is still no strong evidence of an ITEM repetition effect. Like Experiment I, however, a trend is suggestive of interference for ITEM first subjects, where ITEM encoding time does not enter into measured RT. In the context of a repeated TASK, Experiment II replicates the ITEM facilitation effect observed in Experiment I, although in this case it is constant over TASKS. Second, the RESPONSE facilitation effect was also replicated, although in Experiment II it varied over TASKS but not ORDER. Third, also replicating Experiment I, TASK repetition contrasts attest to TASK facilitation for the ITEM first ORDER which varies among TASKS. In the case of the TASK first ORDER, however, the present data are suggestive of TASK interference. Fourth, the additivity Contrast 8 again indicates that ITEM and TASK repetition effects are larger in the context of a repeated second stimulus word.

As in Experiment I, there is ample evidence to attribute all of these repetition effects, at least in part, to the retrieval stage. The possibility of ITEM interference for the ITEM first condition in the context of a non-repeated TASK, the presence of ITEM facilitation in the context of a repeated TASK in the ITEM first condition (at a long DELAY), and the non-additivity of ITEM and TASK repetition, all support the contention that ITEM repetition affects retrieval. That RESPONSE repetition varies among TASKS supports the same claim with respect to RESPONSE repetition. Finally, the possibility of TASK interference in the TASK first condition, the fact that TASK facilitation for the ITEM first condition is larger than ITEM facilitation for the TASK first condition (see Table 16), the variability of the TASK repetition effect over TASKS, and the non-additivity of ITEM and TASK repetition, all support the retrieval hypothesis for TASK repetition effects.

Referring to Table 6, we can interpret these results in terms of the three classes of retrieval. Once again, the large ORDER main effect should be taken as strong support of only procedural retrieval. ITEM repetition effects, on the other hand, are equally compatible with all classes of retrieval. Further, although lack of an effect of ORDER on RESPONSE facilitation is least consistent with intersection retrieval, it is weak counter evidence. Finally, the TASK repetition results are somewhat ambiguous due to the possibility of interference for TASK first conditions; none of the retrieval processes predict such an effect. The presence of TASK facilitation in the context of a non-repeated ITEM in the ITEM first condition, however, replicates Experiment I and is damaging to intersection retrieval.

To summarize, the results of Experiment II which are relevant to questions about retrieval processes are generally consistent with those of Experiment I. The notion of procedural retrieval is again most compatible with these results, although the possibility of TASK interference for TASK first conditions is particularly bothersome to this position. The remaining experiments, among other things, provide additional tests of such an effect. At this point we turn to discussion of the structural issue of a multi-layered LTM which was of major interest in Experiment II.

Structural questions. By examining effects of sequencing lexical and semantic TASKS, Experiment II provided a test of the hypothesis that there are isolable lexical and semantic layers of LTM. The results which are most relevant to this issue are that retrieving lexical information was faster when preceded by a same rather than different memory TASK, but retrieving semantic information was slower in an analogous case (see Figure 11). That is, there is evidence of lexical facilitation but semantic interference. Thus, Experiment II provides general support for the multi-layer notion.

The results of this experiment, however, provide interpretive difficulty for both associative multi-layered models discussed in Chapter IV (see Figure 5). First, both models predict lexical interference, but lexical facilitation was observed in the present experiment. A possible explanation for this effect which would not discredit the associative models is that the observed lexical facilitation is a consequence of the particular lexical TASKS used in this experiment. Specifically, NAME codes may have a special status, causing them not to compete with other lexical information. Alternatively, number of SYLLABLES may be one type of information which must be computed, and therefore, does not compete with other lexical information. A second difficulty for both associative models is that neither of them predict TASK sequencing effects for trials with non-repeated ITEMS. Yet, such effects were observed in the present experiment.

An additional point is that the observed semantic interference is equally compatible with direct and lexical access models. Recall that semantic facilitation could be taken as counter evidence concerning direct access models. Experiments III and IV provide additional tests of this differential prediction.

To summarize, the results of the present experiment provide support for the general multi-layered LTM hypothesis, but are not naturally accounted for by either of two associative multi-layered models introduced in Chapter IV. However, one interpretive difficulty, the presence of lexical facilitation, may be due to the specific TASKS used in this experiment. This was tested in Experiment IV. On the other hand, the presence of TASK sequencing effects for trials with non-repeated ITEMS is more perplexing. It seems appropriate to postpone speculation about alternative multi-layer models until the reliability of this effect is established with different materials. Experiments III and IV both provide relevant data.

CHAPTER VII

EXPERIMENT III

Experiment III was designed with two main goals in mind. First, additional data relevant to the issues considered in the previous two experiments were desired. Although the results of Experiment II were interpreted as supporting procedural retrieval, the possibility of TASK interference could provide interpretive difficulties for that notion. Thus, by using a set of TASKS which partially overlaps with those of Experiment II, Experiment III tests the reliability of a TASK interference effect. In addition, the results of Experiment II supported the general multi-layered analysis of LTM, but provided interpretive difficulties for two associative versions of that notion. The present experiment provides additional data concerning the presence of TASK sequencing effects for trials with non-repeated ITEMS; such effects were observed in Experiment II, but were not predicted by associative multi-layered models. Further, the presence of semantic facilitation would be compatible with lexical but not direct access associative multi-layered models; while semantic interference was observed in Experiment II, the present experiment will also provide additional data relevant to this point.

The second major focus of Experiment III was to test a specific assumption of many current network models of LTM. Specifically, a number of theorists (e.g. Anderson and Bower, 1973; Fiksel and Bower, 1976; Quillian, 1969; and Rumelhart, Lindsay, and Norman, 1972) postulate that associations in the LTM network are labeled. An important question, see whether such an inference rule is automatically applied whenever there is an attempt to retrieve PROPERTY information, or only when the retrieved PROPERTY is, in fact, a PROPERTY of the higher level CATEGORY. This is because half of the PROPERTIES used in this experiment hold only for their ITEM words, while the other half hold for their CATEGORIES as well (see hierarchical representation of stimulus material in Figure 12). Thus, whether and how the semantic TASK sequencing effects depend upon which type of PROPERTY is associated with the trial n and n-1 ITEMS, should allow us to address the automaticity question. Further, whether or not there is an overall difference in RT to retrieve these two types of PROPERTIES will be of some interest because at least some interpretations of Collins and Quillian's (1969) model predict that higher level PROPERTIES (STEM and HEAD) should take longer to retrieve than more immediate PROPERTIES (BARK and BEAK). However, models which do not hold to the cognitive economy principle would not predict such an effect because associative strength between ITEMS and PROPERTIES was controlled (Conrad, 1971).

Method

The procedure was the same as described in Chapter IV.

Subjects. Forty-eight undergraduates at the University of Massachusetts served as subjects; they received extra credit in their psychology classes for participation.

Design. For half of the subjects TASK words appeared above ITEM then, is: What role do these labels play in retrieval? Some theorists have been quite explicit about their assumption that associative search is restricted to appropriately labeled associations (Anderson and Bower, 1973; Fiksel and Bower, 1976). How they might influence retrieval in a procedurally oriented LTM will be considered in the discussion of this experiment.

Anderson (1975) tested the label specificity assumption for SUBJECT and OBJECT relations by orthogonally varying the number of propositions in which a noun played either of these roles. If subjects can restrict their search according to these relations, recognition RT to sentences containing the experimental nouns should vary with number of sentences in which the noun was a SUBJECT _or_ OBJECT, depending upon which role it plays in the test sentence. However, Anderson found that recognition RT increased with both variables. This led him to conclude that the associative network structure and competitive search process are valid, but that subjects do not restrict their search according to available relational information. The present experiment examines this same issue for the relational information generally believed to be available in semantic, rather than episodic, memory. Further, the experimental paradigm and sequential analyses employed in Experiments I and II were used here. Specifically, the three semantic TASKS CATEGORY, INSTANCE, and PROPERTY, as well as the lexical NAME TASK were included in Experiment III.

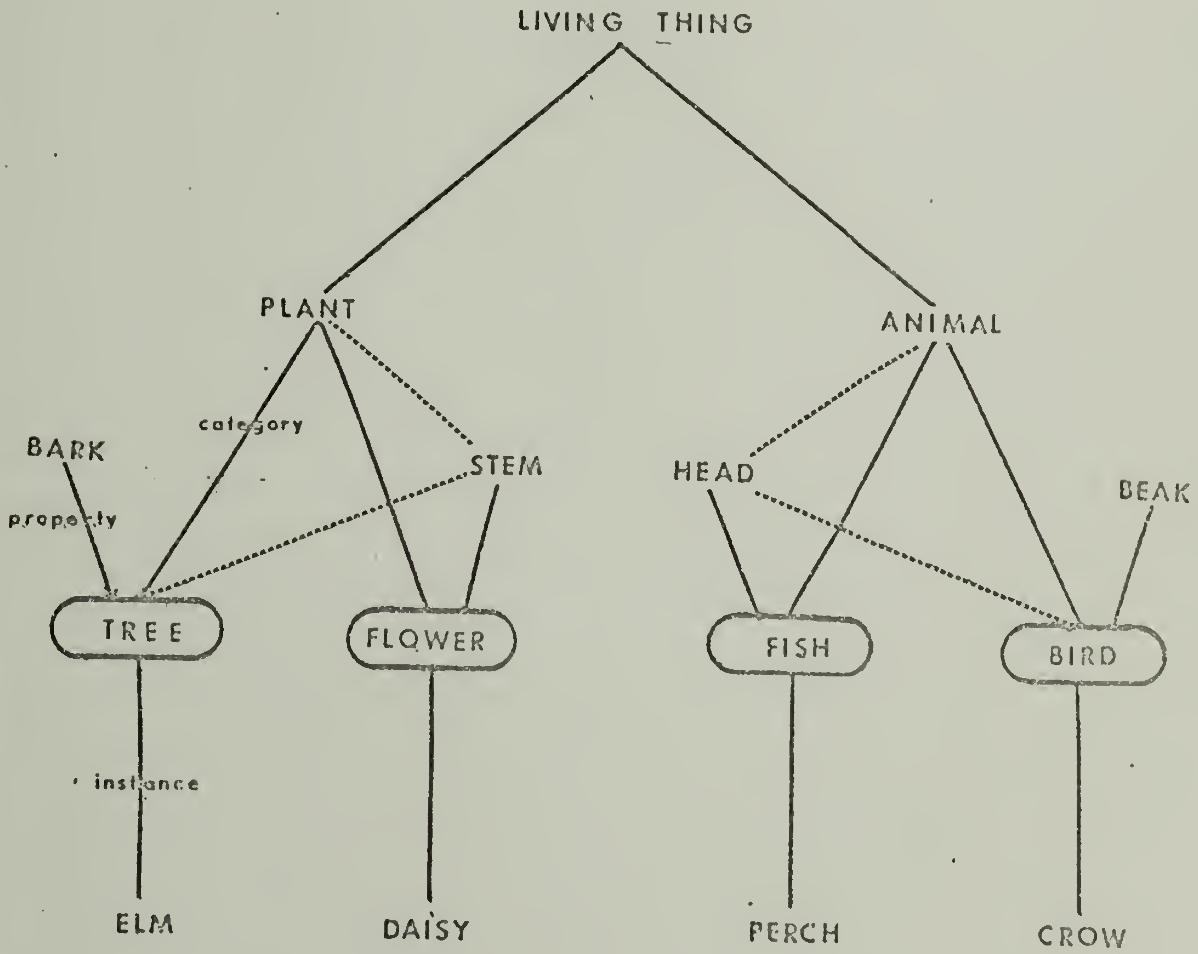
These TASKS have no special status in terms of procedural retrieval and the predictions summarized in Table 6 still hold. On the other hand, either intersection or generate-test retrieval might incorporate the assumption that search is restricted to associations which meet the logical constraints of the present TASKS. Then the scope of the competitive search and spreading activation should also be limited. In terms of the present experimental paradigm, this would lead to predicting repetition effects only when both the ITEM and TASK are repeated.

An issue which is of interest regardless of which class of retrieval is correct is what role the inference rule "a PROPERTY of a superordinate CATEGORY is also a PROPERTY of the concept," plays in retrieval. If this rule is applied when searching for PROPERTIES, as Collins and Quillian (1969) and Fiksel and Bower (1976) believe it is, certain patterns of TASK sequencing effects would be expected. While a detailed presentation of these predictions will be postponed until the relevant results have been reported, the basic idea is that if the inference rule is applied, CATEGORY and PROPERTY, but not INSTANCE trials, may involve searching common associations or using common LTM procedures. Therefore, RT to retrieve CATEGORY information should vary as a function of whether INSTANCE or PROPERTY information was just retrieved. Also, RT to retrieve PROPERTY information may vary as a function of whether INSTANCE or CATEGORY information was just retrieved. On the other hand, RT to retrieve INSTANCE information should be independent of which semantic TASK preceded it.

In addition, the materials chosen for Experiment III allow us to

Figure 12

Hierarchical Representation of Stimulus Material
(Experiment III)



words on the video display (O(T-I) condition); for the other half of the subjects the reverse was the case (O(I-T) condition). There was a 500 msec DELAY between onset of the first and second words for all subjects.

Materials. Subjects were familiarized with material used in this experiment during the instruction phase. They were asked to NAME the ITEM word, tell what CATEGORY it was in, give an INSTANCE, or give a PROPERTY of the ITEM concept. Four nouns (TREE, FLOWER, FISH, and BIRD) served as ITEMS. See Figure 12 for a hierarchical representation of this material.

Results

Error trials (machine and subject errors) and RTs less than 300 msec or greater than 2000 msec were excluded from all analyses. This accounted for 12% of the trials, an uncomfortably large percentage. However, closer inspection of errors indicated that they were randomly distributed among conditions except that NAME trials had fewest errors. Consistent with the previous two experiments, RT for the TASK first condition was significantly faster than for the ITEM first condition (mean RTs equal 953 and 1083 msec for O(T-I) and O(I-T) respectively) ($F(1,46)=13.09$, $p <.01$).

Stimulus material. Mean RT for each ITEM by TASK and ORDER by TASK condition is presented in Table 18. There was significant variability among TASKS (mean RTs equal 681, 1102, 1156, and 1133 msec for

Table 18

Mean RT for ITEM by TASK and ORDER by TASK Conditions (Experiment III)

ITEM	NAME	CATEGORY	INSTANCE	PROPERTY
FLOWER	FLOWER 695	PLANT 1108	DAISY 1078	STEM 1133
TREE	TREE 673	PLANT 1135	ELM 1086	BARK 1104
FISH	FISH 677	ANIMAL 1084	PERCH 1164	HEAD 1131
BIRD	BIRD 678	ANIMAL 1080	CROW 1298	BEAK 1162
TASK FIRST	588	1040	1089	1096
ITEM FIRST	774	1163	1224	1170
MEAN	681	1102	1156	1133

NAME, CATEGORY, INSTANCE, and PROPERTY trials respectively) ($F(3,138)=377.89$, $p < .01$). Further analysis of these means (Bonferroni t tests, $EW < .01$) indicated that NAME trials are significantly faster than CATEGORY, INSTANCE, or PROPERTY trials, but none of these last three TASKS differ from each other. Further, a significant interaction between ORDER and TASK ($F(3,138)=3.99$, $p < .01$) can be attributed to the difference between NAME and other TASKS being 75 msec larger for the O(T-I) than the O(I-T) ORDER.

In addition, there was significant variability among ITEMS ($F(3,138)=16.41$, $p < .01$). Further, the TASK differences varied over ITEMS ($F(9,414)=18.52$, $p < .01$, for the TASK by ITEM interaction), although NAME trials were consistently fastest. A question of interest is whether this interaction can be attributed, at least in part, to PROPERTY times being faster for ITEMS with immediate (TREE and BIRD) rather than higher level (FLOWER and FISH) PROPERTIES (see Figure 12). The answer is negative since mean RTs for the two sets of PROPERTY trials are identical (1132 msec). Thus, Experiment III provides no support for the cognitive economy hypothesis. Finally, the ORDER effect was stable over ITEMS ($F(3,138)=1.54$, $p > .05$, for the ORDER by ITEMS interaction), as was the TASK by ORDER interaction ($F(9,414) < 1.00$, for the three-way interaction).

Repetition contrasts. Mean RTs for the five repetition trial types (see Table 2) are presented for TASK by ORDER conditions in Table 19. Differences among these trial types will again be con-

Table 19

Mean RT for Five Trial Types for ORDER by TASK Conditions
(Experiment III)

		NAME	CATEGORY	INSTANCE	PROPERTY	MEAN
RT(1)	O(T-I)	582	1056	1092	1092	955
	O(I-T)	776	1181	1223	1180	1090
	MEAN	679	1118	1157	1136	1023
RT(2)	O(T-I)	579	1056	1080	1091	952
	O(I-T)	787	1176	1247	1186	1099
	MEAN	683	1116	1163	1139	1025
RT(3)	O(T-I)	603	989	1080	1090	940
	O(I-T)	758	1130	1195	1170	1063
	MEAN	680	1060	1137	1130	1002
RT(4)	O(T-I)	545	899	905	996	836
	O(I-T)	679	980	1053	957	917
	MEAN	612	939	979	977	877
RT(5)	O(T-I)	---	944	---	---	944
	O(I-T)	---	1110	---	---	1110
	MEAN	---	1027	---	---	1027

sidered in terms of repetition contrasts (see Table 3) presented along with F-tests in Table 20. As in Experiment II, numbers in parentheses below Contrasts 1, 4, and 7 are based on trials which can be directly compared to other contrasts. Also, Bonferroni t-tests (EW < .05) were again used to further assess these contrasts when ORDER, TASK, or their interaction significantly affected them.

ITEM repetition: Contrast 1 which examines the effect of ITEM repetition in the context of a non-repeated TASK was non-significant (see Table 20). Further, while ORDER had a significant effect on this contrast, neither the facilitation observed in the TASK first condition, nor the interference observed in the ITEM first condition proved significant by simple effects tests. Contrast 2, on the other hand, tested the effect of ITEM repetition in the context of repeated TASK, and indicated that there was facilitation for CATEGORY trials, the only TASK where computation of Contrast 2 was possible. Further, although this effect was three times larger in the O(I-T) than O(T-I) condition, the ORDER difference was not statistically reliable.

RESPONSE repetition: Contrast 3, also computable only for CATEGORY trials, indicated a RESPONSE facilitation effect which did not vary with ORDER.

TASK repetition: Contrasts 4 and 5 examine the effect of TASK repetition in the context of a non-repeated ITEM. Both of these contrasts indicated significant TASK facilitation which did not systematically vary with ORDER. In the case of Contrast 4, where the effect

Table 20

Repetition Contrasts for ORDER by TASK Conditions
(Experiment III)

		NAME		CATEGORY		INSTANCE		PROPERTY		MEAN		GRAND MEAN
		O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	
Contrast 1 (RT(1)-RT(2))												
Contrast	F(1, 46)<1.00											
Task	F(3,138)<1.00											
Order	F(1, 46)=7.20*	2	-11	0	5	12	-24	1	-6	4	- 9	- 3
Task x Order	F(3,138)<1,00									(0)(	(5)	(2)
Contrast 2 (RT(5)-RT(4))												
Contrast	F(1, 46)=8.02**											
Order	F(1, 46)=1.93	---	---	45	130	---	---	---	---	45	130	87
Contrast 3 (RT(3)-RT(5))												
Contrast	F(1, 46)=2.00											
Order	F(1, 46)<1.00	---	---	46	20	---	---	---	---	46	20	33
Contrast 4 (RT(1)-RT(3))												
Contrast	F(1, 46)=10.26**											
Task	F(3,138)=4.41**											
Order	F(1, 46)<1.00	-21	18	66	52	12	28	2	10	15	27	21
Task x Order	F(3,138)<1.00									(66)	(52)	(59)
Contrast 5 (RT(1)-RT(5)-35)												
Contrast	F(1, 46)=5.15**											
Order	F(1, 46)<1.00	---	---	77	36	---	---	---	---	77	36	57
Contrast 6 ((RT(2)-RT(4))-(RT(3)-RT(5)))												
Contrast	F(1, 46)=13.18**											
Order	F(1, 46)<1.00	---	---	111	177	---	---	---	---	111	177	144
Contrast 7 (RT(2)-RT(4)-35)												
Contrast	F(1, 46)=45.08**											
Task	F(3,138)=5.20**											
Order	F(1, 46)=3.86	- 1	73	122	162	140	158	60	194	80	147	114
Task x Order	F(3,138)=1.21									(122)	(162)	(142)
Contrast 8 (Additivity)												
Contrast	F(1, 46)=5.35**											
Order	F(1, 46)=1.20	---	---	-45	-126	---	---	---	---	-45	-126	-85

*$p < .05$
**$p < .01$

could be measured for all TASKS, differences were detected among TASKS. Specifically, facilitation for CATEGORY trials was greater than for any of the other TASKS which did not differ from each other.

Contrasts 6 and 7 examine the effect of TASK repetition in the context of repeated ITEMS. Again, both of these contrasts indicated significant TASK facilitation which did not systematically vary with ORDER. Also, in Contrast 7, computed for all TASKS, a significant difference among TASKS was detected. Specifically, facilitation for NAME trials was smaller than for other TASKS which did not differ.

Additivity contrast: Consistent with Experiments I and II, a significant violation of additivity of ITEM and TASK repetition effects which did not vary with ORDER was found.

<u>TASK sequencing</u>. A test of the multi-layered LTM hypothesis is available in the present experiment by considering whether RT to one of the semantic TASKS (i.e. CATEGORY, INSTANCE, or PROPERTY) differs as a function of whether it was preceded by a NAME TASK or a different semantic TASK. Table 21, analogous to Table 17 presented in the context of Experiment II, provides mean trial n RTs and *F*-tests as a function of TASK on trials n and n-1 for trials with repeated and non-repeated ITEMS. While there was no systematic effect of TASK on trial n-1, the significant interaction between TASKS on trials n and n-1 suggests that further analysis is warranted. Examining Table 21 column by column, but ignoring the diagonal cells which represent TASK repetition trials, indicates effects consistent with those of

Table 21

Mean RT as a Function of TASK on Trials n and n-1
(Experiment III)

TRIAL n-1		TRIAL n			
TASK	ITEM	NAME	CATEGORY	INSTANCE	PROPERTY
NAME	DIFF	686	1088	1151	1137
	SAME	616	1119	1134	1103
	MEAN	651	1104	1142	1120
CATEGORY	DIFF	687	1056	1177	1172
	SAME	673	947	1173	1192
	MEAN	680	1001	1175	1182
INSTANCE	DIFF	682	1154	1140	1116
	SAME	697	1101	982	1134
	MEAN	690	1127	1061	1125
PROPERTY	DIFF	686	1132	1146	1134
	SAME	706	1152	1180	988
	MEAN	696	1142	1163	1061
MEAN	DIFF	685	1107	1153	1140
	SAME	673	1080	1118	1104
GRAND	MEAN	679	1094	1135	1122

Task(n)	$F(3,138)=381.74^{**}$
Task(n-1)	$F(3,138)= 1.56$
Item	$F(1, 46)= 28.59^{**}$
Task(n) x Task(n-1)	$F(9,414)= 24.83^{**}$
Task(n) x Item	$F(3,138)= 1.35$
Task(n-1) x Item	$F(3,138)= 1.63$
Task(n) x Task(n-1) x Item	$F(9,414)= 15.76^{**}$

$^{*}p < .05$
$^{**}p < .01$

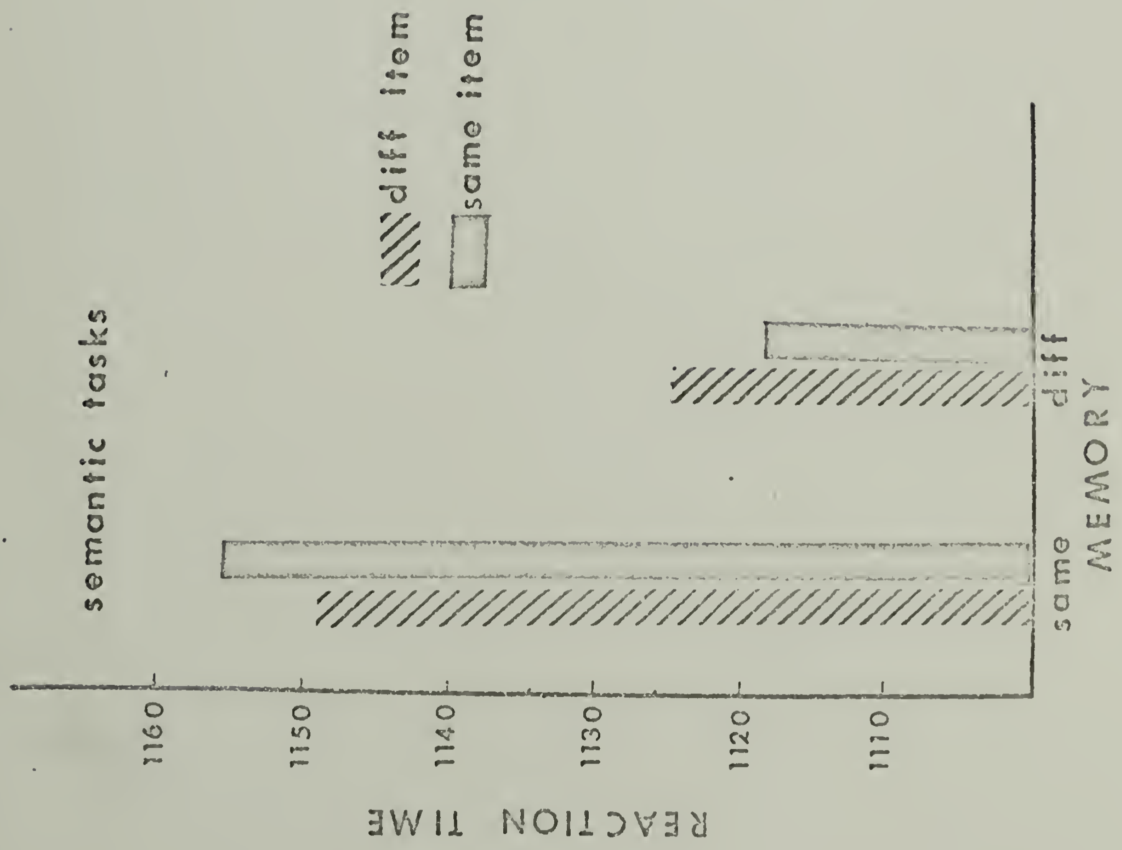
Experiment II. Specifically, each of the semantic TASKS is fastest when preceded by a NAME trial.

Figure 13 presents mean RTs for semantic trials preceded by other semantic TASKS or the NAME TASK with either repeated or non-repeated ITEMS. An analysis of variance of these means indicates that RT was significantly longer for semantic trials preceded by other semantic TASKS rather than the lexical TASK (mean RTs equal 1152 and 1122 msec for semantic and lexical trial n-1 TASKS respectively) ($\underline{F}(1,46)=17.25$, $\underline{p} <.01$). Further, there was neither a main ($\underline{F}(1,46)< 1.00$), nor interaction ($\underline{F}(1,46) <1.00$) effect attributable to ITEM repetition. However, consistent with Experiment II, semantic interference is non-significantly greater for trials with repeated rather than non-repeated ITEMS (mean interference equal 36 and 25 msec for same and different ITEM trials respectively).

Label specificity. Up to this point we have drawn two major conclusions about TASK sequencing, both of which can be seen in Table 21. First, RT is fastest when the TASK has been repeated, regardless of which TASK is considered (i.e. the diagonal cells of Table 21 have the fastest RTs). The present position is that this is due to facilitation of LTM procedures used to retrieve classes of information. Second, TASK repetition aside, RT to retrieve semantic information is faster when preceded by a lexical than by a different semantic TASK (i.e. with the exception of diagonal cells, the first row of Table 21 has the fastest RTs). The present position is that this is due to interference restricted to the semantic layer of LTM. The question

Figure 13

TASK Sequencing Effects
(Experiment III)



of present interest is whether there is additional systematic variability associated with the specific sequence of semantic TASKS. As mentioned in the introduction to this experiment, the presence of such effects could lead to inferences about label directed search and/or a hierarchy of LTM procedures.

Table 22 presents mean RTs and F-tests for CATEGORY, INSTANCE, and PROPERTY trials as a function of TASK on the preceding trial (i.e. one of two alternative semantic TASKS), and relationship between ITEMS in the pair of successive trials (i.e. different, same CATEGORY, or same ITEM). Consistent with the TASK sequencing analyses, variance attributable to the between subjects ORDER manipulation was partitioned from this analysis; however, since that variable is not relevant to the present questions, means are averaged over ORDER). As can be seen from Table 22, RT to CATEGORY trials was significantly faster when preceded by an INSTANCE rather than a PROPERTY trial if the ITEM was repeated, but the reverse was true if the preceding ITEM was the other ITEM from the same CATEGORY. RT to INSTANCE trials, on the other hand, was not significantly affected by TASK on the preceding trial. The trends, however, mirrored the significant differences observed for CATEGORY trials. Specifically, INSTANCE trials were faster when preceded by a CATEGORY rather than a PROPERTY trial if the ITEM was repeated, but the reverse was true in other conditions. Finally, RT to PROPERTY trials was faster when preceded by an INSTANCE rather than a CATEGORY trial, an effect which was significant when the ITEM was

Table 22

Mean RT for Label Specificity Test
(Experiment III)

CATEGORY TRIAL

TRIAL n-1	Diff category	Same category	Same ITEM
INSTANCE	1149	1183	1101
PROPERTY	1137	1115	1152
F(1,46)	<1.00	=6.46*	=4.84

INSTANCE TRIAL

TRIAL n-1	Diff category	Same category	Same ITEM
CATEGORY	1176	1175	1173
PROPERTY	1151	1155	1180
F(1,46)	= 1.06	<1.00	<1.00

PROPERTY TRIAL

TRIAL n-1	Diff category	Same category	Same ITEM
CATEGORY	1174	1156	1192
INSTANCE	1110	1131	1134
F(1,46)	=9.68**	=1.08	=5.96*

*p <.05
**p <.01

repeated or came from a different CATEGORY.

As indicated in the introduction, a number of LTM theories predict systematic differences in these TASK sequencing effects for trials involving ITEMS with immediate versus higher level PROPERTIES (e.g. TREE-BARK and BIRD-BEAK are immediate ITEM-PROPERTY pairs, while FLOWER-STEM and FISH-HEAD are higher level ITEM-PROPERTY pairs; see Figure 12). Therefore, the present analyses were carried out with the additional variable of level of trial n ITEM. Note that for same CATEGORY and same ITEM trials, level of trial n-1 ITEM is totally confounded with level of trial n ITEM since there were only two ITEMS from each CATEGORY. There were neither main nor interaction effects attributable to this manipulation. This fact, paired with the fact that an average of three subjects were eliminated from each of these finer grain analyses due to missing observations, led to presenting means and *F*-tests from the grosser analysis.

Discussion

Experiment III re-addressed the issues of procedural retrieval and of a multi-layered LTM for which some support was found in the previous experiments. The question of what special role CATEGORY, INSTANCE, and PROPERTY relations play in retrieving information from LTM was also addressed. The results relevant to each of these issues will be summarized and interpreted in turn.

Processing questions. As in previous experiments, there is a large speed advantage for TASK first subjects. Also consistent with previous experiments is the presence of repetition effects attributable to the retrieval stage. First, there is no significant effect of ITEM repetition in the context of a non-repeated TASK. However, the significant effect of ORDER on Contrast 1 which is negative for ITEM first subjects is again suggestive of retrieval interference. In the context of a repeated TASK there is ITEM facilitation; its presence in the ITEM first condition (at a 500 msec DELAY) must be interpreted as a retrieval phenomenon. Second, RESPONSE facilitation, measured only for CATEGORY trials, is also present in Experiment III. However, there is no compelling reason to assign this effect to the retrieval, rather than response execution stage. Third, both in the context of repeated and non-repeated ITEMS, the conditions of Experiment III produced a large TASK facilitation effect. That this effect varied over TASKS but not ORDER (and was, therefore, present in a TASK first-long DELAY condition) indicates that the retrieval stage was facilitated. Additional support for this claim is that TASK facilitation for ITEM first subjects was larger than ITEM facilitation for TASK first subjects (see Table 20). Finally, the non-additivity of ITEM and TASK repetition also supports the contention that both ITEM and TASK repetition influence retrieval.

Referring to Table 6, we see that Experiment III, like Experiments I and II, supports procedural, but not intersection or generate-test retrieval. That is, the speed advantage for TASK first subjects argues against generate-test retrieval. Further, that finding, as well as TASK facilitation in the context of non-repeated ITEMS argues against intersection retrieval. On the other hand, both of these findings are consistent with procedural retrieval, and ITEM and RESPONSE repetition effects are equally compatible with all models.

Structural questions. Experiment III also re-examined the multi-layered LTM hypothesis. The major relevant result is that semantic trials again took longer when preceded by other semantic TASKS than by the NAME (lexical) TASK. That is, the semantic interference effect observed in Experiment II was replicated, and thus additional support for the general multi-layered notion was obtained. This particular finding is equally compatible with direct and lexical access models. However, that semantic interference was observed for trials with non-repeated, as well as repeated ITEMS, is not immediately incorporated by either of these associative multi-layered LTM models. Since this result was also observed in Experiment II, it is reasonable to conclude that the associative multi-layered models are in need of modification. Such a modification will be introduced here and will be tested in Experiment IV. An alternative procedurally oriented multi-layered model will be suggested in the context of Experiment IV.

One possible modification of associative multi-layered models assumes that there is general priming following lexical TASKS which causes all trials following them to be fast relative to trials following semantic TASKS. This may be due to the use of verbal stimuli and RES-

PONSES in the present experiments (c.f. Collins and Loftus, 1975). That is, if lexical memory is used in encoding and/or response execution stages of processing, it is likely to be in a highly primed state. Since this should not be true if picture stimuli or button press RESPONSES were used, this hypothesis could be directly tested. An alternative explanation of general priming following lexical trials follows from some limited capacity arguments (c.f. Colker, 1975). The notion is that trials following fast trials should also be fast, independent of other considerations. Then, since lexical trials were, on the average fast, any trials following them should also be fast, regardless of structural considerations. While either or both of these mechanisms may be operating, the present question is whether they are adequate to explain TASK sequencing effects.

Associative multi-layered models with either of the modifications make the following two predictions concerning semantic effects. First, the prediction of semantic interference is strong for these models because semantic trials should be fast following lexical trials as a result of lexical priming, but should be slow following semantic trials as a result of semantic search interference. Consistent with this prediction, semantic interference was observed in both Experiments II and III. Second, since the search interference should only be operative for trials with repeated ITEMS, semantic interference should be more marked in that case than for trials with non-repeated ITEMS. Trends from Experiments II and III are also consistent with this prediction but failed to reach statistical significance (mean semantic interference equals 34 and 11 msec for trials with same and different ITEMS respectively in Experiment II, and 36 and 25 msec for trials with same and different ITEMS respectively in Experiment III). Both of these predictions will be tested again in Experiment IV.

Either of the two modifications of associative multi-layered models may also explain a second result of Experiment II which provided interpretive difficulty for the original associative multi-layered models. That is, while these models predicted lexical interference (see Figure 5), lexical facilitation was observed. However, if the general facilitation following lexical trials predicted by these modifications exceeds lexical search interference, the overall effect may be facilitatory. Further, since the search interference should only be manifest in trials with repeated ITEMS, a corollary to this argument is that lexical facilitation should be more marked for trials with non-repeated than repeated ITEMS. Again, the trend from Experiment II was in the correct direction, but failed to reach statistical significance (mean lexical facilitation equals 12 and 20 msec for trials with same and different ITEMS respectively); Experiment IV will also provide additional data on this point.

To summarize, while the general notion of a multi-layered LTM was again supported in this experiment, the purely associative models introduced in Chapter IV proved to be inadequate. Modifications of these models which are consistent with the results of Experiments II and III were introduced, and predictions which will be more stringently tested in Experiment IV were derived.

Label specificity questions. Experiment III also investigated semantic TASK sequencing effects more closely. Specifically, whether and how labeled associations and the inference rule that "PROPERTIES of CATEGORIES are also PROPERTIES of ITEMS" are utilized in retrieving information from LTM was of interest. The notion of label specific search, as might be incorporated into an intersection (c.f. Fiksel and Bower, 1976) or generate-test (c.f. Anderson and Bower, 1973) retrieval model is rejectable. In addition to the lack of support for intersection and generate-test retrieval provided by the ORDER main effect and the repetition contrasts (see discussion above), three aspects of the present data are especially inconsistent with label directed versions of these models.

First, and weakest is that while the general associative retrieval models predict ITEM interference in the context of non-repeated TASKS (see Table 6), there should be no such effect in this experiment since it used the TASKS assumed to restrict search. While the status of such interference is by no means established, its persistence over three experiments in size and magnitude in the ITEM first conditions where it would not be masked by encoding facilitation is impressive. Particularly relevant here is that it is no less evident in the present experiment than it was in Experiments I or II.

Second, while the general version of generate-test retrieval predicts TASK facilitation in the context of non-repeated ITEMS, a label directed version does not predict such a result for the present experiment. This is because the present TASKS, which are presumably the labels of semantic memory, would affect the generate rather than the test sub-stage of retrieval. Since TASK facilitation for generate-test retrieval was predicted on the basis of priming the test sub-stage, no such effect is predicted for the present TASKS. Likewise, no version of intersection retrieval predicts TASK facilitation in the context of a non-repeated ITEM (see Table 6); yet such a result is clearly present in Experiment III.

The third argument against label directed versions of intersection and generate-test retrieval is based on predictions they make about application of the inference rule. These predictions are summarized in Table 23. A distinction between models with automatic versus selective application of the inference rule should be drawn. In the former case, anytime a PROPERTY retrieval is initiated, pathways to the CATEGORY of the ITEM are activated in attempt to find PROPERTIES of it. In the latter case, on the other hand, pathways to the ITEM's CATEGORY are only activated when the PROPERTY which was retrieved holds for the CATEGORY. The predictions in Table 23 are identical for both classes of models except in cells with $\geq$; in these cases automatic models predict inequality while selective models predict equality. Also, while predictions have been presented for both immediate and higher level properties, the least conservative test of these models for the present experiments treats all PROPERTIES as immediate. Empirically, this assumption seems warranted since there was no main effect for the attempted manipulation of this variable. Further, since in this

Table 23

Predictions for Label Specificity Test

CATEGORY TRIAL

ITEM n	Diff Category	Same Category	Same ITEM
Immediate	$I = P$	$I > P$	$I \geq P$
Higher	$I = P$	$I \geq P$	$I > P$

INSTANCE TRIAL

ITEM n	Diff Category	Same Category	Same ITEM
Immediate	$C = P$	$C = P$	$C = P$
Higher	$C = P$	$C = P$	$C = P$

PROPERTY TRIAL

ITEM n	Diff Category	Same Category	Same ITEM
Immediate	$C = I$	$C \geq I$	$C \geq I$
Higher	$C = I$	$C < I$	$C < I$

C=CATEGORY
I=INSTANCE
P=PROPERTY

experiment subjects repeatedly retrieved the same single PROPERTY to each ITEM, it is reasonable to believe that they became "functionally immediate" PROPERTIES for the course of the experiment. Given these qualifications, there are four classes of predictions which will be considered.

First, none of the associative retrieval models predicts any RT difference for INSTANCE retrieval because the inference rule does not involve INSTANCE information. The data confirm this prediction. Second, none of the models predict any RT differences for trials in which the ITEM on the preceding trial was from a different CATEGORY. This is because there are no shared, relevant associations. The data for CATEGORY and INSTANCE trials confirm this prediction, but PROPERTY trials do not.

Predictions about retrieving CATEGORY and PROPERTY information following trials with related ITEMS require application of the competitive search and spreading activation assumptions. In the case of same CATEGORY trials, weak predictions are derived on the basis of relevant associations which may be in a high strength state due to spreading activation during application of the inference rule. In the case of same ITEM trials, stronger predictions are derived on the basis of associations shared on trials n and n-1 due to application of the inference rule.

The third class of predictions then, involve CATEGORY trials. RT should be faster when preceded by a PROPERTY than INSTANCE trial because in trying to retrieve a PROPERTY on trial n-1, CATEGORY associations may have been activated. They could then be retrieved more rapidly on trial n. This prediction is verified for same CATEGORY trials, but the opposite result was found for same ITEM trials. Finally, the fourth class of predictions concerns PROPERTY trials. Here, if the ITEM is repeated or from the same CATEGORY, interference may be predicted. This is because recently activated CATEGORY associations divert search from the immediate PROPERTY. The data confirm this prediction. In summary, while several predictions about how label directed associative retrieval models could incorporate the inference rule that "PROPERTIES of the CATEGORY of an ITEM are also PROPERTIES of the ITEM" were confirmed, two serious violations of these predictions add to mounting evidence against such models.

The TASK that remains, then, is to establish how a procedurally oriented LTM could accomodate the semantic TASK sequencing effects summarized in Table 22. Clearly such speculation is post hoc and requires further validation. Nevertheless, the present suggestion is that it is reasonable to view the semantic TASKS of the present experiment as three important LTM procedures which operate in an unlabeled LTM network.[1] Then the present data, as well as a priori knowledge about the relationships among CATEGORY, INSTANCE, and PROPER-

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[1] While it has often been argued that only labeled networks can avoid many fatal flaws of associative theories, Anderson and Bower (1973) have demonstrated how an unlabeled network can be generated equivalent to any labeled network. Further, they convincingly argued that the critical flaw in associative theories is due to their usual, but not necessary, acceptance of what Anderson and Bower call the Terminal Meta Postulate.

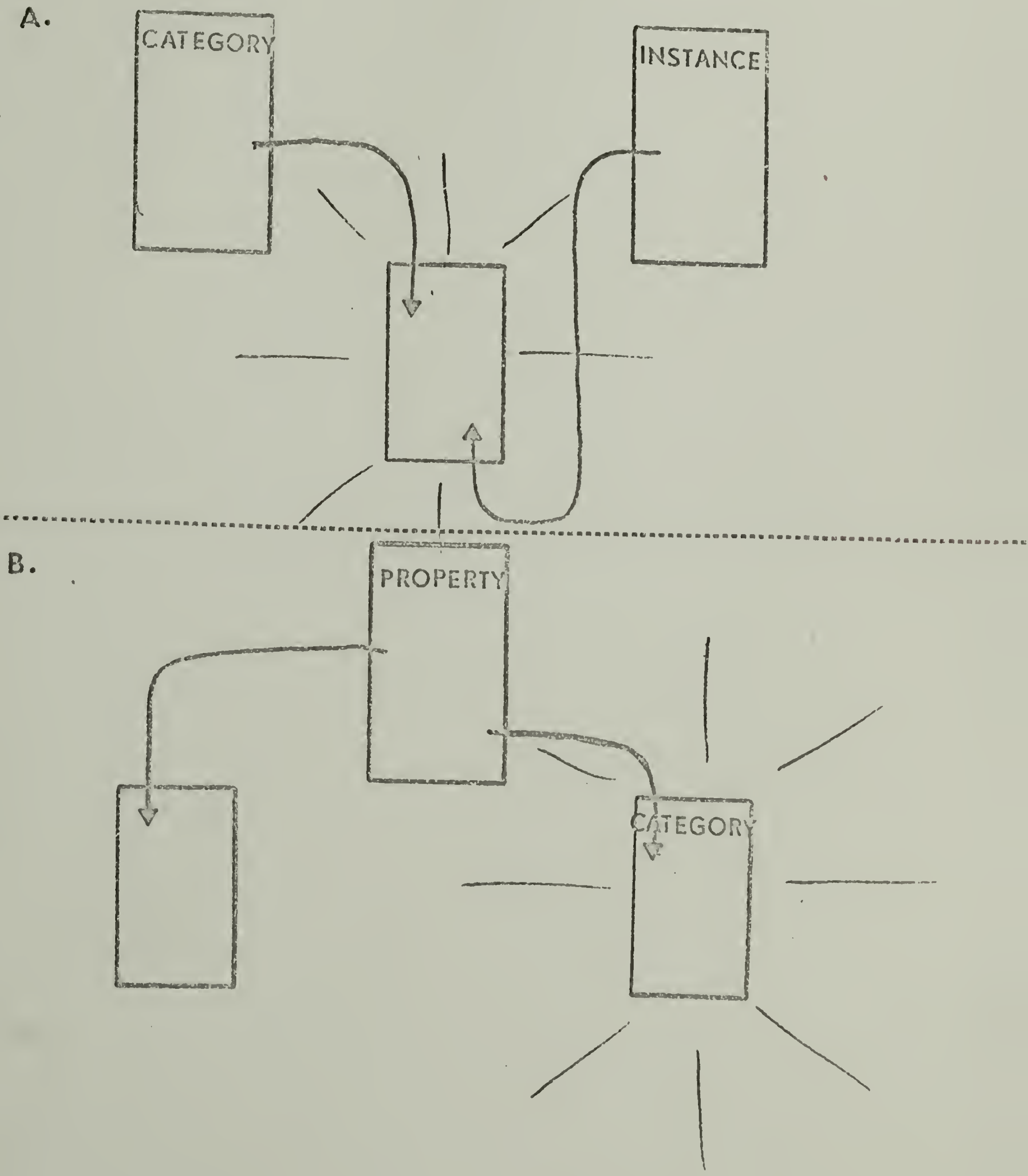
TY information can be used to develop an hypothesis about the nature of a procedurally oriented LTM capable of retrieving these types of information.

Such an hypothesis is presented pictorially in Figure 14. The top panel of this figure emphasizes that CATEGORY and INSTANCE TASKS are, in some sense, inverses of each other. Thus, in terms of the procedural conceptualization, they may share some common computational units. The idea is that if this common sub-procedure is tuned for the appropriate ITEM from the preceding trial, we should expect facilitation; otherwise there may be interference. Such a notion predicts that both CATEGORY and INSTANCE TASKS should facilitate each other in the context of a repeated ITEM, but may interfere otherwise. Since there are only two trial n-1 semantic TASKS in the present experiment, we cannot unambiguously attribute RT differences to interference for one TASK rather than facilitation for the other TASK; at least four semantic TASKS would be required for such an analysis. Nevertheless, with respect to the present speculation about CATEGORY and INSTANCE procedures, it is interesting to note from Table 22 that all six of the relevant comparisons are in the predicted direction, although only two of them are statistically reliable.

A procedural explanation of PROPERTY trials also seems reasonable. While it is premature to precisely define LTM procedures, it may be useful to think of them as packages of dynamically ordered heuristics which may be applied in serial or parallel. The PROPERTY procedure then would include, as one of its heuristics, the inference rule that

Figure 14

Procedural Representation of TASKS
(Experiment III)



the PROPERTY of a CATEGORY is also a PROPERTY of the concept, and would, on occasion, call the CATEGORY procedure in the process of retrieving PROPERTY information. The present suggestion is that such a strategy is inefficient for this experiment which involves repeatedly retrieving the same PROPERTY for each ITEM. However, if the CATEGORY procedure is in a high strength state, it may divert the PROPERTY procedure to use that heuristic. In a serial model this would directly consume time; in a parallel model it would directly consume processing capacity, and hence indirectly time. Either way, it leads to the prediction that PROPERTY trials preceded by CATEGORY trials should be slow regardless of whether or not the ITEM was repeated. The three relevant comparisons are all consistent with this prediction, and two of them were found to be statistically reliable. It thus seems that in addition to the general support for procedural retrieval provided by the ORDER main effect and the repetition contrasts, fine grain semantic TASK sequencing effects may also be incorporated by this notion. The next experiment will consider the structural question of a multi-layered network further, and its results will also be interpreted in terms of a procedurally oriented LTM.

CHAPTER VIII

EXPERIMENT IV

The previous three experiments generally supported the notions of isolable LTM procedures and a multi-layered LTM. A further examination of these issues is provided by the present experiment. Of special interest are the findings of Experiments II and III which provided interpretive difficulty for associative multi-layered models. First, whether the lexical facilitation observed in Experiment II is a general phenomenon, or is specific to the NAME and SYLLABLE TASKS was explored by using two different lexical TASKS in the present experiment. Second, to account for the reliable TASK sequencing effects for trials with non-repeated ITEMS, associative models required the modifying assumption that there is facilitation following lexical trials. This leads to the following predictions which will be tested in the present experiment: (1) all sets of lexical TASKS should lead to lexical facilitation, and this effect should be less marked for trials with repeated than non-repeated ITEMS; and, (2) all sets of semantic TASKS should lead to semantic interference, and this effect should be more marked for trials with repeated than non-repeated ITEMS.

The two lexical TASKS used in the present experiment required subjects to give the FIRST or SECOND syllable of two syllable ITEM words; the two semantic TASKS required subjects to give the COLOR or relative SIZE of ITEM concepts. The logic for choosing these particular TASKS was to see whether conditions could be found in which lexical interference and/or semantic facilitation would be obtained. The two lexical responses associated with each ITEM were of the same type and might be represented in a way which would cause interference which might not be expected between NAME and number of SYLLABLES information. Also, both COLOR and SIZE might be obtained from a "generated image" of the concept; then, having recently generated the image, deriving new information may be faster. Such a notion would be consistent with the idea of a hierarchy of LTM procedures, an idea which will be further considered in the discussion section.

Method

The procedure was the same as described in Chapter IV.

Subjects. Forty-eight undergraduates at the University of Massachusetts served as subjects; they received extra credit in their psychology classes for participation.

Design. For half the subjects TASK words appeared above ITEM words on the video display (O(T-I) condition); for the other half of the subjects the reverse was the case (O(I-T) condition). There was a 500 msec DELAY between onset of the first and second words for all subjects.

Materials. Subjects were familiarized with material used in this experiment during the instruction phase. They were asked to give the FIRST or SECOND syllable of ITEM words (lexical TASKS) or the COLOR or relative SIZE of the ITEM concepts (semantic TASKS). Four two syllable, color-specific nouns (PASTURE, DOLLAR, TIGER, and CARROT) served as ITEMS. Each ITEM was uniquely defined by the conjunction of its COLOR and relative SIZE. However, half of the ITEMS required each of the two

COLOR and SIZE RESPONSES.

Results

Error trials (machine and subject errors) and RTs less than 300 msec or greater than 2000 msec were excluded from all analyses; this accounted for 6% of the trials. Consistent with all previous experiments, RTs from the TASK first condition were significantly faster than those from the ITEM first condition (mean RTs equal 636 and 839 msec for O(T-I) and O(I-T) respectively) ($F(1,46)=45.50$, $p < .01$).

Stimulus material. Mean RT for each ITEM by TASK and ORDER by TASK condition is presented in Table 24. There was significant variability among TASKS (mean RTs equal 633, 692, 796, and 931 msec for FIRST, SECOND, COLOR, and SIZE trials respectively) ($F(3,138)=186.00$, $p < .01$. Further analysis of these means (Bonferroni t tests, EW <.01) indicated that all TASK types differ from each other. Further, in this experiment, the TASK effect was consistent over ORDERS ($F(3,138) < 1.00$, for the TASK by ORDER interaction).

In addition, there was significant variability among ITEMS ($F(3,138)=7.26$, $p < .01$), but as with TASKS, this was not influenced by ORDER ($F(3,138) < 1.00$, for the ORDER by ITEMS interaction). There were, however, differences in the TASK effects over ITEMS ($F(9,414)=21.53$, $p < .01$).

Repetition contrasts. Mean RTs for the five repetition trial types (see Table 2) are presented for TASK by ORDER conditions in Table 25. Differences among these trial types will be considered in terms of repetition contrasts (see Table 3) presented with F-tests in Table 26.

Table 24

Mean RT for ITEM by TASK and ORDER by TASK Conditions

(Experiment IV)

ITEM	FIRST	SECOND	COLOR	SIZE
PASTURE	PAS 635	TURE 724	GREEN 784	LARGE 782
DOLLAR	DOL 616	LAR 687	GREEN 817	SMALL 871
TIGER	TI 624	GER 686	ORANGE 808	LARGE 814
CARROT	CAR 666	ROT 762	ORANGE 776	SMALL 856
TASK FIRST	530	595	694	726
ITEM FIRST	735	789	898	935
MEAN	633	692	796	831

Table 25

Mean RT for Five Trial Types for ORDER by TASK Conditions
(Experiment IV)

		FIRST	SECOND	COLOR	SIZE	MEAN
RT(1)	O(T-I)	536	601	696	733	641
	O(I-T)	747	789	909	944	846
	MEAN	641	695	801	838	744
RT(2)	O(T-I)	532	583	685	709	627
	O(I-T)	742	799	919	948	852
	MEAN	637	691	802	829	740
RT(3)	O(T-I)	535	604	726	731	649
	O(I-T)	707	799	899	924	832
	MEAN	621	701	812	828	741
RT(4)	O(T-I)	482	553	636	662	583
	O(I-T)	666	721	797	792	744
	MEAN	574	637	716	727	664
RT(5)	O(T-I)	---	---	665	732	698
	O(I-T)	---	---	820	928	874
	MEAN	---	---	742	830	786

Table 26

Repetition Contrasts for ORDER by TASK Conditions
(Experiment IV)

	FIRST		SECOND		COLOR		SIZE		MEAN		GRAND MEAN
	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	
Contrast 1 (RT(1)-RT(2)) Contrast F(1, 46)=1.39 Task F(3,138)<1.00 Order F(1, 46)=7.20* Task x Order F(3,138)<1.00	4	5	18	-10	11	-12	24	- 4	14 (17)	- 5 (- 8)	4 (5)
Contrast 2 (RT(5)-RT(4)) Contrast F(1, 46)=20.71** Task F(1, 46)=6.84* Order F(1, 46)=1.14 Task x Order F(1, 46)=1.43	---	---	---	---	28	24	70	136	50	80	65
Contrast 3 (RT(3)-RT(5)) Contrast F(1, 46)=9.67** Task F(1, 46)<1.00 Order F(1, 46)<1.00 Task x Order F(1, 46)<1.00	---	---	---	---	61	79	- 1	- 3	30	38	34
Contrast 4 (RT(1)-RT(3)) Contrast F(1, 46)<1.00 Task F(3,138)=3.61* Order F(1, 46)=9.39** Task x Order F(3,138)=1.96	1	39	- 3	-10	-30	8	1	20	- 8 (-14)	14 (14)	3 (0)
Contrast 5 (RT(1)-RT(5)-35) Contrast F(1, 46)<1.00 Task F(1, 46)=4.93* Order F(1, 46)=2.58 Task x Order F(1, 46)<1.00	---	---	---	---	- 4	51	-35	-19	-19	16	- 1
Contrast 6 ((RT(2)-RT(4))-(RT(3)-RT(5))) Contrast F(1, 46)=16.20** Task F(1, 46)=67.89** Order F(1, 46)=7.91** Task x Order F(1, 46)<1.00	---	---	---	---	-12	43	48	160	18	102	60
Contrast 7 (RT(2)-RT(4)-35) Contrast F(1, 46)=30.92** Task F(3,138)=3.10* Order F(1, 46)=19.09** Task x Order F(3,138)=2.08	15	41	- 6	43	14	87	12	121	9 (13)	73 (104)	41 (59)
Contrast 8 (Additivity) Contrast F(1, 46)=14.78** Task F(1, 46)=3.40 Order F(1, 46)=3.19 Task x Order F(1, 46)=1.07	---	---	---	---	-17	-36	-47	-140	-32	-88	-60

*p <.05
**p <.01

Since RT (5) was not available for FIRST or SECOND TASK types, means for Contrasts 1, 4, and 7 are again presented both including and excluding these TASKS so they may be directly compared to other contrasts. Also, as in previous experiments, significant ORDER, TASK, or ORDER by TASK effects on any repetition contrast were further analyzed using Bonferroni t tests (EW <.05). Each class of contrast will now be considered.

ITEM repetition: Contrast 1 examines the effect of ITEM repetition in the context of a non-repeated TASK. While there is no overall effect, simple effects analysis of the significant ORDER effect (see Table 26), indicate that there is ITEM facilitation for O(T-I) but no effect for O(I-T). Contrast 2, which examines the effect of ITEM repetition in the context of a repeated TASK is significantly greater than zero (see Table 26). Further, while there is more facilitation for ITEM first than TASK first conditions, as evidenced by the significant ORDER effect, simple effects tests indicate that both conditions are facilitated by ITEM repetition.

RESPONSE repetition: Contrast 3 which examines RESPONSE repetition effects indicates that there is significant RESPONSE facilitation which does not significantly vary with ORDER or TASK (see Table 26).

TASK repetition: Contrasts 4 and 5 examine the effect of TASK repetition in the context of a non-repeated ITEM. Neither of these contrasts was significantly different from zero (see Table 26). However, further analysis of the ORDER effect present in Contrast 4 indicates that there is TASK facilitation for the ITEM first condition. In addition, the TASK repetition effect measured by these contrasts varied over TASKS, although only the simple effects test for FIRST trials was significant.

Contrasts 6 and 7 examine the effect of TASK repetition in the context of a repeated ITEM. Both of these contrasts indicated significant TASK facilitation which was only statistically reliable in the ITEM first condition (see Table 26). In addition, the magnitude of these contrasts varied over TASKS. Specifically, in Contrast 6 facilitation was larger for SIZE than COLOR trials, while in Contrast 7 these TASKS did not differ but were both larger than FIRST and SECOND trials which did not differ.

Additivity contrast: Consistent with all previous experiments the significance of Contrast 8 attests to a violation of the assumption of additivity of ITEM and TASK repetition effects which did not vary with ORDER or TASKS (see Table 26).

TASK sequencing. A major purpose of the present experiment was to see whether the lexical facilitation observed in Experiment II, and the semantic interference observed in Experiments II and III would be replicated with this different set of TASKS. Table 27 presents mean trial n RTs and F-tests as a function of TASK on trials n and n-1 for trials with repeated and non-repeated ITEMS. The significant trail n-1 main effect and trial n by trial n-1 interaction suggest that further analysis will be worthwhile. Again, examining this table column by column due to the significant trial n effect, and ignoring the diagonal cells which represent TASK repetition trials, such an analysis is available.

Table 27

Mean RT as a Function of TASK on Trials n and n-1
(Experiment IV)

TRIAL n-1		TRIAL n			
TASK	ITEM	FIRST	SECOND	COLOR	SIZE
FIRST	DIFF	619	678	794	837
	SAME	574	643	805	819
	MEAN	597	660	799	828
SECOND	DIFF	618	701	813	841
	SAME	623	637	810	835
	MEAN	621	669	812	838
COLOR	DIFF	647	700	791	834
	SAME	637	709	720	828
	MEAN	642	704	755	831
SIZE	DIFF	657	709	795	833
	SAME	645	710	799	731
	MEAN	651	709	798	782
MEAN	DIFF	635	697	798	836
	SAME	620	674	784	803
GRAND	MEAN	628	686	791	820

Task(n)	$F(3,138)=175.40^{**}$
Task(n-1)	$F(3,138)= 5.65^{**}$
Item	$F(1, 46)= 51.94^{**}$
Task(n) x Task(n-1)	$F(9,414)= 24.41^{**}$
Task(n) x Item	$F(3,138)= 2.47$
Task(n-1) x Item	$F(3,138)< 1.00$
Task(n) x Task(n-1) x Item	$F(9,414)= 13.29^{**}$

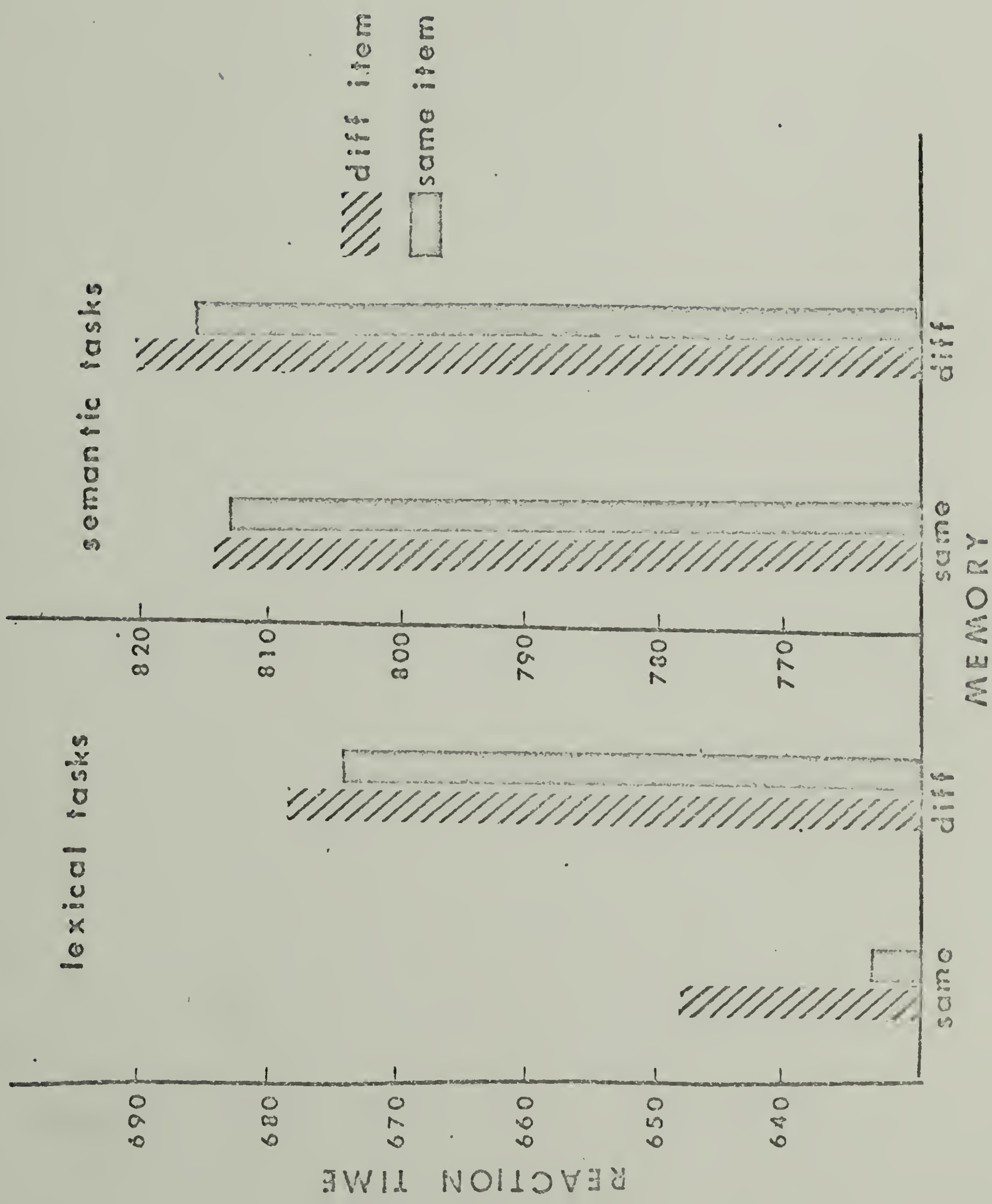
$^{*}p < .05$
$^{**}p < .01$

First, for lexical trials RT is consistently faster when preceded by the other lexical TASK than by either semantic TASK (621 versus 642 and 651 msec for FIRST trials, and 660 versus 704 and 709 msec for SECOND trials), a finding which replicates the lexical facilitation of Experiment II. Second, the results are less consistent for semantic trials. RT does not appear to be systematically slower when preceded by the other semantic TASK than by a lexical TASK as it was in Experiments II and III (798 versus 799 and 712 msec for COLOR trial and 831 versus 828 and 838 msec for SIZE trials).

Averaging over TASKS, mean RT is presented for lexical and semantic TASKS preceded by other TASKS in the same versus different memory for trials with repeated and non-repeated ITEMS in Figure 15. An analysis of variance for these means indicated that RT was faster for lexical than semantic trials (mean RTs equal 727 and 748 msec for lexical and semantic trials respectively) (_F_(1,46)=284.43, _p_ <.01). Further, RT was non-significantly faster for trials with repeated ITEMS (mean RTs equal 735 and 741 msec for same and different ITEMS trials respectively) (_F_(1,46)=3.37, p >.05). Of major interest is that RT was faster when preceded by the alternative TASK from the same memory rather than by either TASK from a different memory (mean RTs equal 727 and 748 for same and different memories respectively) (_F_(1,46)=40.33, _p_ <.01). Further, this effect was more marked for lexical than for semantic TASKS as evidenced by a significant interaction between trial n memory and memory repetition (_F_(1,46)=24.03, _p_ <.01). In fact, simple effects analysis of this phenomenon indicated that the memory facilitation was only reliable

Figure 15

TASK Sequencing Effects
(Experiment IV)



for lexical trials (Bonferroni t tests, EW < .05). Finally, neither the memory, nor the memory repetition effects, nor their interaction was significantly affected by ITEM repetition. There was, however, a trend of more marked lexical facilitation for trials with repeated than non-repeated ITEMS (mean lexical facilitation equals 42 versus 31 msec for same and different ITEM trials respectively).

Discussion

Processing questions. The results of Experiment IV are generally consistent with those of previous experiments which have been interpreted as supporting procedural, rather than intersection or generate-test retrieval. First, and clearest is the large speed advantage for the TASK first condition relative to the ITEM first condition. This is especially damaging to generate-test retrieval which predicts the opposite result. Second, there is no significant ITEM repetition effect in the context of a non-repeated TASK, but there is ITEM facilitation in the context of a repeated TASK. While the ITEM repetition effect is attributable, at least in part, to the retrieval stage, its nature is equally consistent with all retrieval processes considered here. Third, there is RESPONSE facilitation, but no good reason to assign it to the retrieval stage. Fourth, there is clear TASK facilitation in the context of a repeated ITEM, and it is attributable to the retrieval stage. In the context of a non-repeated TASK, the effect is more tenuous. This fact leaves weaker evidence to reject intersection retrieval than that provided in previous experiments. Nevertheless, procedural retrieval is preferred by the present data as well as those of the preceding three experiments.

Structural questions. The systematic effects of TASK sequencing in Experiment IV provide additional support for the general notion of a multi-layered LTM and impose several interesting constraints on this idea. First, like the NAME and SYLLABLE TASKS of Experiment II, the FIRST and SECOND lexical TASKS of the present experiment facilitated each other. One possible explanation for lack of lexical interference for pairs of trials with repeated ITEMS in Experiment II was that NAME and SYLLABLE information is conserved in fundamentally different ways which do not compete during retrieval. Such an explanation, however, is untenable for the lexical TASKS used in the present experiment, and therefore the present result provides serious difficulty for the associative multi-layered models presented in Chapter IV.

A second possible explanation of lexical facilitation follows from a modified associative multi-layered model. In this model general priming following lexical trials leads to the prediction of lexical facilitation. Such a model, however, also predicts that this effect should be more marked for trials with non-repeated than repeated ITEMS. However, the trend in this experiment was in the opposite direction (mean lexical facilitation equals 42 versus 31 msec for trials with same and different ITEMS respectively). Further, the modified associative multi-layered model predicts semantic interference, an effect not observed in the present experiment. Thus, even the modified version of purely associative multi-layered models cannot adequately account for the present data.

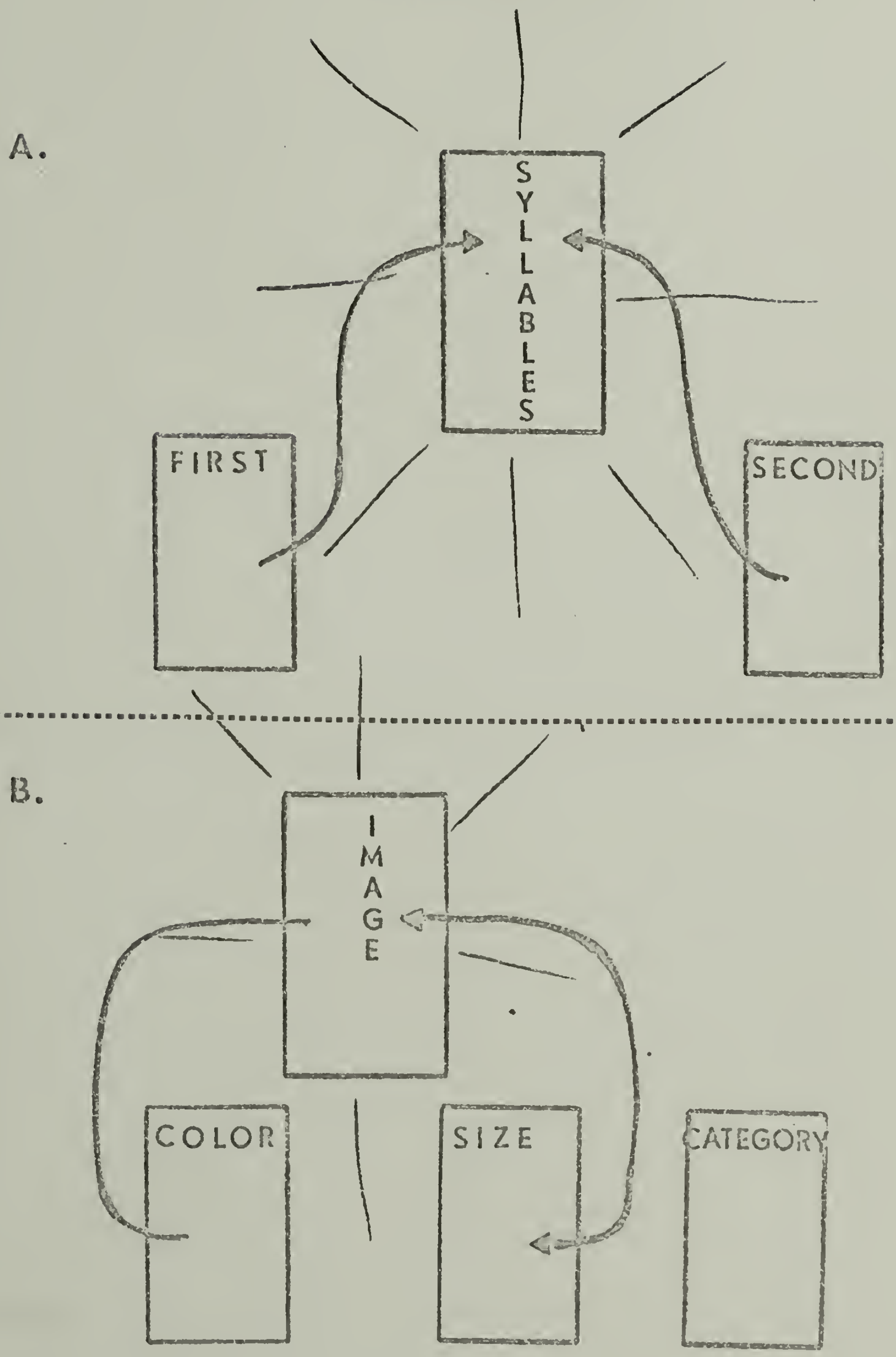
An alternative, albeit post hoc, explanation will be given in terms of a procedurally oriented LTM. Specifically, if we assume that the FIRST and SECOND procedures both involve calling, with appropriate parameters, a higher level SYLLABLE generation procedure, we might expect facilitation. This is because the SYLLABLE procedure would be in an accessible state following either lexical, but neither semantic TASK. This notion is presented pictorially in Figure 16a.

A similar argument can be brought to bear with respect to the possible semantic facilitation observed in the present experiment. That is, if a higher level IMAGE generation procedure is accessed by both the COLOR and SIZE procedures, facilitation would be predicted (see Figure 16b). On the other hand, if this procedure is accessed for COLOR, but not CATEGORY trials in Experiment II, interference may be expected. The fact that the procedural explanation of these phenomena is not contingent upon repetition of the ITEM lends some credence to it since the lack of that effect was replicated three times; most alternative explanations predict such interactions.

To summarize, the results of the present experiment provide additional support for procedural over purely associative retrieval processes. Further, general support for the multi-layered hypothesis was again obtained, but counter evidence concerning several associative versions of this idea were rejected. An alternative procedural explanation was provided.

Figure 16

Procedural Representation of TASKS
(Experiment IV)



CHAPTER IX

SUMMARY AND CONCLUSIONS

In this final section, results from all experiments relevant to the questions of a multi-layered LTM and isolable LTM procedures will each be summarized and interpreted. Then, several additional comments will attempt to integrate notions about structure and process into a unified view of human LTM.

LTM Structure

Summary of results. Aspects of the current experiments relevant to the multi-layered LTM notion are the TASK sequencing effects of Experiments II-IV. In particular, as argued in Chapter IV, the hypothesis that lexical and semantic memories are isolable layers of a multi-layered LTM, can be tested by examining RT as a function of whether recently retrieved information was from the same or a different hypothesized LTM layer. The relevant means for each experiment are presented in Table 28.[1] As discussed in the context of specific experiments and apparent in this table, the presence of systematic RT differences in this type of analysis provides support for a distinction between word (lexical) and concept (semantic) memories.

Three important findings will be summarized. First, in Experiment II NAME and SYLLABLE TASKS led to lexical facilitation, and this effect

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[1] Same TASK RT is not relevant to the present question but is included in Table 28 for comparative purposes. It is interesting to note that these RTs are always fastest.

Table 28

Mean RT as a function of Memory on Trials n and TASK Relationship on Trial n-1 (Over Experiments)

	TASK n-1	SAME TASK		SAME MEMORY		DIFFERENT MEMORY	
	TASK n	LEXICAL	SEMANTIC	LEXICAL	SEMANTIC	LEXICAL	SEMANTIC
	ITEM						
EXP. I	DIFF	651	688	---	---	691	697
	SAME	665	654	---	---	726	739
	MEAN	658	671	---	---	709	718
EXP. II	DIFF	671	835	673	855	693	844
	SAME	639	875	668	848	680	814
	MEAN	655	855	667	852	687	829
EXP. III	DIFF	686	1110	---	1150	686	1125
	SAME	616	972	---	1155	692	1119
	MEAN	651	991	---	1153	689	1121
EXP. IV	DIFF	661	812	648	815	678	821
	SAME	606	725	633	814	675	817
	MEAN	634	769	641	815	677	819

was not eliminated in Experiment IV by using more similar lexical TASKS (i.e. FIRST and SECOND syllable). In fact, the facilitation was more than twice as large in Experiment IV. Second, in Experiment II CATEGORY and COLOR TASKS, and in Experiment III CATEGORY, INSTANCE, and PROPERTY TASKS led to semantic interference. However, in Experiment IV, when the semantic TASKS COLOR and SIZE were used no such interference was observed. Third, neither lexical nor semantic effects were contingent upon repetition of the ITEM; in fact, these effects were no larger for trials with repeated than non-repeated ITEMS.

Interpretation of results. While these results provide support for the general notion of a multi-layered LTM, difficulties they provide for purely associative versions of this notion will be summarized here. Predictions for two associative multi-layered models, a direct and lexical access model, were derived in Chapter IV and are summarized in Figure 5. These predictions follow from the strength assumptions introduced in Chapter I, and the additional constraint that competitive search and spreading activation are more important within rather than between LTM layers. Thus, for trials with repeated ITEMS, search interference is expected if pairs of successive trials involve TASKS from the same rather than different LTM layers. The lack of lexical interference in both Experiments II and IV, as well as the presence of TASK sequencing effects for trials with non-repeated ITEMS is inconsistent with predictions of both of these models.

A modifying assumption of associative multi-layered models, that there is general priming following lexical trials, was introduced in the context of Experiment III. While this notion was consistent with the results of Experiments II and III, it failed to pass the tests of Experiment IV. Specifically, such a model predicts that: (1) all pairs of lexical trials should lead to lexical facilitation which should be more marked for trials with non-repeated ITEMS; and (2) all pairs of semantic trials should lead to semantic interference which should be more marked for trials with repeated ITEMS. While lexical interference was observed in Experiment IV, it was more marked for trials with repeated ITEMS. While this latter result was not statistically reliable, it was opposite the result predicted. Further, rather than semantic interference, there was a trend suggestive of semantic facilitation with the TASKS of Experiment IV. Thus, purely associative multi-layered models are rejectable. An alternative explanation of these phenomena in terms of a procedurally oriented LTM was suggested in the context of Experiment IV, and will be pursued further following consideration of results relevant to processing questions.

LTM Process

Summary of results. Aspects of the current experiments relevant to the processing questions are the ORDER main effect and the repetition contrasts. Mean RTs for each ORDER of each experiment are presented in Table 29. As can be seen, TASK first conditions are consistently faster than ITEM first conditions, and this effect was highly reliable in every experiment.

Mean values of each of the repetition contrasts for each ORDER of each experiment are presented in Table 30. The *F*-tests for each contrast and its ORDER effect are derived from an analysis of variance which included experiment as a factor; the O(T-I) and O(I-T) *F*-tests are derived from simple effects analyses. A fairly consistent picture is available. First, in the context of a non-repeated TASK, there is no reliable ITEM repetition effect (i.e. Contrast 1 is not significantly different from zero), although there is a consistent but non-significant, small interference effect in ITEM first conditions, where encoding facilitation could not mask retrieval interference. In the context of a repeated TASK, there is reliable ITEM facilitation for both ORDERS (i.e. Contrast 2 is positive). In two out of three experiments where this contrast was measured for multiple TASKS, it varied over TASKS. Second, there is reliable RESPONSE facilitation for both ORDERS (i.e. Contrast 3 is positive). Third, in the context of a non-repeated ITEM, there is significant TASK facilitation only for ITEM first conditions (i.e. Contrasts 4 and 5 are positive for O(I-T)). Further, this effect appears to vary over TASKS. In the context of a repeated ITEM, there is TASK facilitation for both ORDERS (i.e. Contrasts 6 and 7 are positive), albeit larger for ITEM first conditions. This effect also varies over TASKS. Finally, there is a reliable violation of additivity of ITEM and TASK repetition (i.e. Contrast 8 is negative), but the magnitude of this effect is stable over ORDER and TASK manipulations.

The reasons for assigning the ITEM repetition effect, at least in part, to the retrieval stage are: (1) the possibility of ITEM interference in the context of a non-repeated TASK; (2) the presence of ITEM

Table 29

Mean RT for ORDER by Experiment Conditions

	EXPERIMENT I	EXPERIMENT II	EXPERIMENT III	EXPERIMENT IV	MEAN
TASK FIRST	651	686	953	636	723
ITEM FIRST	736	846	1083	839	860
MEAN	694	766	1018	738	792

Table 30

Repetition Contrasts for ORDER by Experiment Conditions

		I		II		III		IV		MEAN		GRAND MEAN
		O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	O_{T-I}	O_{I-T}	
Contrast 1 (RT(1)-RT(2)) Contrast Order O_{T-1} O_{I-T}	 F(1,208)<1.00 F(1,208)=4.09* F(1,104)<1.00 F(1,104)=3.75	-13 (-13)	-2 (-2)	9 (8)	-12 (-12)	4 (0)	-9 (5)	14 (17)	-5 (-8)	2 (1)	-7 (-4)	-3 (-2)
Contrast 2 (RT(5)-RT(4)) Contrast Order O_{T-I} O_{I-T}	 F(1,208)=37.80** F(1,208)=2.90 F(1,104)=9.03** F(1,104)=26.54**	12	16	30	22	45	130	50	80	32	57	44
Contrast 3 (RT(3)-RT(5) Contrast Order O_{T-I} O_{I-T}	 F(1,208)=27.97** F(1,208)<1.00 F(1,104)=14.09** F(1,104)=13.98**	7	22	40	58	46	20	30	38	28	33	31
Contrast 4 (RT(1)-RT(3) Contrast Order O_{T-I} O_{1-T}	 F(1,208)=27.96** F(1,208)=22.81** F(1.104)<1.00 F(1,104)=40.15**	14 (14)	42 (42)	-16 (-33)	16 (7)	15 (66)	27 (52)	-8 (-14)	14 (14)	3 (9)	27 (30)	15 (19)
Contrast 5 (RT(1)-RT(5)-35) Contrast Order O_{T-I} O_{1-T}	 F(1,208)=5.91* F(1,208)=3.35 F(1,104)<1.00 F(1,104)=10.16**	-14	29	-28	30	77	36	-19	16	2	28	15
Contrast 6 ((RT(2)-RT(4))-(RT(3)-RT(5))) Contrast Order O_{T-I} O_{I-T}	 F(1,208)=42.79** F(1,208)=7.37** F(1,104)=7.13* F(1,104)=44.01**	39	60	-11	41	111	177	18	102	39	91	65
Contrast 7 (RT(2)-RT(4)-35) Contrast Order O_{T-I} O_{I-T}	 F(1,208)=106.49** F(1,208)=30.85** F(1,104)=10.74** F(1,104)=133.68**	11 (11)	47 (47)	-1 (-6)	65 (64)	80 (122)	147 (162)	9 (13)	73 (104)	23 (32)	79 (89)	61
Contrast 8 (Additivity) Contrast Order O_{T-1} O_{I-T}	 F(1,208)=24.67** F(1,208)=3.25 F(1,104)=4.74* F(1,104)=24.28**	-25	-18	-22	-34	-45	-126	-32	-88	-31	-61	-46

*$p < .05$
**$p < .01$

facilitation in the context of a repeated TASK for ITEM first conditions at long DELAYS; (3) the variability of ITEM facilitation over TASKS; and (4) the non-additivity with TASK repetition. Whether or not RESPONSE repetition exerts any influence on the retrieval stage, or its influence should be solely attributed to response execution facilitation is more ambiguous. It was significantly larger for ITEM first conditions only in Experiment I and varied over TASKS only in Experiment II. Fortunately, predictions about the effect of RESPONSE repetition on retrieval are not importantly different among classes of retrieval; thus, this ambiguity can easily be tolerated. The reasons for assigning the TASK repetition effect, at least in part, to the retrieval stage are: (1) the presence of facilitation in the context of a repeated ITEM for TASK first conditions at long DELAYS; (2) the fact that TASK facilitation for ITEM first conditions is consistently larger than ITEM facilitation for TASK first conditions; (3) the variability of TASK facilitation over TASKS; and (4) the non-additivity with ITEM repetition.

Interpretation of results. By isolating experimental effects to the retrieval stage, we can analyze the nature of processing involved. Predictions which follow from three sets of retrieval assumptions were derived in Chapter IV and are summarized in Table 6. Considering the present results in terms of these predictions, there is consistent support for procedural retrieval as well as consistent counter evidence concerning intersection and generate-test retrieval. The large and reliable speed advantage for TASK first conditions follows naturally from the notion that a TASK procedure directs retrieval. On the other hand, it provides strong evidence against generate-test retrieval which assumes that search proceeds from the ITEM node. Intersection retrieval models could only predict such a result by assuming that search from the TASK is diffuse, and therefore slow relative to search from the ITEM. Then, a head start on the slower search for TASK first subjects would lead to the observed ORDER effect.

A corrollary of this version of intersection retrieval is that the ORDER effect should be most marked for TASKS with large RESPONSE sets, where the LTM network is most diffuse. Clearly, the NAME TASK has the largest RESPONSE set, and the ORDER effect was, in fact, largest for NAME trials in both Experiments II and III. However, as was previously suggested, the NAME TASK may be special. Thus, in assessing the present hypothesis it is important to consider other TASKS, even though their ordering on a RESPONSE set size dimension is somewhat more ambiguous. A possible ordinal scale, along with observed ORDER effects is presented in Table 31 for TASKS from all experiments. As can be seen, NAME trials aside, there is no support for the hypothesis that the ORDER effect is more marked for TASKS with larger RESPONSE sets. Further, it is doubtful that any reasonable modification of the scale would lead to better prediction of the ORDER effect. Therefore, even this modified version of intersection retrieval is not supported by the present data.

Next, neither the ITEM nor RESPONSE repetition effects provide strong evidence for or against any of the retrieval models. TASK repetition effects, on the other hand, are important. All retrieval proc-

Table 31

ORDER Effects as a Function of RESPONSE Set Size of TASKS
(Over Experiments)

TASK	EXPERIMENT I	EXPERIMENT II	EXPERIMENT III	EXPERIMENT IV
NAME	---	218	186	---
SECOND	---	---	---	194
FIRST	---	---	---	205
PROPERTY	---	---	74	---
INSTANCE	---	---	135	---
CATEGORY	---	126	123	---
COLOR	51	117	---	204
SIZE	---	---	---	209
SYLLABLES	119	179	---	---

esses predict TASK facilitation in the context of repeated ITEMS, at least for ITEM first subjects, and it is clearly present in all experiments. The critical prediction concerns TASK repetition effects in the context of non-repeated ITEMS; intersection retrieval predicts TASK interference, while generate-test and procedural retrieval predict TASK facilitation.

The most unambiguous confirmation of either prediction would be found in the TASK first condition of Contrasts 4 and 5 since TASK encoding time does not contribute to measured RT (except in the 0 DELAY condition of Experiment I; see Table 4). However, as argued in Chapter IV, it is likely that Stage III processing masks such effects. For intersection retrieval, this is because in TASK first conditions, search from the ITEM begins after search from the TASK, and therefore dominates RT. For generate-test and procedural retrieval, on the other hand, it is because for TASK first conditions, Stage III priming may have effects equivalent to TASK repetition. Thus, it is not surprising that the data are ambiguous on this point.

A somewhat weaker argument about the effect of TASK repetition in the context of a non-repeated ITEM can be derived from ITEM first data. The issue is whether the observed facilitation should be attributed to the encoding or retrieval stages. Recall that one reason for attributing TASK facilitation to the retrieval stage was based on a subtractive argument. This argument required the assumption that ITEM facilitation (i.e. Contrast 1) in TASK first conditions can be used as an upper bound estimate of encoding repetition effects. Then, that TASK facilitation (i.e. Contrasts 4 and 5) in ITEM first conditions exceeds ITEM facilitation in TASK first conditions, can be taken as support of the retrieval stage hypothesis. However, as mentioned in Chapter IV, the necessary assumption for this argument is of questionable status for repetition effects in the context of a non-repeated second stimulus.

A second reason for attributing the TASK facilitation to the retrieval stage was based on an additive factors argument. This argument required the assumption that variability over TASKS is due to retrieval rather than encoding differences. Then, that TASK facilitation (i.e. Contrasts 4 and 5) in ITEM first conditions varies over TASKS, can be taken as support of the retrieval stage hypothesis. In this case, the necessary assumption seems well-founded because there is TASK variability in TASK first conditions (which do not involve TASK encoding time) for both ITEM repetition Contrast 2 and TASK repetition Contrasts 4-7. For this reason, and because of the consistent and stable non-additivity of ITEM and TASK repetition effects as tested by Contrast 8, the previous conclusion is sound. Specifically, TASK repetition effects in the context of non-repeated ITEMS for ITEM first conditions should be attributed, at least in part, to the retrieval stage.

It is possible, however, that the retrieval effect is interference, but is masked by a large encoding facilitation effect. Counter evidence for this possibility is provided by the lack of an ORDER effect in Contrast 2 in every experiment and in Contrast 1 in two out of four experiments. That is, if the conditions of these experiments were sensitive to large encoding effects, ITEM facilitation for the TASK first but not

ITEM first conditions would be expected. The lack of such a pattern of results indicates that encoding facilitation is not important in the present experiments. Therefore, the conclusion of retrieval stage TASK facilitation in the context of non-repeated ITEMS holds firm.

This conclusion provides further counter evidence concerning intersection retrieval which predicts the opposite effect. While it is compatible with generate-test retrieval, that class of processes was rejectable on the basis of an incorrect, but fundamental, prediction about the ORDER main effect. Thus, upon closer analysis, and considering the data from all experiments, the previous conclusion in favor of procedural retrieval seems well-founded. Also, the counter evidence concerning purely associative retrieval processes was shown to hold for a broader class of models than considered in Chapter IV.

Procedural retrieval. The remaining task is to determine what additional information about procedural retrieval can be derived from the present experiments. Three aspects of the data should be useful--the nature of main effect and repetition differences among TASKS, the nature of the non-additivity of ITEM and RESPONSE repetition, and the fact that Stage III processing apparently masks TASK facilitation in the context of non-repeated ITEMS.

Systematic differences in patterns of RTs among TASKS of the present experiments may help refine the notion of isolable LTM procedures. First, it is interesting to note that mean RT is positively correlated to an overall measure of TASK repetition[2] (r=.80, p<.01).

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[2] The overall measure of TASK repetition was the mean of Contrasts 4 and 7, the two repetition contrasts computable for all TASKS.

However, there are violations of this relationship both within and between experiments. Second, as can be seen in Table 32, the RESPONSE set size dimension introduced in Table 31 is neither a good predictor of mean RT ($\underline{r}$=.12, $\underline{p}$ >.05), nor of TASK facilitation ($\underline{r}$=-.12, $\underline{p}$ >.05). In fact, the only systematic conclusion which is obvious from these data is that both mean RT and TASK facilitation are consistently smaller for lexical than semantic TASKS (mean RTs equal 676 and 931 msec for lexical and semantic TASKS respectively; mean TASK facilitation equals 16 and 50 msec for lexical and semantic TASKS respectively). Third, it is important to note that the TASK effects are context dependent. For example, the COLOR TASK was used in three experiments and mean RT varied from 707 msec in Experiment I to 820 msec in Experiment II, while mean TASK facilitation varied from 9 msec in Experiment II to 41 msec in Experiment I. Given the systematic effects obtained from finer grain TASK sequencing analyses of non-repeated TASK trials, this result is not surprising. Finally, it is suggested that more detailed analysis of specific TASKS may lead to a better understanding of procedural retrieval. Such an analysis was attempted in the context of Experiments III and IV, and several additional points about the SYLLABLE TASK of Experiments I and II will be mentioned in Appendix A.

The nature of interactive effects between ITEM and TASK repetition also provide some insight about the nature of LTM procedures. The relevant finding is that TASK facilitation was larger in the context of repeated than non-repeated ITEMS. That this effect was constant over ORDER suggests that it cannot be explained in terms of encoding facilita-

Table 32

Mean RT and TASK Repetition Effects as a Function
of RESPONSE Set Size of TASKS
(Over Experiments)

TASK	EXPERIMENT I		EXPERIMENT II		EXPERIMENT III		EXPERIMENT IV	
	RT	REP	RT	REP	RT	REP	RT	REP
NAME	---	--	655	40	681	17	---	--
SECOND	---	--	---	--	---	--	692	6
FIRST	---	--	---	--	---	--	633	24
PROPERTY	---	--	---	--	1133	67	---	--
INSTANCE	---	--	---	--	1156	85	---	--
CATEGORY	---	--	902	28	1102	101	---	--
COLOR	707	41	820	9	---	--	796	20
SIZE	---	--	---	--	---	--	831	39
SYLLABLES	680	16	715	-13	---	--	---	--

tion of the ITEM which would only be expected in TASK first conditions of trials with repeated ITEMS and TASKS. The alternative suggestion offered here is that TASK facilitation includes both ITEM independent and dependent components. The former may be thought of as a general increase in accessibility or computability of the TASK procedure, while the latter may be thought of as parameter tuning. Clearly, further work is required to verify this notion. However, one encouraging source of support, available in the present data, is the effect ORDER has on TASK repetition. Specifically, Stage III processing which occurs in TASK first, but not ITEM first conditions masks TASK facilitation in the context of a non-repeated ITEM. On the other hand, it reduces, but does not eliminate the effect in the context of a repeated ITEM. Such a pattern of results would be expected if Stage III processing is equivalent to the ITEM independent, but not ITEM dependent, processing, as seems likely.

To summarize, the results of the present experiments not only provide support for procedural retrieval, but also provide some useful information about isolable LTM procedures. Specifically, different TASK procedures require different amounts of processing time, are more or less susceptible to facilitation, and both of these effects are sensitive to the dynamic state of LTM which varies with recent processing. Also, both parameter independent and dependent components of these LTM procedures can be separately primed.

An implicit assumption in the present discussion has been that the TASK procedures used by subjects when faced with the present experimental paradigm, are part of their semantic representations of the TASK concepts. This may not be correct. Rather, in unnatural laboratory conditions, subjects may compile temporary procedures solely for use in the experiment. However, it is suggested that even if this is correct, it tells us something interesting about cognitive processing. Specifically, human beings have the capacity to establish isolable retrieval processes which can be used, when appropriately cued, to retrieve an entire class of facts. Further, it is suggested that aspects of the present data indicate that semantic memory should, at least in part, be implicated for the present findings. The systematic variability in TASK main and repetition effects indicate that the procedures being used in these experiments have a semantic component. This was especially clear in Experiment III where TASK sequencing effects were explained in terms of the semantic relationship among TASKS. Thus, the present position is that the procedural retrieval notion supported in the present experiments leads to a particular orientation toward structural issues, and may be richer than that provided by alternative processing notions. An attempt to elaborate on this and integrate the structure and processing results obtained in these experiments follows.

LTM Structure and Process

In the introductory chapter of this dissertation it was argued that viewing LTM as a network, a basically associative structure, was useful. However, the present experiments seem to consistently point to inadequacies of purely associative notions about memory. While the multi-layered hypothesis was supported, associative versions were inadequate. Likewise, associative notions about how relational information is used in retrieving information from LTM were also rejectable. In fact, a fairly broad class of purely associative retrieval processes encompassed by intersection and generate-test models failed to capture the results of the present experiments.

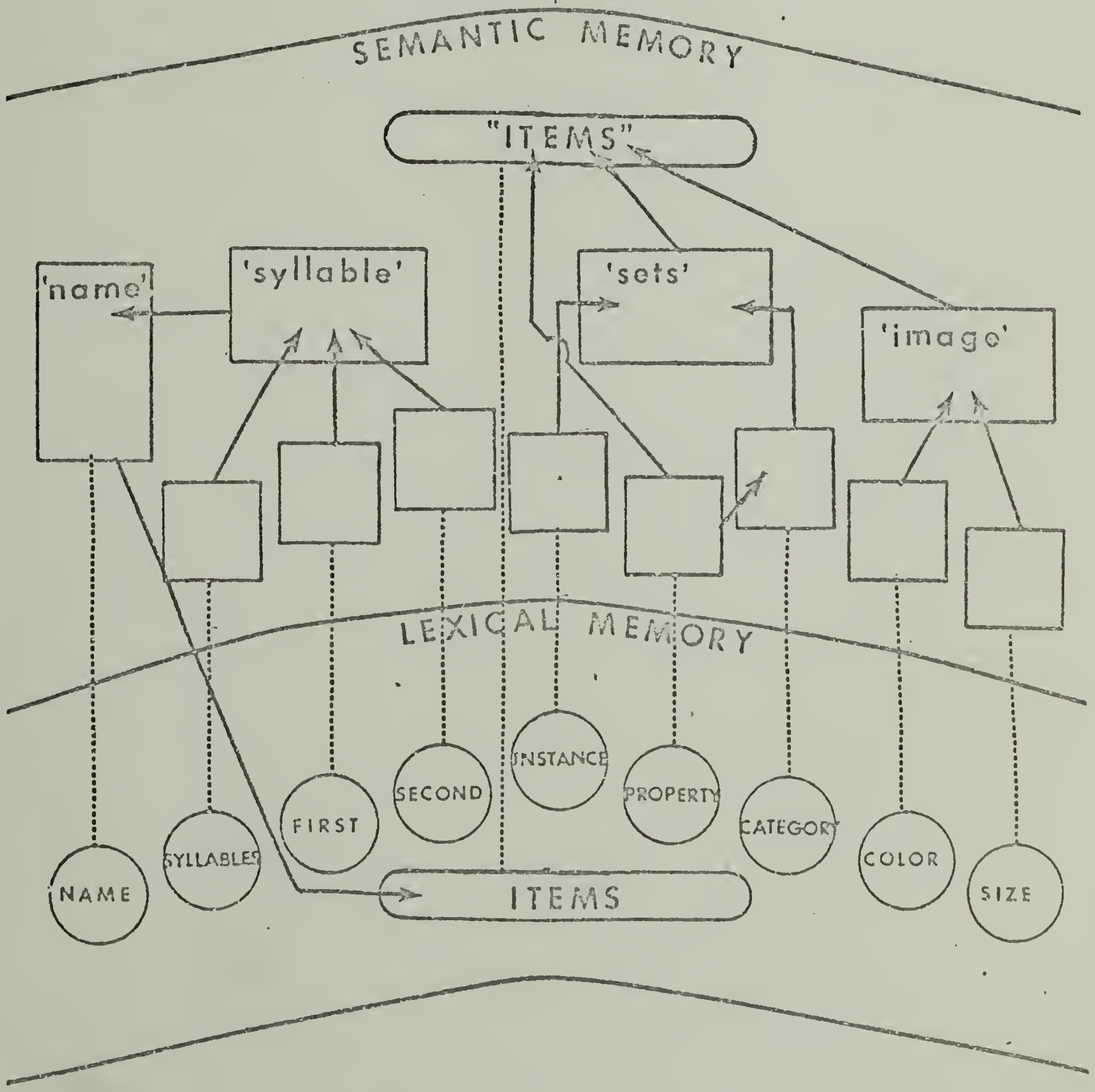
A second point made in Chapter I was that in addition to its associative nature, LTM exhibits a fundamentally constructive property. To the extent that purely associative notions were inadequate to explain the results of the present experiments, they demonstrated some ways this constructive property plays a role in very simple LTM retrieval. A third point expressed in Chapter I was that both the associative and constructive nature of LTM could be captured in a network theory. The remaining challenge is to integrate the constraints imposed by the present results into a broader view of LTM, and thereby come one step closer to that objective.

A post hoc description of procedurally oriented LTM which is consistent with both the results of these experiments and the biases expressed in their interpretation will be presented. First the structure of this memory will be described, along with processes necessary to accomplish the experimental TASKS. Then, how the memory accounts for the major results of these experiments will be outlined.

Figure 17 pictorially presents a segment of LTM which should be adequate to complete any of the experimental TASKS. Lexical memory contains a node for each TASK and ITEM word. The ITEMS are grouped

Figure 17

Procedurally Oriented LTM



together to simplify the figure; however, a fully elaborated drawing would have separate lexical nodes for each ITEM. These lexical nodes are assumed to conserve information about words. In the context of the present experiments NAME, number of SYLLABLES, and FIRST and SECOND syllable of each word can be derived from lexical memory. Associations among lexical nodes are assumed to be phomenic and/or orthographic. There is also an association relating each lexical node to at least one semantic node. In the case of TASK words semantic nodes are pictorially represented in Figure 17 as procedure boxes. As in lexical memory, the semantic representation of ITEM words are grouped together only for economy in the figure.

While we are still a long way from understanding the nature of semantic representations of concepts, several points can be made. First, as stated in Chapter II, these nodes can be thought of as points of intersection among token occurrences of concepts. The token representations are not included in Figure 17, but as previously outlined, are assumed to be represented declaratively (i.e. in propositions) in episodic memory with pointers to semantic nodes. Second, semantic nodes are also the point of intersection among conceptual associations. Thus, meaning is abstracted from experience and from direct semantic associations. Third, the present suggestion is that at least some concepts have additional semantic knowledge which is procedurally represented and allows them to derive classes of information from other parts of LTM.

In terms of the present representation, encoding a word can be defined as making contact with its lexical representation. Also, two types of retrieval processing can be defined. First, associative retrieval involves traversing associative pathways in the LTM network, both within and between memory layers. Second, procedural retrieval is a special type of process available to some semantic concepts. In terms of Figure 17, it involves traversing solid control structure lines between procedure boxes. While it is useful to think of associative retrieval in terms of traversing arcs in the LTM network, it may be more appropriate to think of procedural retrieval in terms of parameter-dependent subroutine calls. Finally, the strength assumptions presented in the introduction serve to make this LTM network dynamic and context dependent. Specifically, both associative and procedural processing times are assumed to be a function of current relative strength of associations and procedures respectively. Further, recently processed associations and procedures, and their LTM neighbors, are in temporary high strength states following use.

The particular hierarchy of procedures and control structure presented in Figure 17 was derived from analysis of the TASKS and results of the present experiments. The NAME procedure is the only one which directly accesses lexical representations of ITEM words. The procedures associated with other lexical TASKS--SYLLABLE, FIRST, and SECOND--indirectly access the lexicon through the NAME procedure. An additional higher order "SYLLABLE" procedure was included to capture the fact that the three non-NAME lexical TASKS used here all dealt with syllable information about ITEMS; presumably other lexical TASKS would not use this higher order procedure. The semantic TASKS used in these experiments form two groups. The CATEGORY, INSTANCE, and PROPERTY TASKS of Experiment III deal with non-physical aspects of the concepts, and have a well-specified internal structure, as discussed in the context of that experiment and diagramed in Figure 14. The COLOR and SIZE TASKS of Experiment IV, on the other hand, deal with physical properties of the concepts, and as such are hypothesized to access semantic representations of ITEMS through a higher order IMAGE procedure.

Since this model is a special case of the procedural retrieval model presented in Figure 8, predictions derived for that model and summarized in Table 6, hold here. Specifically, the procedurally directed retrieval model predicts TASK first subjects to be faster than ITEM first subjects, as observed. It also makes strong predictions about TASK facilitation which are consistent with the data. In addition, TASK main, repetition, and sequencing effects can be interpreted in terms of this model. First, the ordering of TASK RT, summarized in Table 32 can, at least in part, be accounted for. NAME times are fastest since they require a single computation which accesses the same ITEM representation used in encoding. Other lexical TASKS are fast relative to semantic TASKS because while additional computation is required for both types of TASKS, the semantic representation of the ITEM must be accessed for semantic but not lexical TASKS. Second, like many other models, it is reasonable to assume that processes which require more processing are more benefited by repetition. Therefore, as observed we might expect a positive correlation between TASK RT and TASK repetition effects.

Third, a property unique to a procedurally oriented LTM is that TASK sequencing effects can be explained in terms of overlap of procedures. Thus, we find lexical facilitation because all lexical TASKS use the NAME procedure. The effect is larger in Experiment IV than in Experiment II because the FIRST and SECOND TASK share the higher order "SYLLABLE" procedure as well. Further, the particular pattern of semantic interference observed in Experiment III was already explained in terms of the relationship among CATEGORY, INSTANCE, and PROPERTY procedures (see Figure 14). Likewise, the possible semantic facilitation observed in Experiment IV was explained in terms of the common use of a higher level "IMAGE" procedure by both COLOR and SIZE procedures (see Figure 16). Semantic interference in Experiment II, on the other hand, might be expected because while there are no common procedures between CATEGORY and COLOR TASKS, there might be procedural or associative interference.

The present conceptualizations might also explain why these TASK sequencing effects were not contingent upon repetition of the ITEM. Specifically, on the basis of TASK repetition data (i.e. Contrasts 4 and 5) it was previously concluded that there is an ITEM independent component of TASK facilitation. Therefore, TASK sequencing effects should also be expected in the context of non-repeated ITEMS. However, the TASK repetition data indicated that there is additional ITEM dependent TASK facilitation as well (i.e. Contrast 8 was negative). Therefore, we should expect larger TASK sequencing effects in the context of repeated than non-repeated ITEMS; however, there was no clear evidence of this. Since the overall TASK sequencing effect for pairs of successive trials with different TASKS was so small, it is not surprising that the two components (i.e. ITEM independent and dependent facilitation) were not separable as they were for the somewhat larger TASK repetition effects. Nevertheless, it is a point which merits further consideration in the context of a generally acceptable model.

In conclusion, the ideas explored in this dissertation are not particularly new. Both the notions of multiple-layers of representations of knowledge and of procedural retrieval probably have roots in Greek epistomology and certainly have been entertained by modern psychologists and computer scientists. What may be a contribution in the present work is that particular realizations of these notions, albeit simplistic, have been defined in terms of experimental expectations, and contrasted with alternative notions about LTM structure and process. The ideas supported by the present experiments, however, are clearly in need of further refinement. Perhaps the most exciting aspect of the human mind is that exploring one question always leads to a plethora of other questions.

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APPENDIX A

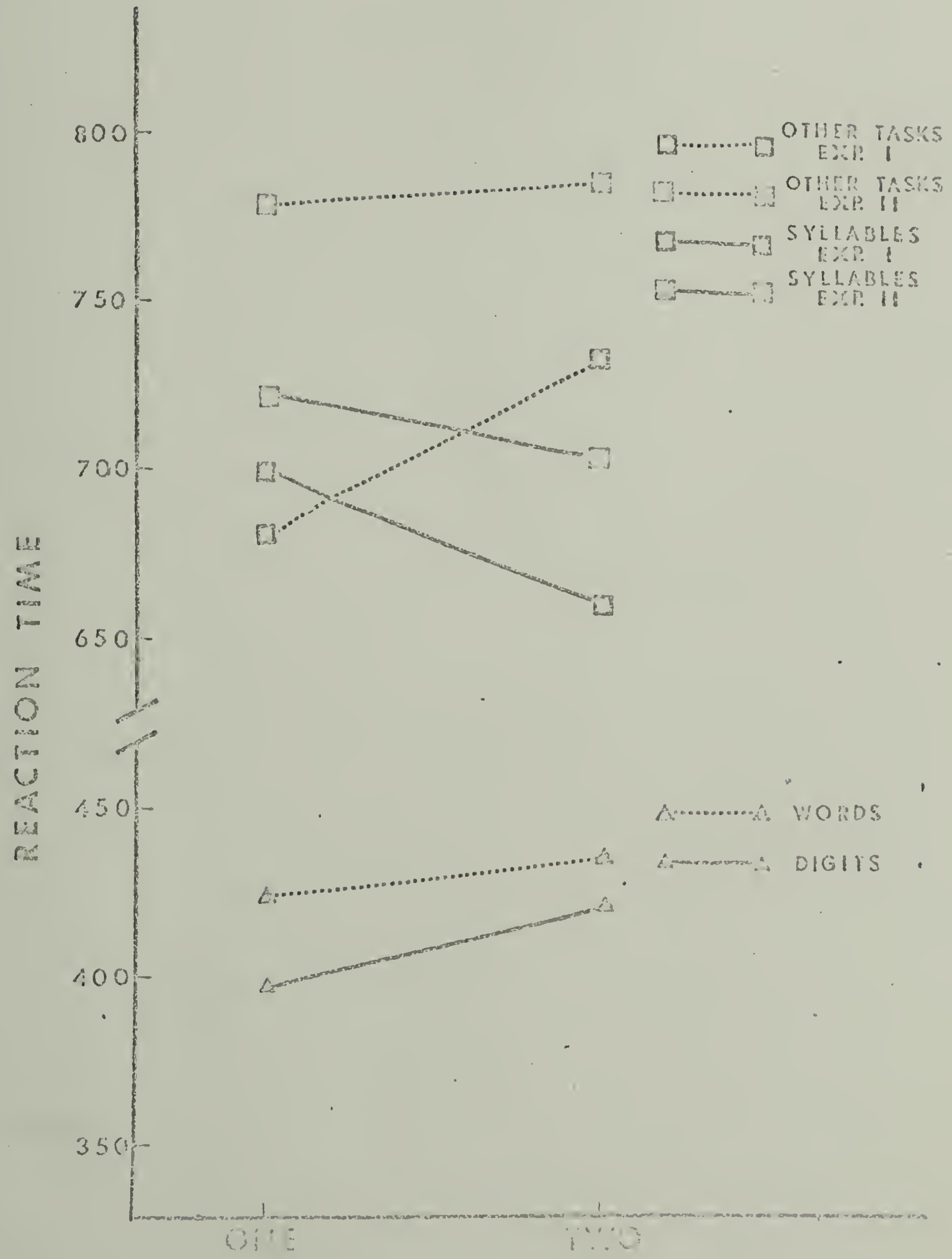
One More Bit of Data: Analysis of the SYLLABLE TASK

The SYLLABLE TASK used in Experiments I and II seems especially well-suited for further considering the nature of the LTM procedures used to generate classes of RESPONSES. In particular, one possibility is that a counting process derives number of SYLLABLES from a lexical representation of the ITEM NAME. Such a notion predicts that retrieval time should be longer for SYLLABLE trials with two rather than one SYLLABLE ITEMS. However, as can be seen in Figure 18, in both experiments mean RTs were ordered in the opposite direction (mean SYLLABLE RTs equal 700 and 661 msec for one and two SYLLABLE ITEMS respectively in Experiment I, $\underline{F}(1,66)=59.79$, $\underline{p} <.01$; and 722 and 707 msec for one and two SYLLABLE ITEMS respectively in Experiment II, $\underline{F}(1,46) <1.00$). Before speculating on the type of LTM procedure which would take longer to decide that a word has one than two SYLLABLES, we must reject the possibilities that these RT differences are attributable to encoding or response execution stage effects. By the former explanation, it simply takes longer to encode one than two SYLLABLE ITEMS; by the latter explanation, it simply takes longer to say "ONE" than "TWO".

Two sources of evidence lead to rejection of an encoding explanation of the SYLLABLE effect. In fact, they indicate that encoding time is longer for two than one SYLLABLE ITEMS. First, as can be seen in Figure 18, in both Experiments I and II RT for non-SYLLABLE TASKS (i.e. COLOR in Experiment I and NAME, CATEGORY, and COLOR in Experiment II) was longer for two than one SYLLABLE ITEMS (mean other-TASK RTs equal 680 and 734 msec for one and two SYLLABLE ITEMS respectively in Experi-

Figure 18

SYLLABLE RT



ment I, $F(1,66)=110.82$, $p<.01$; and 779 and 788 msec for one and two SYLLABLE ITEMS respectively in Experiment II, $F(1,46)=6.74$, $p<.01$). Second, the shorter RT for two than one SYLLABLE ITEMS for SYLLABLE trials was more marked for ITEM first conditions (which do not include ITEM encoding time) than for TASK first conditions (mean SYLLABLE effects equal 8 and 69 msec for O(T-I) and O(I-T) respectively in Experiment I, $F(1,66)=35.96$, $p<.01$; and 5 and 36 msec for O(T-I) and O(I-T) respectively in Experiment II, $F(1,46)=25.98$, $p<.01$).

The interacting effect of number of SYLLABLES and ORDER on SYLLABLE RT discredits a response execution stage explanation as well. However, additional data were collected to directly test the hypothesis that it simply takes more time to say "ONE" than "TWO". Twelve subjects gave four blocks of 48 trials on RT data. The experimental situation was very similar to that used in Experiments I-IV. One difference, however, was that all trials involved READING one of four stimuli; therefore, no TASK word was presented. In addition, in this experiment the minimum intertrial interval was one second, whereas in previous experiments it was 3.5 seconds. Also, here RTs less than 100 or greater than 1000 msec were excluded from analyses. The four stimuli were "ONE", "TWO", "1", and "2".

If RT differences in the SYLLABLE TASK of Experiments I and II are attributable to response execution differences, RT in the present experiment should be longer to "ONE" and "1" than to "TWO" and "2". As can be seen in Figure 18, the opposite was true ($F(1,11)=8.06$, $p<.05$). Further, while word trials took longer than digit trials (F 1,11)=29.09,

$\underline{p} < .01$), the number effect held for both types of code. In fact, the lack of a significant interaction between number and code ($\underline{F}(1,11)=3.69$, $\underline{p} > .05$) provides evidence that the present result should not be attributed to encoding effects.

To summarize, it was hypothesized that the SYLLABLE procedure might involve a counting process which derives number of SYLLABLES from a NAME code. Such an hypothesis predicts longer SYLLABLE RT for two than one SYLLABLE ITEMS. However, the observed RTs from Experiments I and II were opposite this prediction. Further, the longer RTs for one than two SYLLABLE ITEMS must be attributed to the retrieval stage because: (1) it takes longer to encode two than one SYLLABLE ITEMS; and (2) it takes longer to execute the verbal RESPONSE "TWO" than "ONE".

Two properties of ITEM words used in Experiments I and II may explain this counter-intuitive result. First, each SYLLABLE was an average of 4.1 letters for one SYLLABLE ITEMS, but only 2.8 letters for two SYLLABLE ITEMS. Second, the individual SYLLABLES were less common for one than two SYLLABLE ITEMS. These two facts suggest that individual SYLLABLES were more accessible for two than one SYLLABLE ITEMS. Thus, the present suggestion is that the SYLLABLE procedure involves a counting process, but time to count a SYLLABLE depends upon its accessibility. That is, procedural retrieval time is sensitive to properties of the ITEM which information is being derived about, as well as TASK demands. This conclusion is consistent with the previous conclusion that both ITEM independent and dependent repetition effects influence retrieval.