

ENCODING SPECIFICITY AND RETRIEVAL PROCESSES IN EPISODIC MEMORY¹

ENDEL TULVING²

AND

DONALD M. THOMSON

*Yale University and University of Toronto,
Toronto, Canada*

Monash University, Clayton, Victoria, Australia

Recent changes in pretheoretical orientation toward problems of human memory have brought with them a concern with retrieval processes, and a number of early versions of theories of retrieval have been constructed. This paper describes and evaluates explanations offered by these theories to account for the effect of extralist cuing, facilitation of recall of list items by non-list items. Experiments designed to test the currently most popular theory of retrieval, the generation-recognition theory, yielded results incompatible not only with generation-recognition models, but most other theories as well: under certain conditions subjects consistently failed to recognize many recallable list words. Several tentative explanations of this phenomenon of recognition failure were subsumed under the encoding specificity principle according to which the memory trace of an event and hence the properties of effective retrieval cue are determined by the specific encoding operations performed by the system on the input stimuli.

The current transition from traditional associationism to information processing and organizational points of view about human memory manifests itself in many ways. One of the clearest signs of change has to do with the experimental and theoretical separation between storage and retrieval processes. In an important early paper, Melton (1963), for instance, pointed out that "the principal issues in theory of memory . . . are about either the storage or the retrieval of traces [p. 4]." Only 10 years before Melton made the statement, it would have puzzled most students of verbal learning. At that time memory was still a matter of acquisition, retention, transfer, and interference of associations between stimuli and responses. While everyone was aware of the logical distinction between acquisition and retention on the one hand and retention and recall on the other hand, these distinctions shaped

neither experiment nor theory. At the level of conceptual analysis, the mechanism of recall was included in the concept of association; at the level of experimental operations, recall was observable behavior whose measurable aspects simply served to provide evidence about strength of associations. Moreover, the act of recall was empirically neutral in that it did not affect the state of the system; it was theoretically uninteresting because it could not be studied independently of acquisition.

The last 10 or 15 years have changed the ideational framework for studying memory. Today the orienting attitudes clearly include the notion that both recall and recognition are more or less complex retrieval operations or processes that can be studied and analyzed in some sense separately of storage operations or processes. Retrieval operations complete the act of remembering that begins with encoding of information about an event into the memory store. Thus, remembering is regarded as a joint product of information stored in the past and information present in the immediate cognitive environment of the rememberer. It is also becoming increasingly clear that remembering does not involve a mere activation of the learned association or arousal of the stored trace by a stimulus. Some sort of a more complex in-

¹ This research was supported by the National Science Foundation Grant 24171X.

The paper was written during the first author's residence as a Fellow at the Center for Advanced Study in the Behavioral Sciences in Stanford, California.

² Requests for reprints should be sent to Endel Tulving, either at Department of Psychology, Yale University, New Haven, Connecticut 06510 or at the Department of Psychology, University of Toronto, Toronto M5S 1A1, Canada.

teraction between stored information and certain features of the retrieval environment seems to be involved in converting a potential memory into conscious awareness of the original event and corresponding behavior.

Relations between the effects of the past and present inputs and the interaction of the memory trace with the retrieval environment constitute the domain of theories of retrieval. Although the important issues are not yet entirely clear, many questions do seem to be central to the understanding of retrieval processes and are likely to come more directly under experimental and theoretical scrutiny. What, for instance, determines the high degree of selectivity of retrieval, the fact that at any given moment a person can only remember one discrete event? Is the output mode of the memory system different from the input mode? Can information be retrieved at the same time that some other information is stored, or does storage always involve retrieval, and retrieval storage? How do we conceptualize the nature of the effect of a retrieval cue on stored information? Does it activate the trace, does it elicit it directly or indirectly, does it provide access to it, does it restrict the size of the search set, does it somehow complement the information contained in the trace, or what? Is there a fundamental difference between recall and recognition, or do these two retrieval operations differ only in terms of the nature of retrieval cues present at output? What controls retrieval in a situation in which no specific cues seem to be present, such as in free recall? What makes some stimuli effective cues for retrieval of a given event and others not?

Since the separation of the total act of remembering into storage and retrieval processes has only recently been translated into experimental observations and theoretical speculations, there are as yet no theories of retrieval that provide satisfactory answers to these and many other possible questions one might want to ask. The development of these theories is one of the important objectives of research on memory. But a modest beginning has been made, and it is the purpose of the present paper to examine and describe the early state of the art.

In the first part of the paper, we describe a familiar phenomenon that has recently been brought into the laboratory and that has become the source of a minor theoretical controversy. This is the so-called extralist cuing effect, facilitation of recall of a list item by a retrieval cue that was not explicitly a part of the input list. We summarize and briefly evaluate seven theories that have been advanced to explain the effect. In the second major section of the paper, we present some new data from experiments that were initially designed to test the most popular and widely accepted explanation of the extralist cuing effect, the generation-recognition theory. Somewhat unexpectedly, the results of the experiments showed large superiority of recall over recognition, a state of affairs that cannot occur according to the generation-recognition theory as well as most other extant theories of retrieval. In the third and final section, we consider several possible interpretations of the new data and subsume them, together with other data already in the literature, under the encoding specificity principle: What is stored is determined by what is perceived and how it is encoded, and what is stored determines what retrieval cues are effective in providing access to what is stored.

The present analysis applies to memory for simple events of the kind frequently used in laboratory studies. A familiar word or some other object is presented as a member of an unfamiliar collection or list, and the subject's task is to remember that he saw that particular word or object in that particular list in that particular situation. In such a list-item task, the subject may be instructed to retrieve the whole set of presented items, some particular subset thereof, or a single item. At the time of retrieval, he is given general instructions as to the set or subset of items to be retrieved, and sometimes the instructions are supplemented with specific cues. The cues may be units of material that were presented as a part of the input list (inralist cues). They may also be items not explicitly present at the time of the study (extralist cues). An inralist cue to aid retrieval of List Item B may be another List Item A, or it may be

a literal copy of the Target Item B. In the former case, it is customary to refer to the subject's task as that of cued recall; in the latter we say that the task is one of recognition. (Despite the apparent differences in the nature of these two kinds of cues, we assume that the processes involved are essentially the same in both cases, and we make no theoretical distinction between recall and recognition. The subject's task is the same in both cases, namely to utilize the information provided in the retrieval environment to select some specific stored information.)

The paper is about retrieval processes in episodic rather than semantic memory. The distinction between these two memory systems has been described in detail elsewhere (Tulving, 1972). It forms part of the general background of the present analysis. Briefly, episodic memory is concerned with storage and retrieval of temporally dated, spatially located, and personally experienced events or episodes, and temporal-spatial relations among such events. Appearance of a word in a to-be-remembered list in an experimental task is such an event. (In typical laboratory experiments the spatial coordinates of events to be remembered are held constant, hence the focus on their temporal dates and relations only.) Semantic memory is the system concerned with storage and utilization of knowledge about words and concepts, their properties, and interrelations. Thus, episodic information about a word refers to information about the event of which the word is the focal element, or one of the focal elements, while semantic information about a word is entirely independent of the word's occurrence in a particular situation or its temporal co-occurrence with some other words.

We agree with the widely held pretheoretical assumption that the central representation of the to-be-remembered event, the memory trace, is a multidimensional collection of elements, features, or attributes (e.g., Bower, 1967; Norman & Rumelhart, 1970; Posner & Warren, 1972; Underwood, 1969; Wickens, 1970). We also assume, along with many other contemporary students of memory (e.g., Bower, 1967, 1972; Martin, 1968, 1972; Melton & Martin, 1972;

Underwood, 1969, 1972; Wickens, 1970) that an encoding process intervenes between the perception of an event and the creation of the corresponding trace, a process of as yet unknown nature that converts the stimulus energy into mnemonic information. The concern with retrieval processes in the present paper necessarily means that we must take an interest in the nature of stored information and in conditions determining the format of this information, that is, in encoding processes. It makes little sense to talk about retrieval without knowing something, or at least making some assumptions, about what it is that is being retrieved.

One term that we will use rather frequently in the paper is "effectiveness of retrieval cues." By this we mean the probability of recall of the target item in the presence of a discretely identifiable retrieval cue. Effectiveness, as thus defined, can always be expressed in absolute terms, but for certain reasons it is more convenient to describe the effectiveness of any specific cue in relation to the basic reference level of retrieval observed in absence of any specific cues. An effective cue, in this sense, is one whose presence facilitates recall in comparison with free or nominally noncued recall.³

EFFECTIVENESS OF EXTRALIST RETRIEVAL CUES: SEVEN THEORIES

Effectiveness of extralist cues as an empirical phenomenon is well documented. An early experiment by Postman, Adams, and Phillips (1955), experiments by Bilodeau and his associates (e.g., Bilodeau, 1967; Bilodeau & Blick, 1965; Fox, Blick, & Bilodeau, 1964), as well as an experiment

³ Subjects may retrieve items through schemes other than those suggested by the experimenter, and match the item to the cue after retrieval has occurred. Such cases could distort and inflate the absolute measures of effectiveness, and this is why measures relative to the noncued base line are preferred. One can then talk about inhibiting effects of specific cues, although it only means that cues assumed to be present in the nominally noncued situation are more effective in absolute terms than those the subject attempts to use at the experimenter's request (e.g., Earhard, 1969; Postman, Adams, & Phillips, 1955; Slamecka, 1969).

of Bahrick's (1969) have all shown that strong extraexperimental associates of list items, when presented to the subject as recall aids, increase the probability of correct responses. Names of conceptual categories of list words as extralist cues have been used by Hudson and Austin (1970), Tulving and Psotka (1971), and Wood (1967). Light (1972) has shown that homonyms and synonyms facilitate recall of list words. Greater effectiveness of two than of one associative extralist cue has been reported by McLeod, Williams, and Broadbent (1971). In a continuous study-test paradigm, Bregman (1968) studied the effectiveness of semantic, phonetic, and graphemic cues at different retention intervals. Finally, extralist associates have been shown to be effective cues when the subject expects a free-recall test but not when he expects to be tested for list words with other cues (Thomson & Tulving, 1970).

We can identify at least seven theories of retrieval that have been or could be proposed to account for the effectiveness of extralist cues, provided that we use the term "theory" in the sense of its most modest dictionary meaning, as "an idea or a set of ideas about something."

To make the discussion a bit simpler, we occasionally use a concrete example in lieu of more general and abstract terminology. In this example, CHAIR is one of the word events that is presented for study, and *table*, a word not shown in the input list, serves as an effective retrieval cue. The question to be answered then is this: Why does *table* facilitate the recall of CHAIR as the target word?

Guessing from Semantic Memory

Even if the subject does not have the foggiest notion that CHAIR occurred in the list—the stored information has been completely wiped out, or he never saw the word in the list—he can, if he chooses to guess, or is so instructed by the experimenter (e.g., Bahrick, 1969; Fox, Blick, & Bilodeau, 1964; Freund & Underwood, 1970), boost the correspondence between the input list and his output protocol by thinking of and

producing words semantically related to the cue word *table* and thus create the appearance of recalling the specific word event from the list.

Although the possibility of semantic guessing is sometimes mentioned in connection with the interpretation of extralist cuing effects (e.g., Freund & Underwood, 1970), and although it is difficult to deny that some subjects in some episodic memory experiments may utilize information from semantic memory only, the theory cannot be taken seriously for at least two reasons. First, subjects on their own seldom resort to the strategy of semantic guessing in an episodic memory task, as evidenced by the fact that in most extralist cuing experiments a large majority of recall errors consists of plain omissions. Second, the magnitude of cuing effects is usually (a) considerably greater than one could expect on the basis of guessing from semantic memory, regardless of what strategy the subject might follow in such guessing, and (b) independent of, or even inversely related to, the probability of choosing the correct response on the basis of semantic information alone (e.g., Bahrick, 1969; McLeod et al., 1971).

Convergence of Episodic and Semantic Associations

Some theorists are not interested in subjects' memories for particular events but rather in changes in probabilities of particular responses. One might say they are not interested in memory but in learning. In their pretheoretical scheme of things, Word A is identical with Word A, regardless of the situations in which they occur. For instance, "chair" as a response indicating memory for a particular word event in an experimental task and "chair" as a response to the word *table* in the free-association test are lumped together into the same response class. The changes in the probability of emission of responses of this class then constitute behavioral happenings of experimental and theoretical interest.

Given this type of orienting framework, the following simple explanation of extralist cuing effects can be and has been advocated.

A semantic association exists between *table* and CHAIR prior to the experiment. Another association is created between CHAIR, or the corresponding response, and the general contextual stimuli present in the experiment. In the noncued recall test, only the contextual association is reactivated, while in the cued test both the contextual association derived from the experimental input and the specific association with *table* originating outside the experiment converge upon the response CHAIR, producing a higher probability of the correct response in the cued situation.

Such a theory of convergence of experimental and extraexperimentally acquired associations has been proposed by Bilodeau and his associates (e.g., Bilodeau, 1967; Bilodeau & Blick, 1965) to account for their own observations in extralist cuing experiments. It tacitly assumes that the activation of the extraexperimental association between the cue and the target word at the time of recall is independent of what happened at the time of presentation of the target word for study. The demonstration that encoding operations performed on a target word affect the effectiveness of extralist cues would be incompatible with the theory. Such experimental findings are described later in this paper.

Increments in Trace Strength

A theory closely related to the idea of convergent associations holds that presentation of the cue at recall increases the trace strength of the target word, perhaps through the mechanism of elicitation of implicit associative responses. Many theorists assume that the trace of a word can be "strengthened" through repeated presentation of the word for study. They may also find it not too difficult to imagine that the target word could occur as an implicit associate to the cue at recall and that such a covert repetition of the target word would also "strengthen" the trace. Such cue-produced strengthening of originally subliminal traces might thus be responsible for the heightened recallability of target words in the cued test.

The theory of increased trace strength

differs from that of convergent associations principally in that it does not require the assumption that retrieval of CHAIR depends on associative connections between it and *table*, or between it and the experimental context. The theory can, therefore, be extended to recognition tests of trace "strength," in which the role of associative connections among items is thought to be minimal.

This theory has been considered by Broadbent (1973, p. 90) in a discussion of effectiveness of extralist retrieval cues and rejected on the basis of data from an unpublished study by Wingrove and Giddings showing lack of facilitative effect of extralist cues in recognition tests of target items. Similarly, data from earlier experiments of ours, designed to study the effect of context on recognition of list words (Thomson, 1972; Tulving & Thomson, 1971), showed that the presence of the cue word *table* inhibits recognition of the target word CHAIR if CHAIR occurred in the input list by itself, a finding quite contrary to the theory of increased trace strength.

Restricted Search Set

William James's rich legacy includes a colorful metaphor of retrieval as a search process:

We make search in our memory for a forgotten idea, just as we rummage our house for a lost object. In both cases we visit what seems to us the probable *neighborhood* of that which we miss. We turn over the things under which, or within which, or alongside of which, it may possibly be; and if it lies near them, it soon comes to view [James, 1890, p. 654].

Current conceptualizations of retrieval as search (e.g., Atkinson & Shiffrin, 1968; Norman, 1968; Shiffrin, 1970; Shiffrin & Atkinson, 1969; Yntema & Trask, 1963) have been as much influenced by the developments in computer technology as they have been by William James. These search theories reject the possibility that retrieval of information about the occurrence of any specific event entails the examination of the entire contents of memory. Rather, they assume that search for desired information always takes place in a more or less narrowly

circumscribed region of the memory store, the search set. In any given situation the size and nature of the search set is specified by the information available to the retrieval system at the beginning of the search, including specific retrieval cues, and it may be modified as search proceeds. In this scheme, an extralist retrieval cue, for reasons that we have already met in the previous theories, creates a search set more restricted than would otherwise be the case, and since the success of search is, other things being equal, an inverse function of the size of the search set, cued recall is higher than noncued recall.

Search-set theories assume that search sets are smaller in recognition than in recall tests. Probability that a learned item would be recognized, therefore, cannot be smaller than the probability of the item's recall. Experimental data inconsistent with this prediction of search theories are described below.

Generation-Recognition Models

At the present time the most widely accepted theories of retrieval are various versions of the generate-test model of information processing. The generation-recognition models assume that retrieval of stored information consists of two successive or overlapping stages: (a) implicit generation of possible response alternatives and (b) recognition of one of the generated alternatives as meeting certain criteria of acceptability. The generation phase is frequently guided by semantic information the system possesses about the cue word: given *table* as cue, the implicitly generated responses consist of words semantically related to it, including *CHAIR*. The operations in the recognition phase, on the other hand, can be successful only to the extent that relevant episodic information is available. The generated response alternative *CHAIR* would be identified as the desired word if its internal representation carries an appropriate "occurrence tag" (Mandler, 1972) or "list marker" (Anderson & Bower, 1972), information about the membership of the word in a particular list in a particular situation.

Effective retrieval cues of all sorts, including extralist cues, facilitate recall (to

follow the reasoning of generation-recognition models) because they reduce the probability that the desired information, although available in the memory store, cannot be found. Cued recall, in this view, produces a higher level of retrieval than does noncued recall for the same reason that recognition is higher than recall. Bahrck (1969), in one of the most explicit accounts of the workings of the generation-recognition mechanism, said that a cue or a prompt

is likely to produce a hierarchy of responses as a result of past learning. . . . One of these responses is likely to be the training response. *S* is thus unburdened of the search strategy involved in unaided recall tasks. He continues to produce responses associated with the prompt until he can identify one of them as the response presented during training. This portion of the prompted recall task functionally approximates a recognition task [Bahrck, p. 217].

In Bahrck's formal model (1970), the probability of recall of the target item in response to the extralist cue is the product of the probability of its implicit generation and the probability of its recognition.

Many other contemporary thinkers advocate, or at least approvingly mention, the generation-recognition model as an appropriate explanation of cuing effects (e.g., Bower, 1970; Bower, Clark, Lesgold, & Winzenz, 1969; Fox & Dahl, 1971; Kintsch, 1970; Murdock, in press; Norman, 1968; Shiffrin & Atkinson, 1969; Slamecka, 1972; Underwood, 1972). The terminology used by different theorists is not always the same, but the basic ideas are identical. For instance, Shiffrin and Atkinson (1969, p. 187) referred to the generation part of the process as search and recovery, and to the recognition phase as response generation. Underwood (1972) talked about response production and evaluation of the response for correctness "by the attributes used in making such recognition decisions [p. 11]" and Bower (1970), in explaining the effectiveness of rhyming cues, assumed that the subject implicitly generates "the plausible candidate-responses" among which "he needs only to recognize the one that has recently occurred in the list context [p. 22]."

Anderson and Bower's (1972) theory of recognition and retrieval processes deals with free recall, but it could be extended to cover extralist cuing effects without introducing any additional mechanisms. In this theory the generation of potential response items takes the form of activation of previously marked word nodes in an associative network, through pathways also appropriately marked during the presentation of the list. The marking of the pathway between the extralist cue node and the target node—a necessary condition for recall in the model—could be assumed to result from the attempt to link the target node to other list-item nodes in the input phase of the trial.

All versions of the generation-recognition theories subscribe to two closely related assumptions. One is the assumption of transsituational identity of words: every word has but a single representation in memory, or at most a few representations, corresponding to its dictionary meaning or meanings. Perception, encoding, or use of the word in any one of a wide variety of situations and contexts, including list-item experiments, leads to the kind of activation and modification of its internal representation that is thought of as the addition of a list marker or an occurrence tag.

The other assumption is that of "automatic access": long-term memory is a self-addressing storage system in which the location of each unit of information is determined by the nature and contents of the information (Kintsch, 1970; Norman, 1968; Shiffrin & Atkinson, 1969). When a to-be-remembered word is presented for study in a list-item task, its meaning and other properties determine into what part of the memory store it is entered. When the same word occurs again—as a repeated study item, as an implicit response generated by an associated cue word, as an "old" test item in the recognition test, or in some other way—automatic access to the same memory location takes place, permitting the system, among other things, to examine the location for the presence of previously stored episodic information.

The generation-recognition models pro-

vide plausible accounts of effects of extralist cues. They are also consistent with a large number of experimental results showing absence of differences in recognition of learned material between experimental conditions that do produce differences in recall (e.g., Kintsch, 1970; McCormack, 1972). But these models cannot handle situations in which an otherwise effective retrieval cue, such as *table*, fails to facilitate recall of a target item with which it is closely related semantically, such as *CHAIR*. They are also incompatible with findings showing recall to be higher than recognition. These kinds of data are described presently.

Mediation by Input-Generated Implicit Associative Responses

According to a widely accepted assumption, when a word is presented for study, it activates many existing associations (e.g., Underwood, 1965). For instance, when the to-be-remembered word *CHAIR* is presented for study, the implicit associative responses made to it include the word *table*. When at recall the word *table* is presented as a cue, it elicits the word *CHAIR*, and the backward version of the implicit associative response thus revived adds its strength to whatever other associations are elicited by general contextual stimuli responsible for the recall of *CHAIR* under noncued conditions. The theory is rather similar to the theory of convergent experimental and preexperimental associations, except that it makes the critical assumption of the necessity of the experimental updating of the preexperimental association.

This theory was mentioned as a possible explanation of extralist cuing results by Freund and Underwood (1970). Although these authors rejected it, since they thought their own data did not demonstrate a "true" extralist cuing effect, the theory is quite plausible within the framework of current associative views of memory. Indeed, Postman et al. (1955) interpreted their extralist cuing data along the lines of this theory, and it has been used to account for data from other kinds of experiments that are related to cuing studies (e.g., Cramer, 1970; Puff,

1966). The theory is also highly compatible with a well-known principle according to which probability of recall of an item is a direct function of the similarity between the recall situation and the original learning environment (e.g., Hollingworth, 1928; Melton, 1963).

Encoding Specificity Principle

The encoding specificity principle is the final idea about retrieval and extralist cuing effects we discuss. In its broadest form the principle asserts that only that can be retrieved that has been stored, and that how it can be retrieved depends on how it was stored. In its more restricted senses, the principle becomes less truistic and hence theoretically more interesting. For instance, we assume that what is stored about the occurrence of a word in an experimental list is information about the specific encoding of that word in that context in that situation. This information may or may not include the relation that the target word has with some other word in the semantic system. If it does, that other word may be an effective retrieval cue. If it does not, the other word cannot provide access to the stored information because its relation to the target word is not stored.

Thus, the effectiveness of retrieval cues depends on the properties of the trace of the word event in the episodic system. It is independent of the semantic properties of the word except insofar as these properties were encoded as a part of the trace of the event. The distinction between semantic characteristics of words as lexical units and words as to-be-remembered events can be readily demonstrated with homographs—for instance, if VIOLET is encoded and stored as a color name, it normally cannot be retrieved as an instance of the category of flowers, or girls' names—but the same principle presumably holds for all verbal items. The cue *table* facilitates recall of the target word CHAIR if the original encoding of CHAIR as a to-be-remembered word included semantic information of the kind that defines the relation between two objects in the same conceptual category. Most intelligent subjects in episodic memory experiments rou-

tinely encode to-be-remembered words semantically, and hence words meaningfully related to target items will serve as effective retrieval cues.

A recent application of the encoding specificity principle to the interpretation of effectiveness of retrieval cues appeared in a study by Tulving and Osler (1968); one of its more interesting implications was explicitly tested in three experiments by Thomson and Tulving (1970); and its bearing on results from intralist cuing experiments has been discussed by Postman (1972). Since the principle asserts that it is the encoded trace of the target word rather than the characteristics of the target word in semantic memory that determines the effectiveness of extralist retrieval cues, as well as all other cues, it can be experimentally contrasted with theories that attribute the effectiveness of extralist cues to their preexperimental relations with target words. Such contrasts, however, are possible only under special conditions.

Logic of Experimental Comparison between Theories

The main difference between the generation-recognition models of retrieval and the encoding specificity principle that is subject to test lies in the encoding stage of an item's processing as the locus of the effect of cues. According to the generation-recognition models the encoding stage is not important, as long as it does not disturb the capacity of the extralist cue to produce the target item as an implicit response. According to the encoding specificity principle, the target item must be encoded in some sort of reference to the cue for the cue to be effective.

Both theories can account equally well for the finding that a given cue in fact is effective. Thus, for instance, if *table* does facilitate the recall of the target word CHAIR, it is possible that an implicit response "chair" was made to the cue at retrieval and subsequently recognized. It is also possible that the target CHAIR was semantically encoded at the time of presentation in a specific way that rendered the cue word *table* effective. Experiments in which specific encoding conditions

are unknown cannot provide critical data for evaluation of theories that differ in claims that they make about the importance of these conditions. Specific encoding operations performed on an input usually are not identifiable, but they can be experimentally manipulated through instructions and other means. Attempts to determine the nature of specific encoding operations in a particular situation through subjects' introspections (e.g., Light, 1972) are not likely to be any more successful than have been most other attempts to gain theoretical knowledge about mental processes from observations of this sort.

To contrast the encoding specificity principle with other theories, some experimental control over encoding of target items must be exercised. Thus, for instance, the target word CHAIR could be presented, and the subject induced to encode it in the specific context of another word such as *glue* that is semantically unrelated or only vaguely related to the otherwise effective cue word *table*. If CHAIR is encoded in relation to *glue*, it is less likely to be encoded at the same time in relation to *table*, and hence, according to the encoding specificity principle, the effectiveness of the extralist cue *table* should now be reduced. According to the generation-recognition models, on the other hand, the effectiveness of *table* as an extralist cue should not be impaired, as long as the semantic relation between *table* and CHAIR is intact.

The comparison of effectiveness of extralist cues under conditions in which the subjects were free to encode the target item in any way they wished and in which they were induced to encode the target item in the context of a specific list cue was undertaken by Thomson and Tulving (1970). Target words such as CHAIR were presented either alone or in the context of list cues such as *glue*, and the effectiveness of extralist cues such as *table* was observed under the two types of encoding condition. The results showed that extralist cues did facilitate recall of target words, but only if the target words appeared in the list as single items. In this case (Experiment II, Groups 1 and 3) cued recall was on the order of 70% as compared

with the values in the neighborhood of 45% in the nominally noncued test. Under the conditions in which the target word occurred at input with, and was presumably stored in some relation to another word (Experiment II, Groups 5 and 6), cuing with extralist cues resulted in a much lower recall level of some 23%. Noncued recall of target words encoded in presence of specific list cues (Experiment II, Group 4) was approximately 30%. These data seem to be more compatible with the encoding specificity principle than with the generation-recognition theory. It is not known, however, to what extent the pairing of target words with specific list cues at input may have reduced the capacity of extralist cues to produce targets as implicit responses, and therefore the results of the Thomson and Tulving experiment are not entirely unequivocal.

We next report data from three experiments in which the two phases of retrieval as envisioned by generation-recognition theories, generation and recognition, could be directly observed. The experiments were patterned after the Thomson and Tulving study, except that we did not test the effectiveness of extralist retrieval cues under conditions where target words were presented in absence of any specific intralist context. Previous experiments have made it quite clear that extralist associates of target words would be quite effective retrieval cues under these conditions. This kind of result, as we have seen, would not distinguish among theories.

WHEN RETRIEVAL CUES FAIL: THREE EXPERIMENTS

In the experiments to be described, subjects studied a list of target words, such as CHAIR, each presented in the company of a specific input cue, such as *glue*. Since the subjects expected to be tested with these cues, they presumably encoded target words in an appropriate relation to the input cue. After studying the list, the subjects were asked to produce free association responses to strong extraexperimental associates of target words such as *table*. The probability of generation of target words (CHAIR) in

TABLE 1

MATERIALS USED IN THE CONSTRUCTION OF CRITICAL LISTS IN EXPERIMENTS 1, 2, AND 3

List A			List B		
Weak cue	Strong cue	Target word	Weak cue	Strong cue	Target word
ground	hot	COLD	hope	low	HIGH
head	dark	LIGHT	stem	long	SHORT
bath	want	NEED	whiskey	lake	WATER
cheese	grass	GREEN	moth	eat	FOOD
stomach	small	LARGE	cabbage	square	ROUND
sun	night	DAY	glass	soft	HARD
pretty	sky	BLUE	country	closed	OPEN
cave	dry	WET	tool	finger	HAND
whistle	tennis	BALL	memory	fast	SLOW
noise	blow	WIND	covering	lining	COAT
glue	table	CHAIR	barn	clean	DIRTY
command	woman	MAN	spider	eagle	BIRD
fruit	bloom	FLOWER	crust	bake	CAKE
home	bitter	SWEET	deep	bed	SLEEP
grasp	infant	BABY	train	white	BLACK
butter	rough	SMOOTH	mountain	leaf	TREE
drink	tobacco	SMOKE	cottage	hate	LOVE
beat	ache	PAIN	art	boy	GIRL
cloth	lamb	SHEEP	adult	labor	WORK
swift	stop	GO	brave	strong	WEAK
lady	king	QUEEN	door	color	RED
blade	scissors	CUT	roll	carpet	RUG
plant	insect	BUG	think	dumb	STUPID
wish	soap	WASH	exist	human	BEING

response to the extralist cues was one observation of interest. Next, subjects were asked to identify those generated words that they remembered having seen in the input list, their success in doing so being another observation of interest. Finally, a cued recall test involving input cues (*glue*) was given to the subjects in an attempt to estimate the extent to which information about target words (*CHAIR*) was available in the memory store.

General Method

In all three experiments the same procedure was used up to a critical point in time when different treatments and tests were administered to subjects. The procedure common to all experiments follows.

Every subject was shown and tested on three successive lists. The sole purpose of the first two lists was to induce subjects to encode each target word with respect to, or in the context of, another word. The word pairs in these two set-establishing lists were comparable to weak-cue input lists used by Thomson and Tulving (1970). The target words, each paired with its cue word, were shown visually, one at a time, at the rate of three seconds/pair. Immediately at the end of the presentation of the list the subjects were provided with 24 haphazardly ordered input cue words on a recall sheet and instructed to write down the target words. Three minutes were given for the recall of the list. The mean number of words recalled for these two lists were 14.3 and 17.6 in Experiment 1; 15.7 and

18.3 in Experiment 2; and 14.4 and 17.7 in Experiment 3.

The third list in each experiment was the critical list, providing the data of interest. This list, too, consisted of 24 cue-target pairs, with the material presented exactly as in the first two lists.

The target words in the third list in each experiment were those designated as such in Table 1. The two sets, A and B, were used equally frequently with two subgroups of subjects in each of the three experiments; otherwise, all subjects in a given experiment were treated identically. In Table 1, each target word is accompanied by two cue words, one "weak" and the other one "strong." These triplets were selected from free-association norms (Bilodeau & Howell, 1965; Riegel, 1965) to conform to the following criteria: (a) the target word is a low-frequency (mean of 1% for the whole set) associate to its weak cue; (b) the target word is a high-frequency associate to its strong cue (mean of 52%), and (c) weak and strong cues of a given target word are not associatively related to each other in the norms.

The 24 pairs of words in critical lists consisted of weak cues and their corresponding target words. The strong cue words were not shown at the time of the presentation and were used only as extralist retrieval cues in the subsequent test phase. For instance, subjects tested with List A saw the pairs, *ground* COLD, *head* LIGHT, *bath* NEED, and so on, one pair at a time, for all 24 pairs, the cue word appearing in lower-case letters above the capitalized target word. The same instructions that had been given to the subjects in the first two lists were routinely repeated: their task was to remember the capitalized words, but paying attention to cues might help them at the time of the subsequent test. No mention was made of any change in the procedure between Lists 2 and 3. Each pair was again shown visually for three seconds. After all 24 pairs had been presented once, subjects received different treatments in different experiments, as described below.

Experiment 1

After the presentation of the third, critical list—henceforth referred to as "the list"—all 40 subjects, undergraduates at Yale University, were given the same four successive tasks.

First, each subject received a sheet of paper listing 12 extralist cues corresponding to one half of the to-be-remembered words from the list. For instance, subjects tested with List A were given the words *hot*, *dark*, *want*, and so on. They were told that each of the listed cue words was related to one of the capitalized words in the list that they had just studied, and that their task was to write down as many of the capitalized words as they remembered, each one beside its related cue word. Three minutes were allowed for this task. The mean number of target words recalled in this extralist-cue test was 1.8 (15%).

Second, subjects were given the remaining 12 extralist cues, briefly told about the free association procedure, instructed to look carefully at each cue word, produce free associates to each mentally, and then, "if one of the words you generate as a free association is a word from the list that you have just studied," to write it down beside its stimulus word. Again, three minutes were given for this task. The mean number of target words recalled in this test was 3.6 (30%). This figure was significantly higher than the 15% recall level in the first phase.

Third, all 24 extralist cue words, that is, the cues that the subjects had just seen in the first and second phase of testing, were presented to the subjects once more, listed on a sheet of paper, together with instructions to "write down all the words that you can generate as free associations" to these stimulus words. Beside each stimulus word were six blank spaces for up to six responses. Twelve minutes were allowed for this task. Each subject generated, on the average, 104 free association responses to the 24 stimulus words, a mean of 4.4 response words. Among the 104 responses thus generated there were, on the average, 17.7 (74% of the 24) words matching the target words of the list. Of these words, 70% were given by subjects as the primary response to the stimulus words. Thus, the proportion of target words generated as primary responses to the high-frequency stimuli was 52% (70% of the 74%), matching the normative data exactly.

Fourth, the subjects were instructed to look over all their generated responses and to circle all words that they recognized as target words from the list they had learned last. They were given as much time as they needed for this task. The mean number of words circled was 4.2, out of the maximum of 17.7, producing a hit rate of 24%. The percentage of false positives, circled words that were not target words from the list, was 4.5%.

A fifth task in Experiment 1 was an afterthought whose relevance became clear after we had tested and seen the results from 30 subjects. It was administered to the final 10 subjects. (Their performance on the first four tasks was not distinguishable from that of the first 30 subjects.) These 10 subjects were provided, on two sheets of paper, with the 24 input cues from the list and were instructed to recall the capitalized words from the list they had seen last. The mean number of target words recalled on this cued recall test was 15.2, for a hit rate of 63%. Further analysis of the data from these 10 subjects revealed that in their fourth and fifth tasks, they both recognized and recalled a total of 43 words; recognized but did not recall 4 words; and recalled but did not recognize 69 words.

These data can be summarized as follows: (a) Pairing of to-be-remembered words at input with cue words associatively unrelated to subsequently presented extralist cues has no adverse effect on subjects' ability to utilize these extralist cues in

generating target words from semantic memory. (b) Regardless of whether subjects are or are not instructed to use the generate-recognize strategy, under conditions where cues are switched from input to output, the level of their recall performance in presence of extralist cues does not materially exceed that expected under noncued conditions (cf. Thomson & Tulving, 1970). (c) Under the experimental conditions as described, subjects cannot recognize many generated copies of target words, although they can produce these words in presence of what appear to be more effective cues, context items from the input list. The recognition hit rate of 24% contrasted with the hit rate of 63% in the cued recall test.

Experiment 2

One purpose of Experiment 2 was to replicate Experiment 1; another was to find out to what extent the low hit rate in the recognition of generated free association responses was attributable to the source of the recognition test items. In Experiment 1, each subject generated the "old" items and distractors for the recognition test. In Experiment 2 this procedure was replicated with one half of the list items, while for the other half of the list the source of "old" test items and distractors for a given subject was the free association protocol of a yoked subject.

Twenty-two subjects, undergraduate students of both sexes at Yale University, participated in this experiment. Again, they were divided into two groups for the sole purpose of using both Lists A and B, as shown in Table 1, in the critical, third list position. Otherwise, all subjects were administered an identical sequence of tasks.

Each subject was again first tested with two successive set-establishing lists, and then the third list was presented, as in Experiment 1. Following the presentation of the list, subjects were given five successive tasks.

1. They were asked to generate and write down six free association responses to each of the 12 extralist cue words corresponding to the target words. The mean number of words generated was 54 per subject, of which 9.6 (80% of the 12) matched target words in the list. Primary responses coincided with target words 53% of the time.

2. Subjects were asked to examine all the words they had generated in the free association test and to write down, on a separate piece of paper, all those words they recognized as target words from the list. On the average, 1.8 target words were thus recognized, for a hit rate of 18%. The false positive rate was 2.8%.

3. Each subject was given the free associates generated by another subject to the remaining 12 extralist cues, and instructed to perform the same kind of recognition test on these words that they had performed on their own. This time the 22 subjects correctly identified 51 out of the total of

204 copies of target words, for a hit rate of 25%, a score not significantly different from the 18% hit rate of subjects' own generated responses, $t = 1.18$, $df = 21$.

4. Subjects were asked to write down, beside each of the recognized target words from the second set (yoked subjects' free association responses), the corresponding input cues they remembered from the list. The 22 subjects could provide 36 (71%) such cues for the 51 targets.

5. Finally, all subjects were given all 24 original input cues from the list and were asked to recall as many target words as they remembered. The mean number of words recalled on this test was 14.1, for a hit rate of 59%. Again, as in Experiment 1, there were very few words that were recognized in the second task but not recalled in the fifth task (a total of 5 for all 22 subjects), and there were numerous words recalled in the fifth task but not recognized, although generated, in the second task (total of 73 for 22 subjects).

The results of Experiment 2 thus confirmed the results of Experiment 1: when provided with strong extraexperimental associates of target words as stimuli, subjects generated many responses matching the target words but they did rather poorly in identifying these as target words from the list. In Experiment 2, the hit rate in the recognition test of generated target words was, on the average, 22%, while the false positive rate was 2.8%. The source of the "old" test words and distractor items in the recognition test—whether the subject's own semantic memory or that of another subject—did not seem to be an important determinant of the recognition performance under these conditions, although the confounding of order of tests with experimental treatment may have contributed to the absence of a significant difference between the two conditions. Subjects also remembered a sizable proportion of input cues for the target words they correctly identified from among those generated by their yoked partners. Finally, the data from Experiment 2 confirmed those from Experiment 1 in showing that a low hit rate in the recognition test on generated target words did not prevent subjects from doing reasonably well in recalling these words in presence of the original input stimuli. The mean recognition hit rate of 22% in Experiment 2 again contrasted starkly with the cued-recall hit rate of 59%.

While the data in these experiments were averaged over all target words in the two critical lists, A and B, as shown in Table 1, it may be of some interest that large differences in recognition of individual words occurred. The words in both lists in Table 1 are ordered from least to most recognizable, on the basis of data in Experiments 1 and 2. Target words at the top of each list (COLD, LIGHT, HIGH, SHORT, WATER) were never recognized, even though each was generated by anywhere from 13 to 21 subjects; words in the middle (BALL, WIND, CHAIR, MAN, FLOWER, SLOW, COAT, DIRTY) showed individual hit rates of .14 to

.16; words at the bottom (QUEEN, CUT, BUG, WASH, STUPID, BEING) were correctly recognized over 50% of the time.

Experiment 3

A possible interpretation of the very low recognition hit rates of generated to-be-remembered words in Experiments 1 and 2 might be provided by invoking the concept of "high criterion": for reasons unknown, the subjects adopt a very cautious attitude in the recognition test and check off only those words that they are extremely confident about as being identical with target words from the list. While the observed false positive rates, in relation to the observed hit rates, are sufficiently high to weaken the force of this argument, we made a more direct attempt to evaluate this interpretation in Experiment 3.

Fourteen subjects, from the same source as those in Experiments 1 and 2, served in this experiment. Again, they were divided into two groups for the sole purpose of counterbalancing materials in the critical test conditions. The materials and other conditions of the experiment were identical with those used in Experiments 1 and 2.

Subjects were again given two set-establishing lists first. The third list was then presented under the same instructions and conditions as Lists 1 and 2, and followed by three tasks. First, subjects were provided with two sheets of paper, listing the 24 extralist cues corresponding to the target words from the list. They were instructed to write down four free association responses to each of the 24 cue words, words that the cue words "made them think of."

Second, a forced-choice recognition test was given. Subjects were instructed to look at the four words they had generated for each of the stimulus words and circle the word that appeared to be the most likely member of the set of target words in the last list they had learned, guessing whenever necessary. In addition, the subjects were asked to indicate their confidence in the correctness of the response, on a scale on which the three values, 1, 2, and 3, were labeled as "guessing," "reasonably sure," and "absolutely sure."

The 14 subjects generated a total of 221 target words in the free association test, or an average of 15.8 (66%) of the possible 24. The proportion of target items among primary responses was 46%, only a little less than the normative value of 52%. In what was effectively a four-alternative forced-choice recognition test, the subjects correctly circled 118 out of the 221 copies of target words and failed to recognize the other 103 words, for a hit rate of 53%. Of the 118 to-be-remembered words correctly circled in the recognition test, 47 were labeled as guesses, while the remaining 71 were given confidence ratings of 2 or 3. The standard guessing correction yields a corrected recognition score of 38%. Alternatively, if we consider only those to-be-remembered words as recognized for which the

subjects gave confidence ratings of 2 or 3, we obtain a recognition score of 71/221, or 32%.

In the third and final task, subjects were tested for recall of target words in presence of their original input cues, as in Experiments 1 and 2. The mean number of target words recalled was 14.2, for a hit rate of 61%, considerably higher than the recognition scores of 32% or 38%.

The major finding in Experiment 3 was that the failure to recognize recallable words also occurs, perhaps in a somewhat attenuated form, under the conditions of the forced-choice recognition test. It rules out the response bias as the sole explanation of the similar results obtained under free-choice recognition procedure in Experiments 1 and 2.

General Results

A summary of the data from the three experiments, together with those from Experiment II in the Thomson and Tulving (1970) paper, is presented in Table 2. Table 2 shows probability of recall of target words in presence of three kinds of specific cues: (a) input cues, (b) copies of target words generated by subjects in free association tests, and (c) strong preexperimental associates of target words used as extralist retrieval cues.

The importance of the data pertaining to recall in presence of input cues is twofold: the observed levels of recall in various experiments indicate the extent of effectiveness of input cues in relation to other cues, and they provide a lower-bound estimate of the availability of information about target words in memory. The data thus constitute a critical link in the argument that takes us from the results to the general conclusion of the experiments: conditions can be created in which information about a word event is available in the memory store in a form sufficient for the production of the appropriate response and yet a literal copy of the word is not recognized. This phenomenon of recognition failure was a striking one. Ignoring words that could be both recalled and recognized and those that could be neither recognized nor recalled—response categories defining theoretically uninteresting outcomes—we found, in Experiments 1 and 2, that the number of words that were recalled but not recognized exceeded the number of words that could be recognized but not recalled by a ratio of approximately 15:1.

The phenomenon of recognition failure of

TABLE 2
PROBABILITY OF RECALL OF THE TARGET WORD
IN THE PRESENCE OF THREE KINDS
OF RETRIEVAL CUES

Cue	Tulving & Thomson (1970)* Exp. II	Exp. 1	Exp. 2	Exp. 3
Input cue	.65	.63	.59	.61
Extraexperimental associate	.23	.15, .30	—	—
Copy of target	—	.24	.22	.32, .38

* Data are from Group 6, Experiment II, by Thomson and Tulving (1970).

recallable items is not a novel one. Other experiments have been reported in which learned materials were recalled at higher levels than they were recognized (Bahrick & Bahrick, 1964; Lachman & Field, 1965; Lachman, Laughery, & Field, 1966). But in these experiments the subjects were given only a limited amount of time to make the recognition judgments, and it is not known to what extent the outcome was a consequence of time pressure. It is quite likely that if the subjects in the Lachman and Field (1965) experiment, for instance, in which the learned material was a meaningful prose passage, would have been given more time, they might have been able to recognize all words that they could recall, simply by reproducing each word as an element of the learned passage and matching it with the test word. This strategy may not have been feasible under the conditions of Lachman and Field's recognition task in which subjects only had 1.5 seconds to make the decision about each word.

FAILURE OF RECOGNITION OF GENERATED WORDS

The recognition failure of recallable words is an empirical phenomenon that cannot occur according to the two-process theory of recall and recognition (Kintsch, 1970) and other versions of the generation-recognition model of retrieval (e.g., Bower et al., 1969; Murdock, in press; Norman, 1968; Shiffrin & Atkinson, 1969; Slamecka, 1972; Underwood, 1972). Recovery of information through two bottlenecks (generation and recognition) in a recall situation cannot be

more effective than that through only one of the two (recognition). Since the experimental data show that under certain conditions generation and recognition produce a higher level of retrieval than recognition alone, existing generation-recognition models require revision.

The phenomenon of recognition failure of recallable words violates the two critical assumptions on which generation-recognition models are based, the assumption of transsituational identity of words and the assumption of automatic access to the internal representation of a word. If a word had only one representation in memory, and if that representation were modified by the appearance of the word in an experimental list, then recognition could fail only because of loss or deterioration of the relevant list or occurrence information. If recall also depended upon an intact list marker, its level could never exceed that of recognition. In our experiments, the copy of the recallable target word that was not recognized may have provided automatic access to some internal representation of the word, or to some specific location in the memory store, but the information about the membership of the word in a particular list was apparently not stored in that location. The question thus is not whether the occurrence of a stimulus word, produced in whatever fashion, provides automatic access but rather automatic access to what?

One might perhaps argue that the conditions of our experiments lie outside the boundaries of the domain of the generation-recognition models, and that in "normal" experimental situations the models do rather faithfully represent the retrieval process. In that case we need to be told what the domain of the generation-recognition models is, and what kind of a model would account for the data that show strong associates of target words to be ineffective cues. In this connection it is helpful to remember that the procedure we used rendered many recallable words not recognizable, but it did not seem to affect the ability of subjects to successfully generate copies of target words in response to extralist cues. The failure of retrieval as envisaged by the two-process

theory had its source in the recognition phase and not the generation phase.

A plausible modification of the generation-recognition models that would bring them into line with the phenomenon of recognition failure of recallable words would involve making the assumptions that (a) the pairing of the target word with another word at input creates a specific semantic meaning for the target word, and (b) this specific meaning is stored with the "core" representation of the word and marked with a list tag. The input cue may provide access to the appropriate location in the memory store, because of its list-specific association with the marked sense of the target word. But a copy of the target word may fail to do so, because it would be interpreted in a different sense in absence of the input cue, and thus provide access to an incorrect storage location.

A generation-recognition model thus modified would become in many ways quite similar to the encoding specificity principle in its general orientation. In the modified version the requirement would be relinquished that a given lexical item be represented in only one location. It remains to be seen whether it would be possible to retain some other basic features of these models, such as the assumption that episodic information is stored in the same system as semantic information, that occurrence of the to-be-remembered word in a list results in modification of the existing representation of the word in the memory store, and that recall, but not recognition, involves generation of alternatives other than the desired target words.

The phenomenon of recognition failure creates difficulties not only for extant versions of generation-recognition models but for most other theories of retrieval as well. Apart from the encoding specificity principle, to which we will return in the final section of the paper, the theory that seems to be most readily reconcilable with the data is that of mediation by implicit associative responses. The theory represents a special case of the principle of reinstatement of stimulus conditions and we will briefly consider it as such. This principle states that the success of retrieval depends on the completeness with which stimulating conditions

present at input are reinstated at the time of attempted retrieval (Hollingworth, 1928; Melton, 1963). Since the stimulating conditions present at input could be thought to include unobservable processes of the kind that have been labeled implicit associative responses, presentation at the time of the recall of extralist retrieval cues that match implicit associative responses would produce a greater degree of similarity between the test and study conditions than that prevailing in the noncued test situation. While the principle of reinstatement of stimulus conditions does provide a plausible interpretation of the effectiveness of extralist retrieval cues, it cannot account for the phenomenon of recognition failure observed in our experiments. Given that the input consists of a compound stimulus such as *glue*-CHAIR, and given that the subject clearly knows that his memory will be tested for the target word CHAIR, why should the stimulating conditions be "more completely" reinstated when the *glue* part of the compound rather than the CHAIR part is presented at test? Thus the theory of mediation by implicit associative responses and the principle of reinstatement of stimulus conditions do not explain the phenomenon of recognition failure any more readily than do generation-recognition models.

ENCODING AND RETRIEVAL

In this last section of the paper, we consider some possible tentative explanations of the phenomenon of recognition failure, relate the phenomenon to other relevant data reported in the literature, and suggest an overall pretheoretical framework within which this phenomenon as well as other problems of retrieval could be experimentally and theoretically analyzed. The demonstrative nature of our own experiments precludes an enlightened interpretation of the failure of extralist associates and copies of target items as retrieval cues, but some possibilities for interpretation should be mentioned.

Recognition Failure: Tentative Interpretations

One may wish to approach the phenomenon of recognition failure of recallable words

in terms of the concept of asymmetry of associations between the input cue and the target item. The data show and imply that the "forward" association between the cue and the target in our experiments was stronger than the "backward" association between the target and the cue: given the cue, the target word could be recalled without difficulty in many cases; given the target word, the input cue could be recalled only infrequently. Thus, it would be possible to argue that the recognition failure of target words was a result of the weak association between the target and the cue. If that association had been stronger, the input cue could have been retrieved given the target word, and the target word itself recognized in the presence of the cue.

If one adopted this approach, the problem would become that of explaining the asymmetry of the associations between the input cue and the target word. One would also have to keep in mind an equally plausible alternative line of reasoning: backward association appears to be weaker than the forward association whenever the target word is not as readily recognized as the cue word. Recognition of the stimulus item, which depends on the consistent encoding of the item at input and at test, can be thought of as a necessary condition for associative recall (Martin, 1968, 1972). The difficulty here lies in the uncertainty of whether to account for failure of recognition in terms of a weak association or to interpret the apparent weak association in terms of the recognition failure.

Another approach to the problem of interpretation of the phenomenon of recognition failure could begin with the distinction between nominal and functional memory units. This distinction has often been made in discussions of associative and organizational processes in memory (e.g., Asch, 1969; Köhler, 1947; Tulving, 1968). A verbal unit may be designated as an independent to-be-remembered item by the experimenter, but the processing system, that is the subject, may treat it as a part of a larger functional unit. For instance, a subject shown a list of words under instructions to remember them could do reasonably well if he were asked to recall the letter bigrams he saw in

the list. He would "recall" the bigrams by retrieving information about the words and construct the units designated by the experimenter in a postretrieval operation; he would not store bigrams in the same sense as he stores words. Even under intentional learning conditions, subjects are known to have great difficulty in recognizing bigrams they can readily recall as parts of integrated words (Watkins, 1973). Recognition failure of words that were recalled quite well in response to the specific input cues in our experiments may also have come about because the "old" test item in the recognition test did not match the functional memory unit, the complex consisting of the input cue and the target word. If the whole unit had been presented for recognition, the subjects probably would not have had any great difficulty.

While the explanation of the phenomenon of recognition failure in terms of the distinction between nominal and functional memory units is incomplete as long as we do not know exactly what are the functional units in any given situation, the notion might provide some guidelines for identification of more appropriate units of analysis than those defined by the experimenter. For instance, it may be reasonable to claim that a functional memory unit is one which, among other things, must be recognized if it is to be recalled. Thus, if a nominal unit could be recalled as a part of a larger complex but could not be recognized outside the complex, it would not correspond to a functional unit. The recall-cum-recognition criterion could be combined with other rules for identification of functional units, for instance, that they are activated and emitted in an all-or-none fashion (Mandler, 1967b).

Another closely related interpretation of recognition failure could be based on the Gestalt concept of "embeddedness." It is easy to demonstrate failure of perception of a figure embedded in a larger complex, and similar demonstrations have been reported in memory situations. Koffka (1935, p. 622), for instance, discussed an experiment by Harrower (1933) in which punch lines of jokes could not be recognized as readily when they appeared embedded in a meaning-

ful passage than when they were presented as a part of a collection of unrelated statements. Winograd, Karchmer, and Russell (1971) interpreted their data demonstrating effectiveness of retrieval cues in recognition memory by assuming that under certain conditions nominal elements are compounded into a unitary representation. The principle of embedding would also apply to the results of an earlier demonstration of recognition failure of recallable words (Tulving, 1968b) in which the to-be-remembered words could be encoded by subjects as second halves of compound words, for example, air-PORT; house-HOLD; sand-HOG. In our present experiments the encoding operation performed on the input pairs also may have produced tightly knit compounds. The well-known Gestalt principle that properties of elements change when these elements become parts of larger wholes would then explain why copies of target words were not particularly effective in providing access to the trace created by the compound of the input cue and the target word. Thus, CHAIR may have been as difficult to retrieve from the "glue-CHAIR" complex stored in memory as it would be difficult for a person to recognize HIT as an "old" item when the stored unit is "architecture" or POT when the stored complex is "hippopotamus." The embedded part can be discerned easily enough in a perceptual display of the whole, both before the whole has been stored in and after it has been retrieved from memory, but its identification may be impossible after storage and before retrieval.

The major problem with the explanation of the recognition failure in terms of the concept of embedding has to do with the assumed difference in the recognition of input cues and target words: Why is the input cue not embedded in the cue-target complex in the same way as the target word is? Data reported elsewhere (Thomson, 1972) show the same pattern we are assuming here and create the same problem of interpretation: right-hand members of weakly associated input pairs were not as well recognized as left-hand members when the test word was presented alone.

Given the fact that the target word can

be more readily recalled in presence of the input cue than in presence of its own literal copy, it is possible to think of the input cue as a "control element" or "code" that governs the access to the complex of stored information about the target word. The concept of "control element" has been used by Estes (1972) and the closely related concept of "code" by Johnson (1970) in theoretical accounts of processing of serial information. In the present context, we think of anything that controls retrieval of a particular memory unit at a particular time as a control element of that unit. A retrieval cue that is not only effective but also necessary for the recovery of certain stored information (an access cue) would be such a control element.

Recent experiments by Martin (1971) and Slamecka (1972) have produced rather striking demonstrations of the role that control elements play in determining access to stored information. While the two experiments were different in both conception and method, they did make one and the same point: certain stored items can be retrieved only through the activation of certain other items. The latter can be regarded as control elements for the former. In Martin's experiment, subjects learned groups of words consisting of a three-word compound stimulus and a single response word. A subsequent recall test showed that one stimulus word as a cue provided access to another one only through the response word. In Slamecka's study, subjects learned lists of words belonging to conceptual categories. In the recall test, one item in a given category provided access to other items in the same category only through the control element of the category label. These experiments, as well as those of Johnson's (1970) on chunking, do not only illustrate the part that control elements and codes play in retrieval, but they also point to the important distinction between experimenter-designated retrieval cues and control elements. The two are not always the same.

Although the data from our own experiments can be interpreted to reflect the role of input cues as control elements, this interpretation fails to tell us exactly what determined the identity of control elements in

our situation. Why were the input cues, and not the target items, control elements; why not both?

Still another tentative interpretation of our findings could be advanced under the label of the hypothesis of complementary information. It can be briefly stated as follows. The address of an event stored in episodic memory is essentially temporal, defined in terms of the event's temporal relations to other experienced events. The specification of the address is frequently sufficient for the homunculus to read out the contents of that address. Failure of retrieval of desired information in a situation in which only the temporal address is given may sometimes come about because the information stored at that address is fuzzy or incomplete. An effective retrieval cue then is one that provides the missing information. Thus, the retrieval information complements the information available in the trace and permits the homunculus to read the trace without difficulty. According to this formulation, a copy of the list cue presented in the final cued tests in our experiments did contain information that was lacking in the stored traces, while extralist cues and copies of target items did not. The complementary information hypothesis does not say why the list cue, and not the target item, carried the necessary additional information, and therefore it is as incomplete as all others we have considered.

Encoding Specificity

These tentative interpretations of the recognition failure we have briefly considered have not explained the phenomenon, but they have suggested questions that may provide some guidance and direction to future research. At the present time, it is possible only to point once more to the encoding specificity principle as a general answer to the questions. What produced the asymmetry of associations between list cues and target items in our experiments? What determined the functional memory units and their relations to the nominal units? Why was one of the two nominal units embedded in the whole complex more readily recognized when it appeared alone than was the

other? Why did the list cue serve the function of a control element or code of the stored cue-target trace while the target item did not? Why was the information contained in the input cue sufficient to complement the stored information while that in the extralist cue and the copy of the target item was not?

A general answer to all these questions is provided by the encoding specificity principle: Specific encoding operations performed on what is perceived determine what is stored, and what is stored determines what retrieval cues are effective in providing access to what is stored.⁴

In our experiments, encoding of target words was influenced by the list cues present at input and by the subjects' expectations that they would be tested with those cues. But it was influenced by other things as well, factors that cannot as yet be adequately identified or labeled. We have referred to the totality of conditions determining the encoding of a perceived item as its cognitive environment (Tulving & Thomson, 1971), and we think of encoding operations as some sort of an interaction between the perceptual input and its cognitive environment. The terms are ill defined, and the concepts do not explain too much at this time. Yet they serve to remind us that something else besides the properties of a presented item determines how well the item is remembered and that an important research problem is to find out what this something else is and how it works. Specific encoding of input materials in our studies was responsible for asymmetry of associations, embeddedness, control elements, and the nature of effective retrieval information. The same material in other situations, however, in a different cognitive

environment, could have been encoded in ways in which access routes to the stored information would have been different.

It has been known for a long time, of course, that how well a thing is remembered does not depend only on what it is, but also on how it is stored in memory. Ancient orators knew it when they used the method of loci to ensure that they would know the right thing to say at the right time (Yates, 1966), Gestalt psychologists knew it when they kept telling others that the properties of an element depended on the company the element kept in a larger whole, Bartlett (1932, p. 188) emphasized the importance of the "conditions of the prior perception" in determining recall and recognition, and a long tradition of research on incidental and intentional learning has converged on the conclusions that what is learned depends on what happens in the learning situation (Postman, 1964).

In recent research the effects of encoding operations on what is stored, the memory trace, have been studied in a variety of settings and using a number of different techniques and paradigms (Craig & Lockhart, 1972). One method has been to change the context of an item. It has been found that repetition of a to-be-remembered item may or may not facilitate its recall, depending upon its intralist context (e.g., Asch, 1969; Murdock & Babick, 1961), on its semantic interpretation as biased by context (e.g., Bobrow, 1970), and on its membership in the same or different higher order unit (e.g., Bower et al., 1969). Similarly, recognition of a previously seen list word has been shown to be influenced by its presentation and test contexts (e.g., DaPolito, Barker, & Wiant, 1972; Light & Carter-Sobell, 1970; Thomson, 1972; Tulving & Thomson, 1971; Winograd & Conn, 1971).

In another type of experiment, encoding has been manipulated by asking the subjects to do different things with the material when it is presented. Thus, for instance, Mandler (1967a) had one group of subjects sort words into conceptual categories while another group was exposed to the same words under instructions to study and remember them. In a subsequent free-recall test, both

⁴ Although we have emphasized the importance of encoding conditions at input, we do not wish to imply that once an event has been encoded its trace does not undergo further changes. Among many possible modifications of stored information, those produced through active recoding of the trace are most relevant to determining its subsequent retrievability in different retrieval environments. For our present purposes, encoding processes are considered always to subsume recoding processes that occur prior to the act of explicit retrieval of interest.

groups did equally well. In Hyde and Jenkins' (1969) experiment, subjects in one group made judgments about semantic properties of words, while in another group they studied the same set of words in expectation of a recall test. Both groups recalled the same number of words and did considerably better than a third group that had made judgments about graphemic properties of words prior to the test. A particularly effective manipulation of input in terms of encoding operations performed on the presented items has been described by Craik (1973). Words were presented tachistoscopically, always for the same short duration, and the subjects were instructed to answer different questions about each presented word, such as, "Is it printed in capital or lower-case letters?" or "Does it belong to the category of fruits?" Large differences in subsequent recall of these words were observed, depending upon the encoding operation performed at input. These and other similar studies (e.g., Gardiner, 1972; Johnston & Jenkins, 1971; Paivio & Csapo, 1972; Schulman, 1971) thus provide convincing evidence about the important role that encoding operations play in determining subsequent retrievability of perceived items.

Differences in recall and recognition of identical material stored under different encoding conditions do not simply reflect established differences in "strength" of traces. The concept of trace strength makes little sense and has little value if: (a) strength must be estimated from observed levels of recall or recognition and (b) these observed levels vary with specific conditions of retrieval. A number of recent experiments supplement common sense in demonstrating that recall and recognition of items stored under identical encoding conditions are influenced, sometimes greatly influenced, by the nature of information present in the retrieval environment. These experiments (e.g., Bahrick, 1969; Light, 1972; McLeod et al., 1971; Tulving, 1968b; Tulving & Pearlstone, 1966; Tulving & Psotka, 1971; Winograd & Conn, 1971) clearly suggest that a stored trace of an item is more accessible through certain cues than others. Memory traces may be said to vary in

strength, or quality, or durability, but more importantly they vary in the specificity of code they carry as to the effectiveness of various kinds of retrieval information that govern the recovery of the stored information (Earhard, 1969).

Thus, research has shown that it is possible to hold constant the to-be-remembered item and observe large differences in its recall and recognition depending upon its encoding conditions, and that it is possible to hold constant the encoding conditions of the item and observe large differences in its recall and recognition depending upon retrieval conditions. These two basic sources of variability of recall, encoding and retrieval conditions, usually interact in the sense that a cue effective in one situation may or may not be effective in another. The new data we described in this paper strongly imply such an interaction, and other data already in the literature in fact demonstrate it (e.g., Earhard, 1969; Frost, 1972; Ghatala & Hurlbut, 1973; Lauer & Battig, 1972; Mikula, 1971; Thomson, 1972; Thomson & Tulving, 1970; Tulving & Osler, 1968; Tulving & Thomson, 1971; Tversky, in press; Winograd et al., 1971).

All these data suggest that the effectiveness of a particular cue depends on how the to-be-retrieved item was encoded at input. The recognition failure of recallable words represents an extreme case of the general principle that encoding determines the trace, and the trace determines the effectiveness of retrieval cues. The trace itself is simply the link between encoding conditions and the retrieval environment and, from the point of view of psychological analyses of memory, need have no more reality than is implied by the relation between encoding and retrieval.

The formulation of the encoding specificity principle is so general that it covers all known phenomena of episodic memory and retrieval and in a weak sense provides an understanding of them. More detailed conceptual analyses of the relation between encoding and retrieval processes may also be fruitfully undertaken within the same general paradigm.

REFERENCES

- ANDERSON, J. R., & BOWER, G. H. Recognition and retrieval processes in free recall. *Psychological Review*, 1972, 79, 97-123.
- ASCH, S. E. Reformulation of the problem of association. *American Psychologist*, 1969, 24, 92-102.
- ATKINSON, R. C., & SHIFFRIN, R. M. Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation*. Vol. 2. New York: Academic Press, 1968.
- BAHRICK, H. P. Measurement of memory by prompted recall. *Journal of Experimental Psychology*, 1969, 79, 213-219.
- BAHRICK, H. P. A two-phase model for prompted recall. *Psychological Review*, 1970, 77, 215-222.
- BAHRICK, H. P., & BAHRICK, P. O. A re-examination of the interrelations among measures of retention. *Quarterly Journal of Experimental Psychology*, 1964, 16, 318-324.
- BARTLETT, F. C. *Remembering: A study in experimental and social psychology*. Cambridge, England: University Press, 1932.
- BILODEAU, E. A. Experimental interference with primary associates and their subsequent recovery with rest. *Journal of Experimental Psychology*, 1967, 73, 328-332.
- BILODEAU, E. A., & BLICK, K. A. Courses of misrecall over long-term retention intervals as related to strength of preexperimental habits of word association. *Psychological Reports*, 1965, 16 (Monogr. Suppl. 6).
- BILODEAU, E. A., & HOWELL, D. C. *Free association norms*. (Catalog No. D210.2:F87) Washington, D. C.: U.S. Government Printing Office, 1965.
- BOBROW, S. A. Memory for words in sentences. *Journal of Verbal Learning and Verbal Behavior*, 1970, 9, 363-372.
- BOWER, G. H. A multicomponent theory of the memory trace. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation*. Vol. 1. New York: Academic Press, 1967.
- BOWER, G. H. Organizational factors in memory. *Cognitive Psychology*, 1970, 1, 18-46.
- BOWER, G. H. Stimulus-sampling theory of encoding variability. In A. W. Melton & E. Martin (Eds.), *Coding processes in human memory*. Washington, D. C.: Winston, 1972.
- BOWER, G. H., CLARK, M. C., LESGOLD, A. M., & WINZENZ, D. Hierarchical retrieval schemes in recall of categorized word lists. *Journal of Verbal Learning and Verbal Behavior*, 1969, 8, 323-343.
- BREGMAN, A. S. Forgetting curves with semantic, phonetic, graphic, and contiguity cues. *Journal of Experimental Psychology*, 1968, 78, 539-546.
- BROADBENT, D. E. *In defence of empirical psychology*. London: Methuen, 1973.
- CRAIK, F. I. M. A "levels of analysis" view of memory. In P. Pliner, L. Krames, & T. M. Alloway (Eds.), *Communication and affect: Language and thought*. New York: Academic Press, 1973.
- CRAIK, F. I. M., & LOCKHART, R. S. Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, 1972, 11, 671-684.
- CRAMER, P. Magnitude and selectivity as independent factors in semantic generalization. *Journal of Verbal Learning and Verbal Behavior*, 1970, 9, 509-524.
- DAPOLITO, F., BARKER, D., & WIAINT, J. The effects of contextual changes on the component recognition. *American Journal of Psychology*, 1972, 85, 431-440.
- EARHARD, M. Storage and retrieval of words encoded in memory. *Journal of Experimental Psychology*, 1969, 80, 412-418.
- ESTES, W. K. An associative basis for coding and organization. In A. W. Melton & E. Martin (Eds.), *Coding processes in human memory*. Washington, D. C.: Winston, 1972.
- FOX, P. W., BLICK, K. A., & BILODEAU, E. A. Stimulation and prediction of verbal recall and misrecall. *Journal of Experimental Psychology*, 1964, 68, 321-322.
- FOX, P. W., & DAHL, P. R. Aided retrieval of previously unrecalled information. *Journal of Experimental Psychology*, 1971, 88, 349-353.
- FREUND, J. S., & UNDERWOOD, B. J. Restricted associates as cues in free recall. *Journal of Verbal Learning and Verbal Behavior*, 1970, 9, 136-141.
- FROST, N. Encoding and retrieval in visual memory tasks. *Journal of Experimental Psychology*, 1972, 95, 317-326.
- GARDINER, J. M. Studies of word retrieval in human memory. Unpublished doctoral dissertation, University of London, 1972.
- GHATALA, E. S., & HURLBUT, N. L. Effectiveness of acoustic and conceptual retrieval cues in memory for words at two grade levels. *Journal of Educational Psychology*, 1973, 64, 347-352.
- HARROWER, M. R. Organization in higher mental processes. *Psychologische Forschung*, 1933, 17, 56-120.
- HOLLINGWORTH, H. L. *Psychology: Its facts and principles*. New York: Appleton, 1928.
- HUDSON, R. L., & AUSTIN, J. B. Effect of context and category name on the recall of categorized word lists. *Journal of Experimental Psychology*, 1970, 86, 43-47.
- HYDE, T. S., & JENKINS, J. J. Differential effects of incidental tasks on the organization of recall of a list of highly associated words. *Journal of Experimental Psychology*, 1969, 82, 472-481.
- JAMES, W. *Principles of psychology*. New York: Holt, 1890.
- JOHNSON, N. F. The role of chunking and organization in the process of recall. In G. H. Bower (Ed.), *The psychology of learning and motivation*. Vol. 4. New York: Academic Press, 1970.

- JOHNSTON, C. D., & JENKINS, J. J. Two more incidental tasks that differentially affect associative clustering in recall. *Journal of Experimental Psychology*, 1971, 89, 92-95.
- KINTSCH, W. Models for free recall and recognition. In D. A. Norman (Ed.), *Models of human memory*. New York: Academic Press, 1970.
- KOFFKA, K. *Principles of Gestalt psychology*. New York: Harcourt, Brace & World, 1935.
- KÖHLER, W. *Gestalt psychology*. New York: Liveright, 1947.
- LACHMAN, R., & FIELD, W. H. Recognition and recall of verbal material as a function of degree of training. *Psychonomic Science*, 1965, 2, 225-226.
- LACHMAN, R., LAUGHERY, K. R., & FIELD, W. H. Recognition and recall of high frequency words following serial learning. *Psychonomic Science*, 1966, 4, 225-226.
- LAUER, P. A., & BATTIG, W. F. Free recall of taxonomically and alphabetically organized word lists as a function of storage and retrieval cues. *Journal of Verbal Learning and Verbal Behavior*, 1972, 11, 333-342.
- LIGHT, L. L. Homonyms and synonyms as retrieval cues. *Journal of Experimental Psychology*, 1972, 96, 255-262.
- LIGHT, L. L., & CARTER-SOBELL, L. Effects of changed semantic context on recognition memory. *Journal of Verbal Learning and Verbal Behavior*, 1970, 9, 1-11.
- MANDLER, G. Organization and memory. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation*. Vol. 1. New York: Academic Press, 1967. (a)
- MANDLER, G. Verbal learning. In *New directions of psychology, III*. New York: Holt, Rinehart & Winston, 1967. (b)
- MANDLER, G. Organization and recognition. In E. Tulving & W. Donaldson (Eds.), *Organization of memory*. New York: Academic Press, 1972.
- MARTIN, E. Stimulus meaningfulness and paired-associate transfer: An encoding variability hypothesis. *Psychological Review*, 1968, 75, 421-441.
- MARTIN, E. Stimulus component independence. *Journal of Verbal Learning and Verbal Behavior*, 1971, 10, 715-721.
- MARTIN, E. Stimulus encoding in learning and transfer. In A. W. Melton & E. Martin (Eds.), *Coding processes in human memory*. Washington, D. C.: Winston, 1972.
- MCCORMACK, P. D. Recognition memory: How complex a retrieval system? *Canadian Journal of Psychology*, 1972, 26, 19-41.
- MCLEOD, P. D., WILLIAMS, C. E., & BROADBENT, D. E. Free recall with assistance from one and from two retrieval cues. *British Journal of Psychology*, 1971, 62, 59-65.
- MELTON, A. W. Implications of short-term memory for a general theory of memory. *Journal of Verbal Learning and Verbal Behavior*, 1963, 2, 1-21.
- MELTON, A. W., & MARTIN, E. (Eds.). *Coding processes in human memory*. Washington, D. C.: Winston, 1972.
- MIKULA, G. Der Einfluss mnemotechnischer Hilfen auf das Erlernen und Behalten verbalen Materials. *Psychologische Forschung*, 1971, 34, 312-324.
- MURDOCK, B. B. *Human short-term memory*. Potomac, Md.: Lawrence Earlbaum Associates, in press.
- MURDOCK, B. B., JR., & BABICK, A. J. The effect of repetition on the retention of individual words. *American Journal of Psychology*, 1961, 74, 596-601.
- NORMAN, D. A. Toward a theory of memory and attention. *Psychological Review*, 1968, 75, 522-536.
- NORMAN, D. A., & RUMELHART, D. E. A system for perception and memory. In D. A. Norman (Ed.), *Models of human memory*. New York: Academic Press, 1970.
- PAIVIO, A., & CSAPO, K. Picture superiority in free recall: Imagery or dual coding? (Research Bulletin No. 243) London: University of Western Ontario, Department of Psychology, 1972.
- POSNER, M. I., & WARREN, R. E. Traces, concepts, and conscious constructions. In A. W. Melton & E. Martin (Eds.), *Coding processes in human memory*. Washington, D. C.: Winston, 1972.
- POSTMAN, L. Short-term memory and incidental learning. In A. W. Melton (Ed.), *Categories of human learning*. New York: Academic Press, 1964.
- POSTMAN, L. A pragmatic view of organization theory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory*. New York: Academic Press, 1972.
- POSTMAN, L., ADAMS, A., & PHILLIPS, L. W. Studies in incidental learning: II. The effects of association value and of the method of testing. *Journal of Experimental Psychology*, 1955, 49, 1-10.
- PUFF, C. R. Clustering as a function of the sequential organization of stimulus word lists. *Journal of Verbal Learning and Verbal Behavior*, 1966, 5, 503-506.
- RIEGEL, K. F. Free associative responses to the 200 stimuli of the Michigan restricted association norms. (USPHS Tech. Rep. No. 8, Grant MH 07619) Ann Arbor: University of Michigan, 1965.
- SCHULMAN, A. J. Recognition memory for targets from a scanned word list. *British Journal of Psychology*, 1971, 62, 335-346.
- SHIFFRIN, R. M. Memory search. In D. A. Norman (Ed.), *Models of human memory*. New York: Academic Press, 1970.
- SHIFFRIN, R. M., & ATKINSON, R. C. Storage and retrieval processes in long-term memory. *Psychological Review*, 1969, 76, 179-193.

- SLAMECKA, N. J. Testing for associative storage in multitrial free recall. *Journal of Experimental Psychology*, 1969, **81**, 557-560.
- SLAMECKA, N. J. The question of associative growth in the learning of categorized material. *Journal of Verbal Learning and Verbal Behavior*, 1972, **11**, 324-332.
- THOMSON, D. M. Context effects in recognition memory. *Journal of Verbal Learning and Verbal Behavior*, 1972, **11**, 497-511.
- THOMSON, D. M., & TULVING, E. Associative encoding and retrieval: Weak and strong cues. *Journal of Experimental Psychology*, 1970, **86**, 255-262.
- TULVING, E. Theoretical issues in free recall. In T. R. Dixon & D. L. Horton (Eds.), *Verbal behavior and general behavior theory*. Englewood Cliffs, N. J.: Prentice-Hall, 1968. (a)
- TULVING, E. When is recall higher than recognition? *Psychonomic Science*, 1968, **10**, 53-54. (b)
- TULVING, E. Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory*. New York: Academic Press, 1972.
- TULVING, E., & OSLER, S. Effectiveness of retrieval cues in memory for words. *Journal of Experimental Psychology*, 1968, **77**, 593-601.
- TULVING, E., & PEARLSTONE, Z. Availability versus accessibility of information in memory for words. *Journal of Verbal Learning and Verbal Behavior*, 1966, **5**, 381-391.
- TULVING, E., & PSOTKA, J. Retroactive inhibition in free recall: Inaccessibility of information available in the memory store. *Journal of Experimental Psychology*, 1971, **87**, 1-8.
- TULVING, E., & THOMSON, D. M. Retrieval processes in recognition memory: Effects of associative context. *Journal of Experimental Psychology*, 1971, **87**, 116-124.
- TVERSKY, B. Encoding processes in recognition and recall. *Cognitive Psychology*, in press.
- UNDERWOOD, B. J. False recognition produced by implicit verbal response. *Journal of Experimental Psychology*, 1965, **70**, 122-129.
- UNDERWOOD, B. J. Attributes of memory. *Psychological Review*, 1969, **76**, 559-573.
- UNDERWOOD, B. J. Are we overloading memory? In A. W. Melton & E. Martin, (Eds.), *Coding processes in human memory*. Washington, D. C.: Winston, 1972.
- WATKINS, M. J. When is recall spectacularly higher than recognition? *Journal of Experimental Psychology*, 1973, in press.
- WICKENS, D. D. Encoding categories of words: An empirical approach to meaning. *Psychological Review*, 1970, **77**, 1-15.
- WINOGRAD, E., & CONN, C. P. Evidence from recognition memory for specific encoding of unmodified homographs. *Journal of Verbal Learning and Verbal Behavior*, 1971, **10**, 702-706.
- WINOGRAD, E., KARCHMER, M. A., & RUSSELL, I. S. Role of encoding unitization in cued recognition memory. *Journal of Verbal Learning and Verbal Behavior*, 1971, **10**, 199-206.
- WOOD, G. Category names as cues for the recall of category instances. *Psychonomic Science*, 1967, **9**, 323-324.
- YATES, F. A. *The art of memory*. Chicago: University of Chicago Press, 1966.
- YNTEMA, D. B., & TRASK, F. P. Recall as a search process. *Journal of Verbal Learning and Verbal Behavior*, 1963, **2**, 65-74.

(Received January 10, 1973)