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The constructive process of memory for sentences and pictures.

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THE CONSTRUCTIVE PROCESS OF MEMORY

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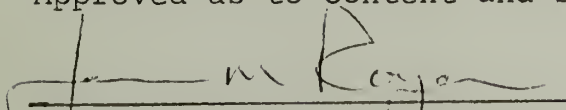
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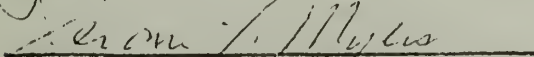THE CONSTRUCTIVE PROCESS OF MEMORY

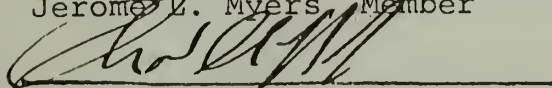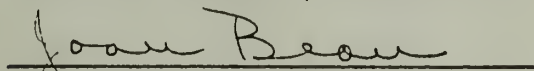FOR SENTENCES AND PICTURES

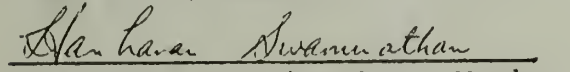A Dissertation

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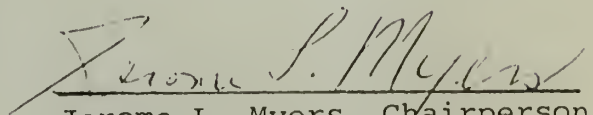
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April, 1975

The Constructive Process of Memory

for Sentences and Pictures

(April 1975)

Kathy Pezdek, University of Massachusetts

ABSTRACT

The purpose of the present study was to assess the effect of intervening items on the accuracy of recognition memory for pictures and sentences. Subjects were presented a sequence of 24 pictures and sentences, later followed by the presentation of 24 intervening items. Each intervening item corresponded to, but was in the opposite modality as one of the original items. These intervening items were either semantically relevant or irrelevant to the corresponding originals. Subjects then received a "same-different" recognition test which included original and changed items. The presence of a semantically relevant intervening item depressed the obtained values of d' and the probability of a hit, relative to the effects of an irrelevant intervening item. The data are discussed in terms of support for the integration property of constructive memory. The interpretation was that subjects semantically integrated the original items with the relevant intervening items and made subsequent recognition responses on the basis of the integrated memory.

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INTRODUCTION

LITERATURE REVIEW

An increasing number of studies in the human memory literature have been interpreted in terms of memory being a constructive process. The purpose of this paper to explicate and synthesize the vast body of research which has lead many psychologists to find the constructive approach to memory convincing.

The constructive position considers comprehension to be an elaborate process which depends on extra-sentence, as well as intra-sentence context. The constructive process is based on the interaction of the information presented, the context of that information and the existing knowledge schemata of the subject. This conception of memory has been elaborated to various degrees in several areas within psychology. These include: Gestalt psychology (Koffka, 1935; Bartlett, 1932), pragmatism (James, cf., 1970; Peirce, cf., 1968; Dewey, 1920, 1931), and more recently, contextualism (Jenkins, 1973, based on Pepper, 1942), constructionism (Piaget, 1970; Cofer, 1973) and assimilation theory (Bransford and Franks, 1971). Because the notion of a constructive memory has almost independently emerged from so many different sources, and because no one has sufficiently laid out and defined the theory specifically, the need for an integrative review such as this is particularly apparent.

The introduction to this paper discusses five topics regarding constructionism: (1) the word as a unit in language processing, (2) semantic prerequisites for comprehension, (3) integration of information in memory, (4) memory for original input, and (5) inferences formed from

material presented. These topics highlight facets of the significant effect of context dependence on constructive memory. Context dependence refers to the relationship between the material presented and the linguistic and situational setting in which it is couched.

The Word as a Unit in Language Processing

The first property of the constructive theory of memory to be discussed is that words do not have fixed meanings, and thus cannot be considered to be stable units of language. This view accepts that numerous meanings may be attributed to individual words but contends that for any one of these classes of meanings the range of meanings and the appropriate meaning specifically, is determined by the context of the word rather than by the absolute nature of the word alone. For example, the word "can" can mean small receptical for liquids, a trash container, a prison cell, etc. But even within any one of these classes of meanings, the context in which the word is presented determines the range of possible meanings (e.g., "Kick the can," "can of deodorant," "toss me a can of beer," "crushed can," etc.).

This view was expounded by Pepper (1942) as well as others more recently who contend that experiences consist of unambiguous "events" and are preserved in memory as such rather than as words. Events are subunits of experience which are charaterized by the fact that although they can be disected into components, they derive their meaning wholistically from the interaction of the experiencer with the experience and the setting of the experience, i.e., the context of the event. In reference to linguistic experiences, the event, being a perceived unit, does not necessarily correspond to grammatical or word boundaries; nor is the meaning of an event constant in different contexts. This is because the meaning of an

event can be derived from an accompanying gesture, a previous topic, pre-
sumed common knowledge, etc.

It is in part related to the realization that linguistic analysis
alone is insufficient to analyze intended meaning, that cognitive theories
of semantics have emerged and linguistic theories of semantics have with-
drawn from equating words with their reference. Reference refers to the
specification of the meaning of words in terms of the objects or events
they are concerned with. One obvious reason why meaning cannot be equated
with reference is because a single referent may be labeled by many words,
depending on the context, a particular woman may be a doctor, a driver, a
mother, an animal, an idol, Sue, etc. In other words, word meaning is
more than references.

Another reason, more to the point of this paper, why equating word
meaning with referent is inaccurate is because the choice of words in a
sentence is more a function of the speaker's knowledge and the environ-
mental context than it is a function of syntactic or semantic selection
restrictions (Ortony, 1973). Also, from the listeners point of view, the
meaning attributed to a sentence is as much a product of extra-linguistic
variables as it is a product of the specific words used. The perception
of a referent is a cognitive process, not a linguistic one. For example,
consider the "ambiguous" sentence provided by Katz and Fodor (1963),

The stuff is light.

The sentence is ambiguous because "light" may refer to color, weight,
level of involvement, etc. One way to disambiguate the sentence would be
to linguistically elaborate it,

The stuff is light enough to carry.

However, the same effect can be achieved simply by having knowledge of

context; if one person offers to help another person carry his groceries and hears the original sentence, the meaning is unambiguous. In other words, judging a sentence to be ambiguous or unambiguous may depend more on perceived (extra-linguistic) context than on linguistic knowledge. Perhaps, too, anomalous sentences are more a function of the limits of experience or imagination than incompatible semantic components. In reality, anomaly seems to be more related to (real or imagined) knowledge of the referent, than to the markers on the lexical items in the mental dictionary. Are the following examples anomalous?

        The honest snowball . . .
        The flying horse . . .
        Colorless green ideas . . .

(See Olson (1970) for the development of a theory of reference in terms of a cognitive theory of semantics.)

What evidence is there that words do not have fixed meanings and thus that words cannot be considered stable units of language comprehension?

Several studies support the notion that words do not play a static role in our language and that the context and thus the meaning of a word is affected by the learning strategy of the subject at the time of encoding. Hyde and Jenkins (1969) presented subjects with word lists and instructed them to use different strategies for learning. One group received comprehension instructions. Their task was to rate each word as being pleasant or unpleasant. Another group was instructed to use a formal task. This task was either to estimate the number of letters in each word or to decide if the letter e were present in each word. To summarize, all subjects were presented the same words but the context of the words was varied by the instructions. The question of interest was, did the change in contexts resultingly change the nature of the events in memory? The results

were that the comprehension group recalled the words at a higher rate and showed a higher degree of associative clustering than the formal group. A control group of intentional learners who performed no orienting task, surpassed the formal group but not the comprehension group in recall and associative clustering. These results were maintained even when the presentation duration was doubled and the list was presented twice before recall. Simlar results have been reported by Hyde (1973).

An alternative explanation of these data is that the comprehension task facilitated recall of the word list by highlighting intra-list associates. However, in a comparable study, Hyde and Jenkins (1973) included lists of both related and unrelated words. In both types of lists the task requiring comprehension resulted in a recall level twice as high as that resulting from the tasks not requiring comprehension.

Elias and Perfetti (1973) controlled word encoding and measured the effect on later recognition memory. Word encoding was directed by instructing subjects to simply learn a list of words or to produce rhymes, synonyms or associates for each word. When the recognition test items consisted of original words and associative distractors, the results reflected the superiority of instructions encouraging a semantic focus.

The results of these studies indicate that learning strategies (tasks) are part of the context and thus affect the processing of words. Further, these processed units, rather than the originally presented material are stored in memory. Mistler-Lachman (1972, 1974) and Rosenberg and Schiller (1971) have provided additional evidence for the relationship between learning strategies and comprehension using sentences rather than individual words.

Another way in which altering the context of individual words can be shown to affect the meaning attributed to the words is demonstrated in studies where words are provided context by the sentences in which they are embedded. Anderson and Ortony (1973) presented subjects with a series of sentences, followed by cued recall for the sentences. The cues for each sentence were chosen to be effective or ineffective for retrieval of the sentence, depending on the assumed mental representation of the original sentence. For example, some subjects saw the sentence,

The container held the apples.

The other half of the subjects saw,

The container held the cola.

The corresponding cues for the sentences were basket and bottle, exemplars of the words, container. If it were the case that the mental representation of the word container were not context-dependent than it would be predicted that the cues basket and bottle would be equally effective. On the other hand, if comprehension of the original sentence involved constructing a particularized and elaborated mental representation, then the effectiveness of each cue would depend on the details of the mental representation, i.e., basket would be a better cue for the first sentence, and bottle would be a better cue for the second sentence, despite the fact that the original sentence had the same subject, container. A significant effect of type of cue was reported in the direction predicted by the context-dependence hypothesis; cues close to the meaning of the original sentence were more effective than remote cues.

Tulving and Thomson (1973) have discussed similar results as examples of encoding specificity, where the context ("cognitive environment")

affects the access routes to the stored information. Similarity between encoding access routes and retrieval access routes consequently facilitates retrieval.

A second experiment in the study by Anderson and Ortony (1973) confirmed and extended the generalizability of the first study. It was suggested in the first experiment that subjects formed particularized mental representations of the sentences because the definite article in the beginning of each sentence implied that the sentence was predicating something about a specific thing, event, or person. Thus, in the sentences in the second experiment, the subject nouns were general terms. Subjects were presented sentences from 14 sets of four sentences each. One such four sentence set was the following:

    A. Nurses are often beautiful.
    B. Nurses have to be licensed.
    C. Landscapes are often beautiful.
    D. Taverns have to be licensed.

When cued with actress, sentence A was the target sentence; B was the subject control sentence; C was the predicate control sentence; and D was a double control sentence. When the cue was doctor, then B was the target sentence; A the subject control; D the predicate control, and C the double control. The following predictions were confirmed by the results. First, the probability that a certain cue allowed the retrieval of a target sentence was greater than the sum of the probabilities of the cue allowing the retrieval of the subject and predicate of the target sentence. This result supports the notion that the meanings of the individual words in a sentence interact in the process of constructing a mental representation of the sentence. Second, the probability of a cue facilitating the retrieval of either the subject or the predicate of the double control

sentence was zero. Had this probability deviated from zero, there would
be some doubt as to the construction of a particularized memory at the
time of encoding. From the results of this study it is apparent that the
mental representation of sentences is not simply the lexical readings of
the individual words.

Further evidence of the dynamic nature of words can be found in the
speech perception literature. Numerous studies have shown that the con-
text of a sentence functions to set the subjects to perceive the individ-
ual words (see Rubenstein and Aborn (1960) for a review of this litera-
ture). Miller, Heise, and Lichten (1951) showed that while listening to
sentences, subjects successfully used the context of the sentence to pre-
dict successive words. Subjects listening to a list of individual words,
by comparison, showed little predictive processing. Consequently, words
presented in a sentence context were perceived more accurately than the
same words pronounced separately as individual items in a list of test
words.

More recently, Leventhal (1973) examined the locus of the set effect
of sentence context on word perception. Subjects in this study were pre-
sented sentences or individual words and were tested for their accuracy
in identifying (1) the initial word of the sentence presented in noise
(Post-context), (2) the final word of the sentence presented in noise
(Pre-context), (3) the isolated words presented in noise (Control). The
result was a linear positive relationship between word predictability
(determined by the context) and intelligibility, such that

$$P(C/Post\text{-}context) > P(C/Pre\text{-}context) > (C/Control).$$

In the Post condition, the facilitative effect was attributed to subjects

delaying decision about the initial word in the sentence until the entire sentence was encoded. These studies support the notion that to consider words as stable units of language is to ignore the import of extra-linguistic factors on comprehension.

One question raised by the discussion of words as language units is exactly how does context affect the meaning of words? Does context operate by limiting or focusing in on the range of possible meanings of a word or does context operate by enhancing the realization of possible meanings? While this issue remains unanswered, it has been interestingly suggested by Stahlin (cf., Blumenthal, 1970);

> It hardly needs to be said that individual words must be understood before the sentence-thought can be comprehended. But the important fact is that the reverse relationship also exists; with the majority of words we do not at all arrive at a recognition and assimilation of word meaning separate from sentence comprehension. As soon as the sentence thought is assimilated in consciousness—and the tendency to do this as soon as possible is always there—then sentence comprehension determines the manner in which the individual words are assimilated as parts of the sentence context. (pages 52-53)

Semantic Prerequisites for Comprehension

The second basic property of the constructive theory of memory is that the stored form of linguistic information in memory represents a context-dependent interplay between linguistic input and prior (possibly extra-linguistic) knowledge. This characteristic of constructive memory suggests more specifically that prior knowledge often provides the semantic prerequisites for comprehension. This view of memory has been suggested by Butler (cf., Blumenthal, 1970):

> Given two speakers of the same language, no matter how well one of them structures a sentence, his utterance will fail if both parties do not share the same field

to some degree . . . there are inner aspects of the
field, such as an area of knowledge, or outer aspects,
such as objects in the environment . . . The structure
of any particular language is largely field independent,
being determined by its own particuconventional rules,
but the field determines how the rules are applied.
(page 56)

Bransford and Johnson (1972) tested this hypothesis by comparing the

recall of subjects presented a passage without accompanying context with

the same passage with accompanying context. The absence of context was

controlled for by using novel materials such as the prerequisite semantic

information was not likely to be in the subjects pre-experimental reper-

tory. An example of such a passage (without context) is the following:

If the balloons popped the sound wouldn't be able to
carry since everything would be too far away from
the correct floor. A closed window would also
prevent the sound from carrying, since most buildings
tend to be well insulated. Since the whole operation
depends on a steady flow of electricity, a break in
the middle of the wire would also cause problems. Of
course, the fellow could shout, but the human voice is
not loud enough to carry that far. An additional
problem is that a string could break on the instrument.
Then there could be no accompaniment to the message.
It is clear that the best situation would involve less
distance. Then there would be fewer potential problems.
With face to face contact, the least number of things
could go wrong.

Context was provided by the inclusion of an appropriate picture. The ap-

propriate context for the balloon passage is included in Figure 1. Using

dependent measures of comprehension rating (on a scale of one to seven),

and idea units recalled, it was reported that providing a context had a

significant facilitative effect. Stronger evidence for the fact that the

picture constituted a prerequisite setting for comprehending the passage

is the result that the group presented the context and then the passage

outperformed the group presented the same passage twice (context 2) by

twofold. Further, the context-after group did not recall significantly

more than the no context group, suggesting that the superiority of the
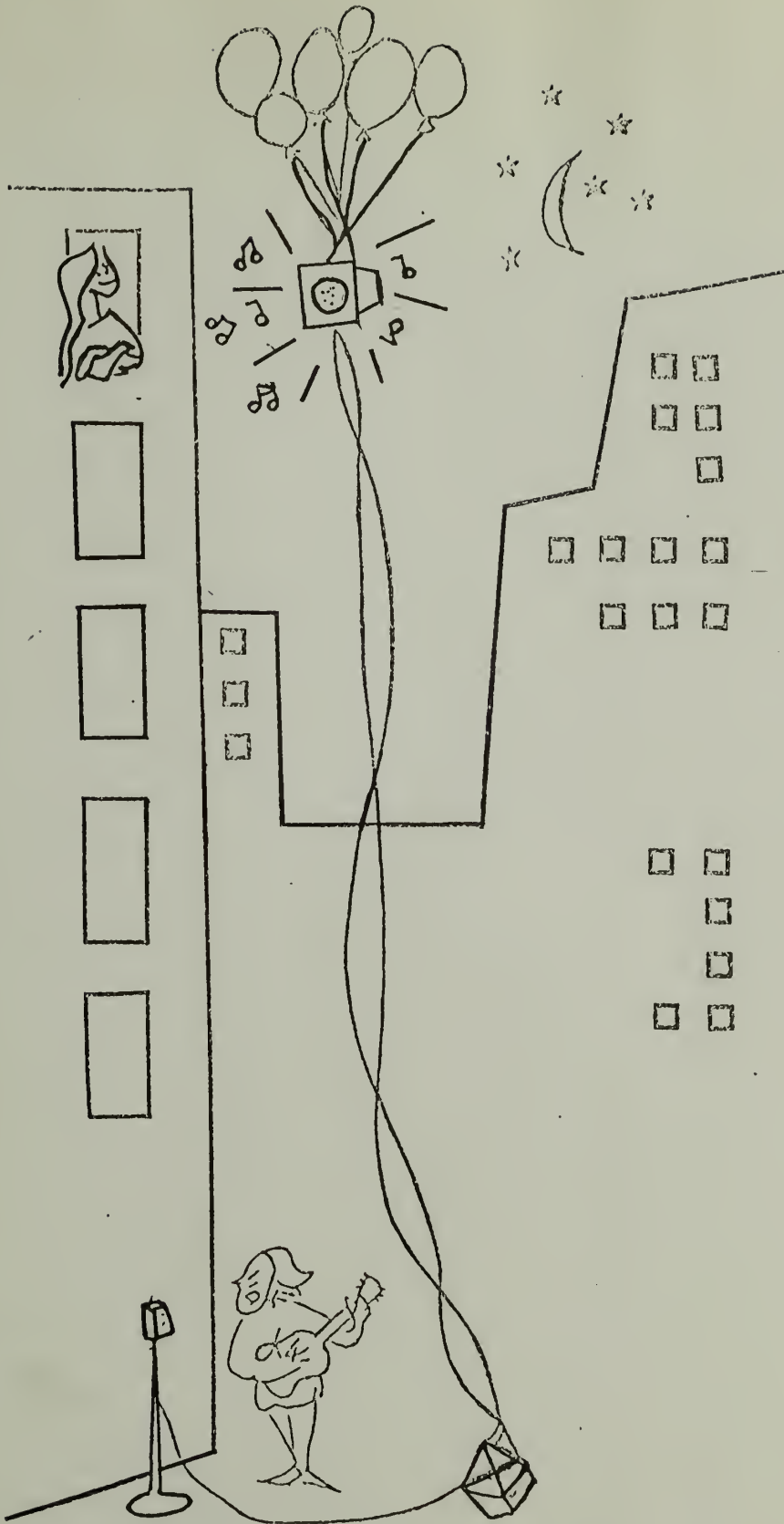
Figure 1. Appropriate context for the balloon passage used by Bransford and Johnson, 1972.

context effect was not due to facilitating subjects' generation of ideas compatible with the picture. To refute the interpretation of these results as evidence for the importance of providing retrieval cues rather than evidence for prerequisite knowledge, a fourth comparison was included. A partial context picture was derived which contained all of the objects in the appropriate context picture, but the arrangement of the objects was different. The effect of presenting the partial context picture was inferior to that of the context before condition and not significantly different from the context 2 group. Clearly, supplying the picture before presenting the passage provided a context which facilitated comprehension of the novel passage.

Johnson, Doll, Bransford, and Lapinski (1974) followed up this experiment with a study in which subjects read sentences with an appropriate context, inappropriate context or no context. The materials were presented at a fast rate (one second inter-sentence interval) or a slow rate (seven second inter-sentence interval). They found no effect of presentation rate when comparing the appropriate context and no context groups. However, the inappropriate context retarded over-all recall relative to the no context group with the effect greater at the fast presentation rate than at the slow rate.

Dooling and Mullet (1973) replicated the Bransford and Johnson result in a study in which context was provided using theme rather than picture. By presenting the theme before reading, after reading, or not at all, they provided evidence that the locus of this effect was at input.

The Bransford and Johnson (1972) study demonstrated the importance of prior knowledge in comprehending verbal material by using a novel passage with which it was unlikely that subjects were familiar. However, several

other studies have illustrated that relevant prior knowledge alone is not sufficient to insure comprehension. These studies involve the comprehension of materials where the semantic prerequisites are available to the subjects from their prior knowledge, but these prerequisites are not necessarily activated at the time the materials are presented. Evidence supporting this phenomenon has been discussed by Bransford and Johnson (1973). Anecdotal evidence can be seen in trick sentences such as, Pas de la Rhone ques nous. This sentence is usually approached with an inappropriate set, yet is easily comprehended when subjects are told that it is a mispelled English sentence beginning with the word Paddle.

Dooling and Lachman (1971) investigated the role of prerequisite semantic knowledge by manipulating thematic title (absence or presence) and syntactic constraint of the passage (random words, random phreases, or words in a list). The passages were about "Christopher Columbus Discovering America" and "The Space Trip to the Moon." The results were that recall was significantly higher when the topic was presented before the passage as compared with the no topic condition, and that the facilitative effect of topic increased with syntactic constraint. Similarly, Pompi and Lachman (1967) had subjects read verbal passages presented one word at a time on cards. The cards were arranged so as to represent either a syntactically organized paragraph or random order. In a word recognition test that followed, subjects saw old words and new words of which half were high thematic associates to the passage and half were low thematic associates. Subjects tended to falsely recognize highly thematic words which had not actually been previously presented. Further, the difference between the relatively high rate of high-thematic word errors and the lower low-thematic

word error rate was greater with syntactic order than with random order.

Another way to manipulate context using thematic idea has been demonstrated by Dooling and Christiansen (1974) and Sulin and Dooling (1973, 1974). In the later studies, subjects read the same biographical passages and were told that the main character was either a famous person (Adolf Hitler or Helen Keller) or a fictitious person (Gerald Martin or Carol Harris). It was hypothesized that the subjects who were told that the paragraph they would read was about a famous person would integrate the information in the paragraph into an already existing elaborate mental schema, thus providing information extraneous to the input sentence. This hypothesis was supported by the results. On a sentence recognition test, subjects in the famous person condition were less accurate than subjects in the fictitious person condition, the difference accountable by false positive recognition errors. Further, these errors were thematic; when the test sentence was a high thematic associate, the difference between recognition scores for the famous person and fictitious person was greater than when the test sentence was a low thematic associate. This suggests that recognition of material from a passage describing a person who is already familiar to the subjects draws on knowledge already existing in the mental schemata and resultingly accuracy is affected.

A more subtle type of thematization has been examined in several studies by manipulating recall prompts for sentences. When presented a sentence such as,

The admiral captured the bandit,

the subject noun and the object nound are equally good as recall prompts when the two nouns have equal imagery value, and more important to the

point, when the sentence is presented without context (Elias, 1973; Per-
fetti, 1973; Perfetti and Goldman, 1974; Perfetti and Tucker, 1973). How-
ever, when the sentence is embedded in a context paragraph, and the subject
noun in the sentence is thematized (i.e., the passage is primarily about the
admiral), the subject is superior to the object as a recall prompt. Fur-
ther, thematizing the object of the sentence improved its effectiveness as
a prompt without decreasing the effectiveness of the subject prompt. The-
matization is measured by the number of propositions which contain a cer-
tain referent. The relative effect of the subject noun and the object noun
as recall prompts for a sentence has also been demonstrated by Ehri and
Rohwer (1969). By manipulating the syntactic and semantic characteristics of
verbs which linked noun paired associates, they found that object related
verbs provided less facilitation to later recall than subject related verbs.

Perfetti and Goldman (1973) studied the locus of this effect by mani-
pulating thematization (subject or object), topicalization (active or
passive), recall prompt (recipient or agent), and retention interval (15
minutes or two days). They found that the agent of a sentence was a better
recall prompt than the recipient and that a thematized noun was a better
prompt than a noun which had not been thematized. Also, an interaction
was reported such that the effectiveness of the agent prompt was not affec-
ted by its position in the original sentence (as indicated by active vs.
passive form), but the recipient was a better prompt when it was in the
first noun position in the sentence (passive form) than when it was second.
The context of a sentence and the extent to which the context thematizes
aspects of the sentence is thus shown to have a significant effect on sen-
tence comprehension.

Context has also been manipulated by the use of various incidental learning tasks and been shown to resultingly affect comprehension. Bobrow and Bower (1969) attempted to explain why subjects who generated a verb to link noun pairs could better remember the second noun when cued with the first noun than could subjects who were supplied the linking verb. As a result of imposing various conditions on the subject as the noun pairs were presented, they primarily found that the conditions which encouraged the subjects to generate a specific context for each noun pair aided retention of the noun pair. Examples of facilitative conditions are (1) generating sentences to relate noun pairs, (2) distinguishing the meaning of an ambiguous noun on the basis of its context sentence, and (3) providing a plausible continuation sentence from a sentence provided. Their results support the general notion that comprehension improves recall, and more specifically, since subjects performed better in the generate sentence condition than in the supplied sentence condition, they concluded that the subjects' relation to the context of the noun pairs seems to have had significance to memory. Additional examples of facilitation have been reported as a result of contrasting a group required to supply a sentence mediating paired associates with a group which did not mediate (Jensen and Rohwer, 1963; Rohwer, 1966; Rohwer and Lynch, 1967). Using sentences rather than word pairs, Anderson, Goldberg, and Hidde (1971) reported somewhat the same result. Subjects who read sentences aloud and had to fill in blanks in the sentences were better able to recall the sentences than subjects for whom the blanks were filled in (e.g., Dictionaries list words in alphabetical _____). Rosenberg and Schiller (1971) compared the recall of subjects who employed an incidental semantic task while learning sentences with subjects

who employed an incidental non-semantic task. The incidental non-semantic task involved estimating the number of letters in each sentence as it was presented. The incidental semantic task required subjects to rate the relative familiarity of each sentence. They found that subjects who employed an incidental semantic task while learning sentences, were subsequently able to recall the sentences at a higher rate than subjects who employed an incidental non-semantic task. As previously mentioned, Hyde and Jenkins 1969) found that subjects who employed incidental tasks at the time of input, were required to use word pairs as semantic units and consequently recalled more of the word pairs than subjects who used the words as physical objects. In a similar task using sentences, Mistler-Lachman (1974) found that tasks demanding "deeper comprehension" of sentences facilitated recall. In order of facilitation (from lowest to highest) the tasks which she used were having subjects (1) judge the meaningfulness of a presented sentence, (2) judge if a sentence followed from a given context, (3) form a continuation sentence.

Kintsch, Crothers, and Jorgensen (1971) also had subjects perform various activities during each short study period following the presentation of three stimulus nouns. Their results suggested that the type of incidental task affects the context and thus the storage of the words in memory. They concluded, however, that it was not the semantic processing of the words per se which facilitated retention in their short-term memory task, but rather the process of successfully "grouping" or "chunking" the words in memory. The "chunking" argument, although consistent with the studies presented which used isolated words as stimuli, seems less appropriate to studies involving memory of sentences or more complex verbal materials.

The studies discussed above have been presented in support of the second major characteristic of constructive memory to be discussed in this paper; that the stored form of linguistic information represents a context dependent interplay between linguistic input and extra-linguistic knowledge. More specifically, the level of comprehension, as manipulated by thematization, incidental task, etc., can provide a variable context for any given linguistic material being learned.

Integration

The third characteristic of constructive memory is that subjects combine isolated ideas into more integrated ideas in memory, and the resulting integrated ideas are qualitatively different from the isolated ideas, not just more complicated. On another level, this notion has been expressed in the statement that the total is more than the sum of the parts. There are two ways of looking at this qualitative difference between the simple ideas input and the integrated ideas stored in memory. First a subject, when presented linguistic information, seldom treats the material simply as objects to be remembered. Convincing evidence suggests that subjects do not appear to be only storing the surface structure (Bregman and Strasberg, 1968; Honeck, 1971, 1973a; Sach, 1967a, b) or even the deep structure (Bransford, Barclay and Franks, 1972; Bransford and Franks, 1971) of individual sentences. In general, at the time of input, subjects draw on a broad range of world-knowledge and spontaneously integrate the information, making inferences and assumptions about the individual ideas presented.

A second way of looking at the differences between the isolated ideas presented and the integrated ideas stored can be seen as a part-whole relationship, to some extent similar to the fundamental principle of Gestalt

psychology. This principle is basically that perception of the whole takes on "emergent properties" which transcend the properties of the parts. These emergent properties represent aspects of a psychological organization which tend to develop in the direction of a stable, wholistic mental organization. To the point of this paper, this suggests that complex linguistic materials convey qualitatively more information than is expressed by any of the component parts.

This relationship between linguistic part and whole is also strongly suggested by a characteristic of constructive memory mentioned earlier in this paper--that comprehension determines the quality of events in memory. The notion that subjects treat linguistic information as cues to activate and modify mental knowledge structures, rather than simply as information to be stored (e.g., the "reappearance hypothesis," cf. Neisser, 1967) clearly suggest that what is stored is thus qualitatively different from what is input. The mental representations of objects become richer as the environment and one's knowledge are enhanced. Piaget and Inhelder (1973), who have dedicated their lives' work in psychology to studying epistomology from this perspective, contend that,

> Moreover, perception is invariably extended by inter-
> pretations based on assimilation to the sensorimotor,
> conceptual, pre-operational or operational schemata,
> and it is obvious that remembrance must impinge on
> these interpretations or significations, no less than on
> the antecedent perceptions themselves. (page 1)

The tendency of subjects to use the information expressed in individual sentences to form wholistic mental representations which transcend the meaning expressed in the individual sentences, receives experimental support from studies by Barclay (1973), Bransford and Franks (1971), Honeck (1973b), and with children, Barclay and Reid (1974a). In the study

by Barclay, subjects were presented similarly construced sentences which
randomly described a linear array of five animals, one pair in each sentence.
One such sentence was,

The bear is to the left of the mouse.

Half of the subjects (the imagers) were informed that the sentences they
would hear described a linear order of animals and that their task would be
to figure out the order of the animals. The other half of the subjects,
not informed of the general structure of the array, attempted to memorize
the sentences. Five minutes after the subjects heard the acquisition set
of eleven sentences, they were presented with an unexpected recognition
test. The recognition sentences consisted of true and false sentences
which had or had not been included in the acquisition list. The results
were that the imagers rated all of the true sentences as "old" and all of
the false sentences as "new," regardless of whether they had been previ-
ously presented or not. The recognition judgments of the memorizers,
however, while being consistently lower than the imagers, depended more
on their linguistic similarity to the acquisition sentences than on their
"truth value." Since the array was never presented in its exact linear
order, but was only described by eleven sentences drawn from the possible
set of 25 (five nouns taken two at a time), it can be assumed that the
imagers had thus constructed the array mentally. The imagers were using
the acquisition sentences as base information from which to form the over-
all structure of the array. Thus, later comparisons of recognition sen-
tences with the stored representations of the input material resulted in
the verification of all test sentences consistent with the constructed image
and the rejection of test sentences which did not accurately describe the

array.

Another study demonstrating that subjects use individual sentences to construct wholistic representations which are qualitatively different from the sentence input, is that by Bransford and Franks (1971). The task of subjects in this study was similar to that utilized by Barclay. Subjects were presented sentences in the acquisition phase which described various aspects of composite complex sentences in various combinations, and were later presented old and new sentences to recognize. In this study, each complex sentence represented the relations among four simple declarative sentences. The sentences which the subjects were presented were composed of combinations of one, two, or three of the four simple sentences. Thus, the number of semantic relations expressed in any one sentence varied. The result of most interest here is the direct relationship between subjects' confidence in their recognition judgments and the extent to which the test sentence exhausted the four simple sentences contributing to the complex sentence. That is, subjects were more confident that test sentences were old when the sentences were comprised of a greater number of semantic propositions, even when the test sentences were new. These results suggest that subjects were integrating the semantically related information at the time of presentation even though the information had been presented in individual, nonconsecutive sentences. Later recognition then, was a process of comparing the test sentence with the integrated information stored and responding on the basis of the extent to which the test sentence matched the memory.

The results of Honeck (1973b) also support the notion that subjects construct and store abstract representations of verbal information at the

time of input. Subjects heard several one sentence proverbs, followed

later by one supplementary sentence for each proverb. The supplementary

sentences were repetitions of the proverb, grammatical transformatons of

the original (T), parasyntactic paraphrase (P), or unrelated control sen-

tences (U). An example of a proverb and the corresponding sentence con-

ditions is the following:

  Proverb: Great weights hang on small wires.
    T: On small wires hang great weights.
    P: Many important things are dependent for
      their outcome on details, small wires,
      that is.
    U: Wrapping certain packages with small
      wire is a good idea sometimes.

The test phase consisted of prompted free recall of the proverbs. The

proverbs supplemented with parasyntactic paraphrases were later recalled

at a significantly higher rate than those in the other three conditions,

including proverb repetition. The expanded context of the parasyntactic

interpretation seemed to have a facilitative effect due to the redundency

with the conceptual base of the original proverb. The superiority of the

parasyntactic condition over the repetition condition strongly suggests

that the stored form of the proverbs consisted of the constructed repre-

sentation rather than an interpretative form more isomorphic with the

original.

Memory for Information Presented

The previous section offered support for the notion that information

is spontaneously integrated in memory. A logical consequence of integra-

tion is that memory for the original material does not endure. This is the

next point to be considered. The fourth characteristic of constructive

memory is that once individual language segments are integrated and fused

into events, subjects cannot recover the original pattern which had provided support for the construction made.

Bartlett (1932) provided a classic demonstration of this point. Bartlett held that in remembering, the subject reconstructs the products of constructive acts of the past. One convincing way in which he demonstrated this quality of remembering was by presenting subjects with a passage from "The War of the Ghosts" and having them free recall it at various intervals after the reading. The general finding was that what endured in memory was a consolidation of the points related to the theme, integrated across sentence boundaries. As the delay of test increased, the amount recalled decreased, usually while retaining the essence of the passage. Bartlett contended that the transformation of the original passage resulted from adaptive and organizational factors operating on the individual items repeatedly reconstructing the information and incorporating it into a knowledge system. This is how Bartlett explained the fact that the subjects could not recall the original passage, only their constructed version of it.

The nature of what does not endure in memory has been addressed by Sachs (1967a, b). In the second of these studies, subjects heard 28 passages, each interrupted by a bell and then a repetition of a previously heard sentence. The test sentence was repeated either exactly as it had been previously heard, with an active-passive reversal, with a change in the form of the sentence, or semantically changed. The amount of interpolated material between presentation and test was varied from 0 to 160 syllables. The task of the subjects was to identify each test sentence as changed or identical, when changed to indicate whether the change was

in the meaning or the form of the sentence and to specify their degree
of confidence in each judgment. As would be predicted from the work of
Bartlett, the results were that subjects were significantly more accurate
in recognizing semantic changes than syntactic changes or identical sen-
tences, as the lag increased. Results of Perfetti and Garson (1973) con-
firm those of Sachs using lag times varying from four minutes to one week.
These data support the notion that subjects transform information very
shortly after presentation and that the nature of the transformation is
related to the meaning of the material. Once the construction has occurred,
however, subjects do not have access to the original material.

The notion demonstrated by these examples, that is that once individual
segments are integrated into wholistic units, the segments are not retained,
receives support from numerous areas in psychology. Posner and Keele (1968)
presented subjects with randomly constructed dot patterns followed later by
a recognition test. The stimulus set was composed of three prototype pat-
terns and four distortions of each prototype. In the presentation phase,
subjects were presented only the patterns specified as the distortions, and
were instructed to classify the patterns into three categories. Subjects
were informed whether each response was correct or incorrect. In the
second phase of the experiment, subjects were shown several patterns and
were asked to sort them into the three categories again. The patterns were
old distortions, prototypes (not previously seen) and new distortions. The
old distortions were classified with 87% accuracy. The prototypes were
classified with a significantly inferior accuracy of 73%. Since the dis-
tortions were recognized at the same level of accuracy as the prototypes
which had not been previously seen by the subjects, it was suggested that

the enduring mental representation of visual patterns is in the form of an abstraction of the exemplar patterns. When the retention interval was extended to a period of one week (Posner and Keele, 1970; Strange, Keeney, Kessel, and Jenkins, 1970) recognition accuracy for old distortion decreased considerably, while memory for the prototypes declined only slightly. This demonstrates the stability in memory of the abstraction despite the fading memory for the individual exemplars from which the abstraction derived.

Using line drawings of faces for stimuli, Reed (1970) reported similar recognition results. The faces were differentiable on the basis of four characteristics--nose length, mouth position, distance between the eyes and the height of the forehead. In the first part of the experiment, subjects classified the pictures into two categories. Results suggested that while classifying the pictures, subjects tended to abstract a prototype to represent each category and then classify each test item on the basis of its similarity to the two prototypes. Later recognition rates were higher for the prototypes (which subjects had never seen) than for control items.

Similarly, Esper (1925) trained subjects to label items in a systematically ordered color-form matrix. Later recognition indicated that the subjects had abstracted the system of the matrix but had little memory for the specific instances that had previously been presented, despite the fact that subjects had seen each of the instances several times. Studies by Segal (1962), Foss (1968), and Keeney (1969) have found similar results. The indication of these studies is that with a limited set of individual items in a system to learn, subjects can retain memory for the items. But with a large set of items, the (adaptive and economical) learning process seems to be to abstract the pattern or system of the instances, thereby

losing the capability to discriminate instances presented from acceptable instances in the system. This is termed an adaptive process because given the limited capacity of long-term memory, it is more likely of adaptive value for a person to remember a generalized system (from which particulars can be generated) than to remember seven plus-or-minus two (Miller, 1956) of all of the possible acceptable particulars.

The evidence above supports the notion that integration of instances into abstract systems is a common memory strategy. More specifically now, two qualitites of integration in memory will be discussed. The first of these is that integration occurs on the basis of semantic import and re-latedness, regardless of temporal proximity. This was demonstrated in the previously discussed study by Bransford and Franks (1971). In that study, subjects in the first part of the experiment were presented 24 acquisition sentences arranged so that in each successive sequence of four sentences there was one sentence from each of the four base idea sets. Despite the fact that each sentence was separated from the next semantically related one by at least four sentences with an intervening task following each sentence, results indicated that integration of the separate but semanti-cally related sentences did occur. This aspect of their data has been discussed elsewhere (Bransford and Franks, 1970).

Sulin and Dooling (1974) in an extension of the previously discussed experiment, Sulin and Dooling (1973), reported that subjects reading a prose passage about a famous person performed less well on a later recog-nition test of the sentences presented, relative to recognition test scores for a passage about a fictitious person. In addition, the inferior recog-nition scores of the famous person passage further decreased and thematic

intrusion errors increased as the retention interval increased (from five minutes to one week). The subjects were apparently integrating the information in the famous person passage into a previously established knowledge base for that person and the congruence with prior knowledge increased over time. In other words, the fact that the two sources of information (prior knowledge and the passage) were greatly separated in time did not seem to interfere with their integration.

The second specific quality of the integration process in memory is that this fusion of ideas into integrated units is based on the appropriateness of the integration process to the items involved. This point is suggested by considering the following four sentences:

(1) The first man on the moon became a national hero.

(2) Neil Armstrong has several children.

(3) The first man on the moon has several children.

(4) Neil Armstrong became a national hero.

In most imaginable contexts, it would be considered appropriate to integrate only sentences (1) and (4), and (2) and (3). The description of Neil Armstrong as "the first man on the moon" is inappropriately matched with "has several children" as is the name "Neil Armstrong" inappropriately matched with "became a national hero" in the general context. The test of appropriateness is that the semantic connection between the description-subject and the predicate is closer that that between the name-subject and the predicate and visa versa. This relationship is taken up in more detail by Ortony (1973). Ortony and Anderson (1973) used materials such as those above and demonstrated subjects' ability to perceive "appropriateness." They presented subjects with 32 sentences from a set of 16 quadruples like the one above. Following this was a recognition test on the full set of 64 sentences.

The results confirmed the appropriateness of use hypothesis anticipated. Incorrect rejections were most often of sentences involving inappropriate uses, and false alarms tended to be of sentences involving appropriate uses. The subjects tended to encode and then integrate the sentences in the semantically most acceptable way.

Inference

The fifth and final characteristic of constructive memory following from the proposition that comprehension is context dependent, is that logical inferences are commonly made from information presented. "Inference" referes to information which is based on what is presented but is a continuation or extension of the original input. The constructive theory of memory argues that comprehension involves more than concretizing or simply preserving what is input, and consequently subjects have substantially more information at their disposal than is actually presented. This additional information can often be described as logical inferences of the original material.

Evidence for spontaneous and induced production of inferences comes from numerous sources. The previously discussed study by Barclay (1973) reported that subjects inferred the order of a linear array of five animals when presented a limited number of sentences which only randomly described the array by discussing the animals' positions, two animals at a time. Although this study illustrates the process of integration in memory, it also evidences subjects' ability to make inferences which go beyond the information presented. Barclay discussed this study as support for the notion that "the memory representation of a sentence can contain more information than was linguistically expressed." Other studies which

reported subjects' ability to infer relationships and construct linear arrays from partial input have been carried out by Steinheiser (1972) and Potts (1972).

Subjects also have demonstrated spontaneous production of inferences concerning more general spatial relations among objects. Bransford, Barclary, and Franks (1972), had subjects listen to a set of sentences and then later complete a recognition test on those sentences. An example of the materials is the following sentence pair:

(1)   The painter stood on the platform and the boy sat under him.

(2)   The painter stood near the platform and the boy sat under him.

An individual subjects' acquisition list included one of the above sentences as:

(1')   The painter stood on the platform and the boy sat under it.

(2')   The painter stood near the platform and the boy sat under it.

The critical difference is that sentence (1') is implied by sentence (1) but sentence (2') is not implied by sentence (2). If subjects make inferences about the spatial relations among objects when the basic information is presented, then subjects presented sentence (1) in the acquisition set would be unable to differentiate sentences (1) and (1') in the recognition test. Subjects presented sentence (2), however, would be expected to correctly recognize sentence (2') as a new sentence. This predicted outcome was reported by Bransford, Barclay, and Franks in support of the inference hypothesis.

Barclay and Reid (1974b) conducted a more pointed test of the inference

hypothesis by asking whether different types of inferences from the same memory representation were distinguishable. The five inference types were derived from a base structure which expressed the relative values of a white, green, blue, and yellow car in terms of the dimensions, weight, and speed. Subjects were presented an acquisition set of eight sentences and were later (unexpectedly) asked to recall the sentences. The set of inferences (true, non-old sentences) recalled was then subdivided into inference types. The following excerpt from their study describes the inference types used as classification categories:

(1) Old: acquisition sentences; The white car is lighter than the blue one, and The blue car is lighter than the yellow one.

(2) Equivalent: a logical equivalent of an Old: The blue car is heavier than the white one.

(3) Correlate: sentence which maps a relationship stated in an Old from one dimension to the other; The white car is faster than the blue one.

(4) Correlate Equivalent: the logical equivalent of a Correlate; The blue car is slower than the white one.

(5) Transitive 1: a transitive inference in which both premises and conclusion refer to the same dimension; The white car is lighter than the yellow one.

(6) Transitive 2: a transitive inference in which the premises refer to one dimension, the conclusion to the other; The white car is faster than the yellow one.

The results were that these categories of inferences were not distinguished from each other, nor from the original items in memory. Looking at the groups data over four trials, the proportions of inferences recalled (commission errors) reflected the proportion represented on each trial. The proportions did not decrease over trials as would have occurred if the categories had been distinguishable in memory.

Johnson, Bransford, and Solomon (1973) have also demonstrated sub-
jects ability to remember inferences of sentences. Subjects read descrip-
tive stories such as,

> John was trying to fix the bird house. He was pounding
> (looking for) the nail when his father came out to
> watch him and to help him do the work.

Control subjects read the same description with the verb phrase changed
as indicated by the parenthesis. A later recognition test included in-
ference items. The inference of the above example was,

> John was using the hammer to fix the bird house when
> his father came out to watch him and to help him do
> the work.

On the recognition test, subjects were at least as likely to "recognize"
inferences to be old sentences as they were to recognize actual old sen-
tences. This was not the case with the control group, which did not differ
from the experimental group on mean number of yes-responses during recog-
nition on old sentences but had significantly fewer such responses on in-
ference sentences. The experimental subjects, then, were not able to
differentiate between old sentences and sentences consonant with implica-
tions of the old sentences.

Similarly, Fillenbaum (1974) had subjects read sentences, some of
which were written in an uncommon form. The extraordinary sentences were
disordered conjunctive sentences (e.g., John dressed and had a bath) and
disjunctive sentences with "perverse" threats (e.g., Get a move on or you
will catch the bus). Subjects were instructed to, "paraphrase or re-
phrase the sentences as accurately as you can, conserving meaning as com-
pletely as possible." The subjects interpreted most sentences in the
direction of conforming to customary order and connections among events.

In this example, prior knowledge and expectation played such an important role in the interpretive process that it was actually the inferred meaning of sentences which was retained, rather than that presented. This issue of the relative roles of inference and literalism has been explored in pilot work discussed in a thesis prospectus by Till (1974). Till constructed a list of sentence pairs which were identical except for the subject-word. The subject noun for each sentence was chosen so as to limit the range of possible interpretations of the sentence. An example of one sentence pair is:

> The parents fixed the airplane.
> The soldier fixed the airplane.

Given these two sentences, the effectiveness of the recall cue, glue or wrenches, depends on its relation to the inference made during comprehension. For example, subjects reading the first sentence are likely to infer that the instrument of fixing was glue (not wrenches), and thus glue will serve as a more effective recall cue for that sentence. This study is similar to that mentioned by Anderson and Ortony (1973) using sentences of a different form.

Tzeng (1972) has reported data which support the notion that subjects make inferences based on materials presented and over time construct schemas which integrate the original information and the inferences. In this study, Tzeng used a continuous presentation-recognition procedure. Subjects were presented three blocks of 12 semantically interrelated sentences, one sentence at a time. For each sentence, the subjects had to respond "old" or "new." Some of the sentences were repetitions of old sentences; other sentences were not old but were logical inferences of the old sentences. In the beginning of the sequence the new valid sentences were

correctly classified as new a high percentage of the time. As the sequence progressed, however, the new valid sentences were more often classified as old. Tzeng discussed this result as a consequence of subjects developing schematic representations of the sentences over time and making their subsequent judgments on a comparison of the presented sentence with the schema rather than with the stored form of the individual sentences.

Kintsch and Monk (1972), required subjects to read a paragraph and then answer a question which required the subjects to make an inference from the information in the paragraph. Paragraphs were constructed in pairs such that each pair contained the same propositions but were arranged in either a syntactically simple or syntactically complex structure. The results of this study were that although subjects took more time to read and comprehend the syntactically complex paragraphs, there was no comparable difference in accuracy of correct inference or in reaction time to verify inferences based on the paragraphs. The experimenters concluded that the information was stored similarily for both simple and complex paragraphs and that subjects were able to draw inferences from the presented information accurately and with facility.

Similarly, but with reading time controlled, Rosenberg and Parkman (1971) presented subjects with information describing a set of genealogical relations and used measures of speed and accuracy to draw conclusions about how the subjects stored and retrieved the information in memory. The passages were presented in paragraphs or as a sequence of sentences. In both conditions, the order of the sentences was scrambled or logically ordered. They found that subjects were able to make accurate inferences based on the information presented. Using response latencies to indicate

"distance" between stored properties in memory, they reported that response latencies for verifying specific inferences did not vary with order of passage presentation. That is, different organizations and memory loads did not affect the form of the representation in memory but did reduce the amount learned in the less ordered conditions.

The ability of subjects to make logical inferences from information presented has also been demonstrated in children. In a study similar to that by Tzeng (1972), Paris and Carter (1973) found that both second- and fifth-grade children made many false positive recognition responses to sentences which were new, but semantically consistent with old sentences. Paris and Upton (1974) ran a prompted recall study much like the studies by Till (1974), and Anderson and Ortony (1973) with kindergarten, second- and fourth-grade children. They used recall cues which were instrumental case relation inferences of the previously heard sentences. Consistent with the adult data, they found that post-kindergarten children spontaneously constructed and remembered inferences from sentences presented. Their data also suggested that this ability increases with age.

Data have been presented in support of the occurrence of inferences constructed from information presented. Implicit in this point is the notion that mental representations may contain more information than exists in the linguistic input. Given this point, then an interpretive approach to semantics in terms of a deep-structural analysis alone is not sufficient to fully analyze the cognitive process of sentence memory.

Summary and Implications

This paper has reviewed a body of research which argues for a constructive theory of memory. The data presented support five characteristics of

the constructive process. These characteristics are the following: (1) That individual words do not have fixed meanings and thus cannot be considered to be stable units of language. Several studies were presented which demonstrate that even the meaning of individual words, often considered to be a fixed and stable unit of language, is determined by various manipulations of context. (2) That the comprehension process assumes semantic prerequisites. These semantic prerequisites include thematization of materials as well as prior knowledge on the part of the subjects. (3) That information is integrated in memory. Integration is reflected by subjects reorganizing, consolidating and otherwise constructing representations in memory from the ideas presented. (4) That memory for the exact material input does not endure. Once language segments are integrated in memory, the original pattern of input cannot ordinarily be recovered. (5) That logical inferences are spontaneously constructed from information presented. Data presented affirm the notion that while subjects integrate information presented, they have substantially more information at their disposal in memory than has actually been presented. This additional information often represents inferences drawn from the original input.

The five characteristics support the general context-dependent nature on comprehension and memory. Each characteristic highlights the fact that subjects do not treat sentences or even words as isolated linguistic objects, and also, that what is remembered from a comprehended sentence often exceeds the product of a surface- or even deep-structured analysis. An adequate deep structural analysis may be a necessary but certainly not sufficient tool for deriving what is retained in sentence comprehension.

The research presented in this paper argues that a constructive process of memory is a more accurate and integrative way to characterize com-

prehension and memory than is usually considered. The constructive orientation has direct implications to real world experiences outside of the laboratory tradition because it takes into account the multitude of contextual factors which operate to affect memory. These factors are usually eliminated or ignored in standard memory research. The requisite conditions for construction are not artificial or contrived, but are representative of every day experiences as well as most situations in memory and comprehension research.

Further, this orientation is consistent with the notion that memory is an ever-developing, dynamic process. Another implication of the material presented in this paper is that any model of memory which does not include a mechanism for reconstructing information stored in memory as new, related information is processed, falls short of looking at the whole picture of memory. A more complete and generalizable view of memory is to consider it as an interaction of the information presented with the context in which it is presented and the existing knowledge schemata of the subject.

PROPOSED STUDY

The aim of this dissertation is to begin to explicate the variables underlying the cognitive process of construction im memory. The preceeding portion of this paper focused on defining aspects of constructionism. Attention will now be directed to variables which affect the constructive process of comprehension. The conditions underlying cognitive construction have not been elaborately examined in the literature. The previously discussed data suggest that the general prerequisites are (a) that the materials involved be semantically or contextually related, and (b) that the learning task be at least minimally demanding such that memorization of individual items is precluded. These conditions are representative of everyday experiences as well as most situations in comprehension research.

The variable of interest in the present study is modality. This study is concerned with the integration of semantically related information across modality conditions. Integration occurs when two or more propositions which were presented as separate, make contact with each other in memory and resultingly are considered as related aspects of some greater memory. Integration of semantically related information within the verbal and pictorial modalities has been convincingly demonstrated already. That integration of semantically related verbal materials occurs has been supported in numerous sources discussed earlier in this paper. Similarly, in the visual mode, recall for pictorial materials has been shown to be better when the stimulus elements are presented in unitized, meaningful, interactive context than in an isolated form (Bower, 1970a, 1972; Epstein, Rock and Zuckerman, 1960, and with children, Horowitz, Lampell and Takanishi, 1969; Milgram, 1967; Odom & Nesbitt, 1974; Paris & Mahoney, 1974; Rohwer,

1970). The semantically integrated form of presentation is assumed to resemble an easily encoded and retrieved form, facilitative to memory.

The primary experiment in the present study deals with integration of information which is presented partly in the verbal modality and partly in the pictorial modality, that is, integration across modality. Subjects were presented information about specific scenes in the pictorial and verbal (visual) modes and tested on the extent to which the two types of information were integrated. The sequence consisted of slides presented one at a time, displaying pictures and sentences grouped into a presentation phase followed by a test phase. In the presentation phase, subjects viewed a series of slides describing several scenes. Each scene was described by two slides, a single picture and some time later a sentence (the intervening item), or first a sentence and later a picture (the intervening item). Half of the intervening items were semantically relevant to the originally presented item with which it had been matched, and half of the intervening items were semantically irrelevant. The test items were then slides which were in the mode of the initial slide for each scene and either described an integration of the two previous slides related to that scene or repeated the first slide in the set. The task of the subjects was to decide if each test slide were the same as one they had seen previously or a new slide.

If semantic integration occurs across modalities, then it would be expected that subjects would falsely recognize as old, new test sentences which integrated the information previously presented in a semantically relevant sentence and a picture. Additionally, under this expectation, subjects would be expected to falsely recognize as new, old test items

for which a semantically relevant intervening item had been presented.
Subjects would be expected to correctly recognize old and new items in
the absence of semantically relevant intervening items.

This study offers information directly related to the nature of the
constructive process. It does not, however, necessarily distinguish which
of several types of storage units more accurately characterize long-term
memory. The nature of the storage unit is relevant to this experiment
because the study involves the processing of verbal and nonverbal materials.

PROCESSING OF PICTORIAL AND VERBAL INFORMATION

There are two predominant hypotheses describing the nature of the
storage of pictorial and verbal information in long-term memory. These
will be referred to as (1) the dual-coding hypothesis and (2) the concep-
tual-propositional hypothesis. According to the dual coding hypothesis,
information is stored in memory in two distinct forms, basically a verbal
form and a nonverbal or imaginal form. The alternative hypothesis contends
that information is stored in memory in a common, abstract informational
base, and the two symbolic form are only superficial expressions of this
base store. Ordinarily, memory researchers assume the veracity of one or
the other of these positions and then operate within the framework of that
position. The results of this study would not necessarily favor one or
the other of these hypotheses, but an interpretation of the results relies
on an understanding of the two positions.

Dual Coding Hypothesis

The dual-coding hypothesis assumes that verbal and nonverbal informa-
tion are processed and stored in distinct but interconnected systems, and
that the nature of the symbolic information in the two systems is qualita-

tively different (Paivio, 1974). The qualitative distinction between the two codes is specifically that information concerning nonverbal objects is primarily stored in the form of imagery. The content of this store can be retrieved in a parallel process. Information which is expressed in the verbal mode and is processed sequentially is stored similarly as an abstraction of the verbal form and is retrieved serially. (For a discussion of this property in terms of specificity of hemispheric processing, see Kinsbourne, 1974; Seamon, 1972; Seamon and Gazzaniga, 1973.) This characterization of the verbal and imagery codes is not meant to imply that the mental code is an unabstracted, unfiltered version of the real experience. The stored codes are interpretations and constructions of the input material.

The property of independence of the verbal and the nonverbal systems implies that one system can be active without the other, or both systems can be processing concurrently. At the same time, however, there are interconnections between these two independent systems. Verbal descriptions can arouse images, and pictures or images can arouse verbal labels. These properties of independence and interconnectedness are characterized in the heuristic diagram of the dual coding hypothesis presented in Figure 2. Information which is in either an imagery or verbal form is processed and stored in one of the two modality-specific stores. Verbal materials directly access the verbal store and nonverbal materials directly access the imagery store. Verbal information can access or be transformed into imaginal information and vice versa only indirectly after it has been initially processed by the system compatible with the input.

Evidence favoring the dual-coding hypothesis comes from numerous

Modality-Specific
Processing & Storage
System

VERBAL MATERIAL — INTERPRETATION & PRODUCTION RULES ◄—► VERBAL
(Input/Output)

NONVERBAL MATERIAL — INTERPRETATION & PRODUCTION RULES ◄—► IMAGERY
(Input/Output)
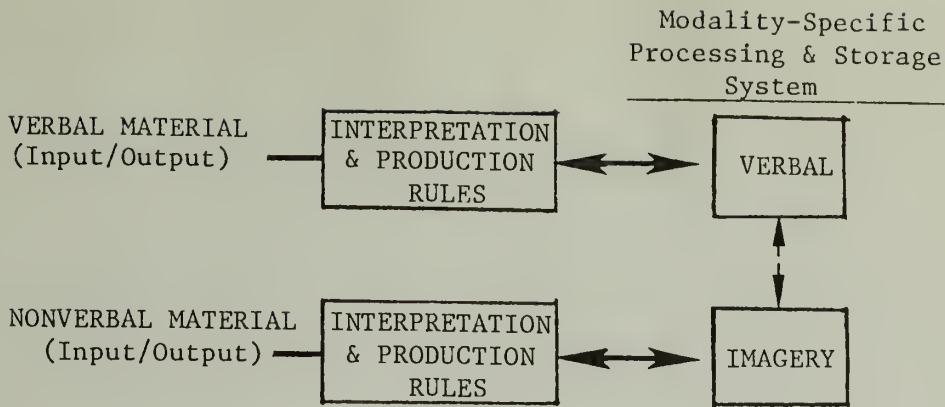
Figure 2. Heuristic diagram of the dual-coding hypothesis

Modality-Specific   Modality-free
Processing System   Storage System

VERBAL MATERIAL — INTERPRETATION & PRODUCTION RULES ◄—► VERBAL ◄ — ABSTRACT
(Input/Output)   INFORMATION
                                                                  BASE
NONVERBAL MATERIAL — INTERPRETATION & PRODUCTION RULES ◄—► IMAGERY —►
(Input/Output)
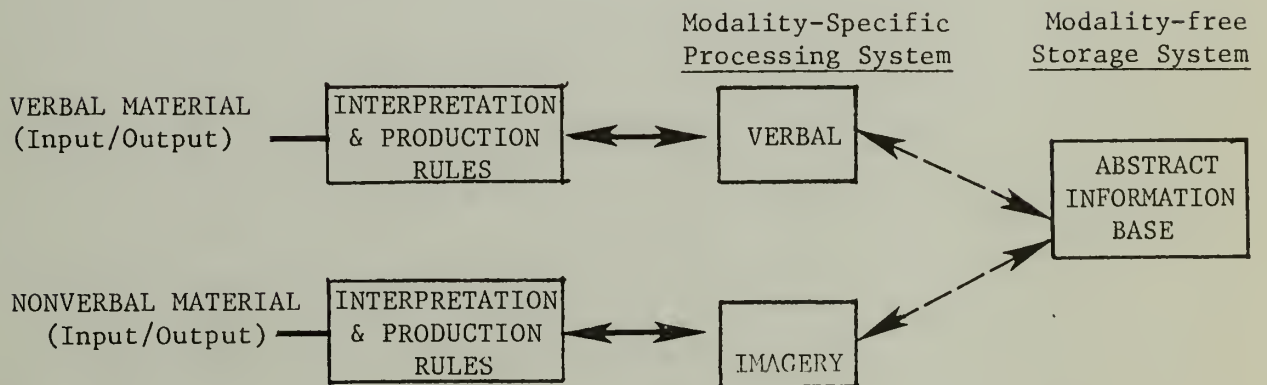
Figure 3. Heuristic diagram of the conceptual-propositional hypothesis

sources. Seamon (1973) has reviewed the behavioral and neurological data supporting the separate coding and storage of verbal and nonverbal information. Summaries of psychological research supporting the dual-coding hypothesis have been published by Bower (1970b, 1972), Paivio (1969, 1974) and Paivio and Csapo (1969).

Conceptual-Propositional Hypothesis

The conceptual-propositional hypothesis contends that all knowledge whether derived from verbal or nonverbal sources is represented in a common memory store. The form of the information in this store can be characterized as abstract propositions about properties of objects and relations between these objects. This representation is neutral with respect to modality. The conceptual-propositional hypothesis is outlined in the heuristic diagram in Figure 3. As the figure indicates, information input in either modality is processed in that modality but then only the abstracted informational base is stored in long-term memory. This stored information is then equally accessible to output in either the verbal or imaginal form. This position is depicted in most recent memory models which claim to represent the total content of memory within a common network (e.g., Anderson and Bower, 1973; Collins and Quillian, 1972; Kintsch, 1972; Rumelhart, Lindsay and Norman, 1972). A recent paper by Pylyshyn (1973) espouses the general conceptual-propositional hypothesis by arguing that the components of imaginal and verbal memory representations on some atomic level must be identical. More to the point of this paper, Chase and Clark (1972) carried out several studies in which subjects were asked to compare the information presented in sentences and pictures. They concluded that:

. . . visual and auditory images are modality-specific
representations corresponding to more general modality-
free representations, loosely called here meaning.
There is evidence that meaning is the more basic re-
presentation for comparisons, durable memory, and the
like, while images are working models for deriving new
and different abstract representations. (p. 232)

Picture Superiority

In addition to discussing the dual-coding hypothesis and the con-

ceptual-propositional hypothesis, a third issue relevant to the topic,

processing of pictorial and verbal information, is that picture memory

is in many respects superior to memory for verbal information. The

overwhelming memory capacity for pictorial materials has been demonstrated

in numerous studies. Nickerson (1965) presented subjects with 600 black-

and-white photographs representing a broad spectrum of subject matter, at

the rate of five seconds each. The first 200 pictures were original items

with no duplications. The rest of the slides comprised the recognition

test. Half of the subsequent 400 slides were duplicates, separated from

the original by 40, 80, 120, 160 or 200 slides. The average performance

was at an accuracy level or 95% correct. There was a significant effect

of lag such that the accuracy level was 97% at lag 40, but still 87% at

lag 200. Similarly impressive results were reported with a delayed recog-

nition test (Nickerson, 1968). Haber (1970) presented subjects with 2,560

photographs over the duration of several days at the rate of ten seconds

per slide. Subjects were later able to correctly recognize 85-95% of the

stimuli. Recognition memory for pictures was contrasted with recognition

memory under similar conditions for words and sentences by Shepard (1967).

Subjects viewed approximately 600 words (common nouns and adjectives),

sentences, or pictures (colored magazine advertisement-like pictures).

Accuracy rates for the three conditions in the forced-choice recognition test were, pictures 98%, words 90% and sentences 88%. The later two rates are not significantly different. Similarly, using a free recall measure, Bevan and Steger (1971) reported a positive relationship between item concreteness and recall using pictures, concrete nouns and abstract nouns.

In a less direct way, the superiority of nonverbal memory over verbal memory is suggested by the facilitative effect of imagery in verbal learning tasks. This effect has been observed in two types of experiments. (1) Subjects who are simply instructed to learn the materials presented, consistently learn high-imagery or concrete materials faster than low-imagery or abstract materials (Begg, 1972; Bower, 1970a, 1970b; Johnson, 1972; Paivio, 1969; Smyth and Paivio, 1968). And (2) instructions to image or unitize relationships within materials improves retention of the materials (Anderson, 1971; Rohwer, 1970). Reviews of the research substantiating the facilitative effect of imagery have been written by Bower (1970b) and Paivio (1971).

The conceptual-propositional hypothesis accounts for picture superiority in terms of a combination of speculative factors. One factor is that subjects engender facilitative mnemonic coding strategies when imagery instructions are suggested or when pictorial materials are presented. These coding strategies allow more information to be taken into the abstract informational base from pictures (Dallett and Wilcox, 1968; Nelson, Metzler and Reed, 1974). Another suggested factor is that pictures and concrete materials are encoded and efficiently stored as propositions involving spatial relationships, and that this feature of propositions facilitates retention.

The dual coding hypothesis accounts for picture superiority by several, as yet indefinitely proposed hypotheses (Paivio and Csapo, 1973; Paivio, Rogers and Smythe, 1968). The strongest statement of explanation is that pictures are encoded with two overlapping traces in memory, resulting from verbalizing and imaging to the pictures. Another hypothesis is that the spatial organization of the imaginal store is a more efficient, more ac-cessable store than is the sequentially organized verbal store. In a given amount of time, more information can resultingly be taken in from a picture than from prose describing the picture.

The issue of how pictorial and verbal information is processed is clearly unresolvable from the existing data. However, the arguments are relevant to the present study which hypothesizes that the semantically relevant content of two messages will be integrated, even if the messages are presented in different modalities. If the dual-coding hypothesis is actually a more accurate representation of long-term memory, than semantic integration of verbal and nonverbal information would rely on an active network of interconnections between the two separate stores. If, on the other hand, the conceptual-propositional hypothesis more accurately char-acterizes long-term memory, than it would be assumed that the propositions representing the separately input but semantically related messages would be integrated with facility in the common store. The effect of superior memory for pictures may, however, overshadow the effect of semantic inte-gration if subjects integrate the information in the picture and the sen-tence of each set while retaining visual memory for the original pictures presented. The recognition test in the present study would not rule out this possible effect. If results are that information is integrated when

the modality of the test item is verbal but not when the test item is pic-
torial, than superior memory for pictures would necessarily be a factor in
interpreting the results.

Experiment I

METHOD

Subjects

Fifty-six undergraduates in psychology courses at the University of
Massachusetts served as subjects. They were run in groups of fourteen
subjects each. Each group received a different order of presentation of
the items in each phase of the experiment. At the time of selection,
subjects were told only that they would be participating in a verbal and
pictorial memory experiment.

Materials

The materials were divided into two categories, verbal and pictorial.
Each category was composed of twelve basic sets of items. A verbal set
consisted of two presentation items and one test item. In the verbal cat-
egory, the first item of a set was always a sentence (S_1), the intervening
item was a picture (RP or IP), and the test item was a sentence (S_1 or S_2).
On half of the trials the test sentence was the same as the originally
presented sentence and on half of the trials it was the changed version of
the original. All of the items in a verbal set described a concrete scene.
The first sentence (S_1) described a general scene. The relevant interven-
ing picture (RP) supplemented the sentence by providing an additional detail
of the scene. The S_2 test sentence incorporated the pictorial detail into
the otherwise identical version of S_1. An example of a verbal set is:

S_1: The bird was perched atop the tree.

RP: A picture of an eagle perched on top of a tree.

S_2: The eagle was perched atop the tree.

All sentences were constructed using a similar grammatical structure. The

complete set of materials is included in the Appendix.

Similarly, in the pictorial category the first presentation item was always a picture (P_1), the second item was a sentence (RS or IS), and the test item was always a picture (P_1 or P_2). On half of the trials the test picture was the same as the originally presented picture, and on half of the trials it was the changed version of the original. All pictures were simple line drawings in black and white. The first picture (P_1) presented a general scene. The relevant intervening sentence (RS) described the pictorial scene and additionally highlighted a specific detail of the picture. The highlighted detail was either a new detail in the original pictorial scene or a changed old detail in the scene. The P_2 test picture was identical to P_1 with the addition of the specific detail incorporated into the picture. An example of a pictorial set is:

P_1: A picture of a car parked by a tree.

RS: The car by the tree had ski-racks on it.

P_2: A picture of a car with ski-racks on it parked by a tree.

In both verbal and pictorial sets of items, the relevant intervening item (RS or RP) focused on a specific instance of the general category presented in the original item of the set. The instances were highly associated with the general items. This was achieved by using the Battig and Montague (1969) category norms when possible as a source for selecting items. Six sets of the verbal items were drawn from this source. The category items selected from the norms were rated as the forth to the seventh most frequent associates to the category names. The remaining items were constructed to resemble these six.

In the control condition the intervening items were six pictures (IP)

and six sentences (IS), constructed using the same procedure used to gen-erate the relevant items, but semantically irrelevant to the original presentation items. The subject matter presented in the irrelevant items did not overlap with other items. The complete set of items is included in the Appendix.

Design

The design of the experiment is depicted in Table 1, together with an indication of the expected outcomes. A four factor design was utilized. Each subject was presented with both pictorial and verbal material, seman-tically relevant and irrelevant intervening items, and both changed and unchanged test items. Fourteen subjects were randomly assigned to each of four conditions of presentation order. In arranging the four orders, the asssignment of type of intervening item and type of test item was random-ized each time, as well as the order of presentation of the items, with the restriction that no more than three sentences or three pictures be presented sequentially. This variable was included to enhance the gener-alizability of the results.

Procedure

Subjects were told that they would be presented a continuous series of slides, some of which would be pictures and some of which would be sen-tences. The sequence included 24 original presentation items, followed by 24 intervening items, a delay task, and then 24 test items. The delay task was a three-minute Peterson and Peterson (1959) counting task in which sub-jects counted backward by threes from randomly designated numbers, and wrote the number sequences on a sheet of paper.

Subjects were instructed to try to comprehend the meaning of each of

Table 1

Experimental Design

Original Items	Intervening Items	Test Items	Correct Response	Expected Relative Outcomes
	RS	3 — P_1	"SAME"	Low Hit Rate
		3 — P_2	"CHANGED"	High False Alarms
P_1	IS	3 — P_1	"SAME"	High Hit Rate
		3 — P_2	"CHANGED"	Low False Alarms
	RP	3 — S_1	"SAME"	Low Hit Rate
		3 — S_2	"CHANGED"	High False Alarms
S_1	IP	3 — S_1	"SAME"	High Hit Rate
		3 — S_2	"CHANGED"	Low False Alarms

24 — 12 — P_1; 12 — S_1. 6 to each of RS, IS, RP, IP.
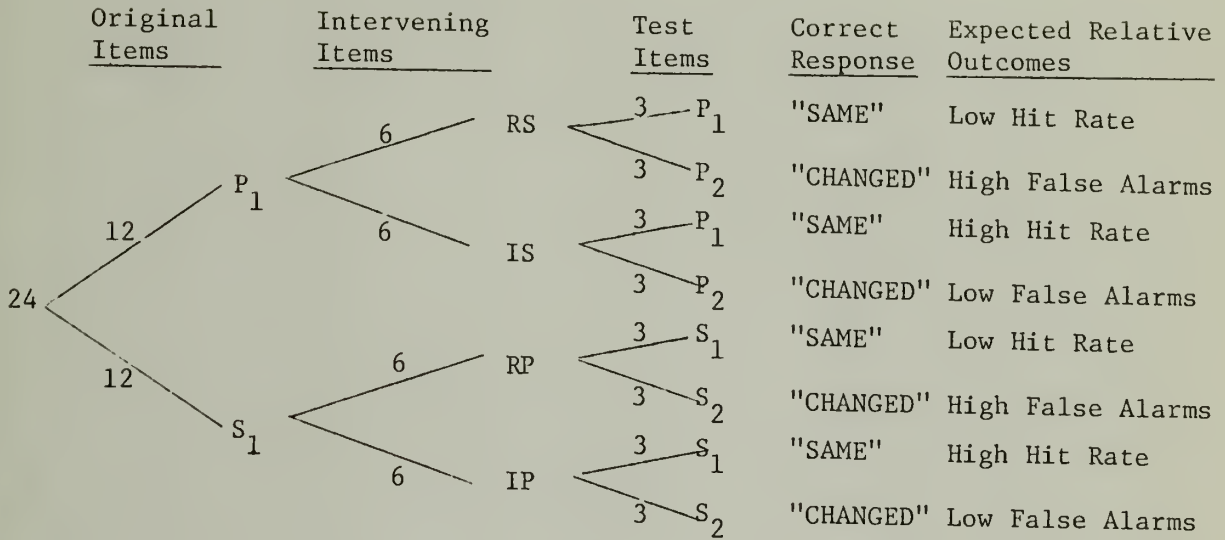
the 48 items in the presentation phase as this would be important in a later part of the experiment. In the recognition test the subjects had to decide if each slide was old or new. A slide was old if it was the same as one they had seen earlier ("same"). A new slide was the changed version of an earlier slide ("changed"). In addition, subjects were asked to rate their confidence in making each response on a five-point scale.

The slides were presented by a Kodak Carousel slide projector with a shutter attachment regulated by a millisecond timer. During the presentation phase, slides were exposed for three seconds with a two and a half second interval between slides with the shutter closed. In the test phase, the slides were exposed for three seconds with six seconds between slides to allow subjects to respond.

<div align="center">RESULTS</div>

The data were scored in several different ways. The dependent variables analyzed were accuracy, accuracy adjusted for confidence, confidence ratings, and signal detection measures. The signal detection analysis was included because the conditions of the experiment suggested that response bias as well as sensitivity might affect the accuracy data. Because the signal detection analysis was particularly revealing, attention will be focused primarily on these results. Analyses of the two measures of accuracy will not be presented, as these results provided no additional information.

Signal Detection Data

The dependent variables in the signal detection analysis were d' scores, B scores, the probability of a hit, and the probability of a false alarm. The mean values for each of these variables are presented in Table 2 as a function of the type of intervening item and the modality of the

Table 2

Mean Values for Each Signal Detection Variable as a Function of Type of Intervening Item and Modality

Dependent Variables

Intervening Item Modality	d'		B		P(Hit)		P(False Alarm)	
	Relevant	Irrelevant	Relevant	Irrelevant	Relevant	Irrelevant	Relevant	Irrelevant
Pictures	2.00	2.89	10.86	9.17	.78	.90	.40	.37
Sentences	2.55	2.78	41.68	34.33	.63	.70	.17	.19

test item.

It should be noted that there is some ambiguity involved in analyzing the signal detection parameters in this study, particularly the B values, due to the fact that the probability values on which these measures are based have a limited, fixed number of values. This is because the primary independent variables occurred as within-subject variables and produced insufficient data. As Table 1 indicates, each subject contributed only three responses to each of the eight stimulus conditions. As a consequence, the actual values of d' and B, computed over individual subjects for each condition, are somewhat inflated as compared with the same values computed on the group means. However, plots of the two ways of determining d' and B values appear almost identical in direction and magnitude of difference. For this reason, the signal detection results are discussed on the basis of the values computed on individual subjects, since the quantitative distortion in the individual values discussed did not alter the qualitative pattern of outcomes in the experiment.

The analysis of d' values will be presented first as this measure is most relevant to the hypotheses being considered in this study. An analysis of variance was carried out on the d' scores for each subject. There were three independent variables in this analysis, order of presentation (four orders), modality (pictures and sentences), and type of intervening item (semantically relevant or irrelevant). Type of test is not included as a separate independent variable in this analysis but does contribute to the outcome, as hit data are based on old test items and false alarm data are based on the new test items. The results of this analysis are reported in Table 3. The critical finding was that subjects were significantly more

Table 3

Analysis of Variance for Signal Detection Measures of d', B, P(Hit) and P(False Alarm)

Source of Variance	df	d' MS	d' F	B MS	B F	P(Hit) MS	P(Hit) F	P(False Alarm) MS	P(False Alarm) F
Order (O)	3	5.91	1.93	1391.90	.93	.1819	3.33*	.1011	1.26
Modality (M)	1	2.77	.86	43873.88	31.26**	1.6691	28.78**	2.3618	34.58**
Intervening Item (I)	1	17.39	6.25**	1143.07	1.10	.5081	12.36**	.0045	.09
S (O)	52	3.06		1494.84		.0547		.0805	
OM	3	8.95	2.77*	356.96	.25	.0867	1.49	.0766	1.11
OI	3	4.18	1.50	687.07	.66	.0264	.64	.1184	2.31
MI	1	6.09	1.35	449.33	.18	.0316	.58	.0403	.64
SM (O)	52	3.23		1403.56		.0580		.0683	
SI (O)	52	2.78		1036.90		.0411		.0513	
OMI	3	12.62	2.81*	2489.09	3.08*	.0635	1.17	.2810	4.48
SMI (O)	52	4.49		809.12		.0545		.0627	

*Significant at .05 δ level

**Significant at .01 δ level

sensitive when an irrelevant item intervened between the original and the test item (d' = 2.83) than when the intervening item was relevant (d' = 2.28), F (1, 52) = 6.25, p < .01. In addition to this main effect, there was a significant first order interaction of order x modality, F (3, 52) = 2.77, p <.05, and a significant second order interaction of order x modality x intervening item, F (3, 52) = 2.81, p < .05. Because order was confounded with day of the week and time of day, it is difficult to interpret any order effects. Effects of order will be reported but not discussed due to the fact that they are uninterpretable and psychologically unimportant.

The same analysis was performed with B values as the dependent variable. These results appear in the second panel of Table 3. The main effect of modality was significant, F (1, 52) = 31.26, p <.01, with B values higher in response to sentences (B = 38.00) than in response to pictures (B = 10.01). This result indicates that subjects had a bias to respond "new" to sentences and a bias to respond "old" to pictures. There was also a significant second order interaction of order x modality x intervening item, F (3, 52) = 3.08, p <.05. The results of the analysis of the cutoff values (c) duplicated that of the B values and thus will not be presented.

Analyses were carried out on the hit [P(Hit)] and false alarm [P(False Alarm)] data to assess the effect of the type of intervening item on the different decision conditions in the study. Although this analysis is somewhat redundant with the analysis of d' values, it is presented because the specific predictions specified in Table 1 were in terms of the values of P(Hit) and P(False Alarm). Also, the analyses of the P(Hit) and P(False Alarm) separate out the effects of type of test.

An analysis of variance carried out on the hit date [i.e., P("old"/ old)] resulted in three significant main effects. First, the hit rate for pictures was significantly greater than that for sentences (.84 and .67, respectively), F (1, 52) = 28.78, p < .01. Second, the type of inter-vening item was significant, F (1, 52) = 12.36, p < .01, in the direction that the hit rate for irrelevant items was significantly higher than that for the relevant items (.80 and .71, respectively). Third, order was also significant, F (3, 52) = 3.33, p < .05. No interactions were significant on the basis of probability of a hit data. These results are included in the third panel of Table 3.

Applying the same analysis to the probability of a false alarm data [i.e., p ("old"/new)] resulted in a significantly higher false alarm rate to pictures (.39) than to sentences (.18), F (1, 52) = 34.58, P < .01. The second order interaction of order x modality x type of intervening item was also significant, F (3, 52) = 4.48, p < .01. The fourth panel of Table 2 presents these results.

A comparison of the obtained probability of a hit and probability of a false alarm data presented in Table 4 with the predicted outcomes spec-ified in Table 1 reveals a consistent pattern. In the pictorial mode, the hit rate was higher when an irrelevant item intervened than when a relevant item intervened (.90 vs. .78). Also, the false alarm rate was greater when a relevant item intervened than when an irrelevant item intervened (.40 vs. .37). This difference in false alarm rates was not significant. In the verbal modality, the difference between the comparable hit rate values was significant in the predicted direction (irrelevant = .70, relevant = .63). The false alarm rates to sentences did not differ with type of

Table 4

Obtained Mean Hit and False Alarm Data

Original Items	Intervening Items	Test Items	Obtained Values
	RS	P_1	$P(Hit) = .78$
		P_2	$P(F.A.) = .40$
P_1			
	IS	P_1	$P(Hit) = .90$
		P_2	$P(F.A.) = .37$
	RP	S_1	$P(Hit) = .63$
		S_2	$P(F.A.) = .17$
S_1			
	IP	S_1	$P(Hit) = .70$
		S_2	$P(F.A.) = .19$

intervening item (irrelevant = .19, relevant = .17).

Confidence Rating Data

Confidence ratings ranging from zero to 15 were analyzed to assess the effect of the treatment on the confidence with which subjects expressed judgments. The four independent variables in this analysis were order (four orders), modality (pictures and sentences), intervening item (relevant and irrelevant) and type of test (old and new items). Subjects responded with significantly more confidence to pictures (12.4) than to sentences (11.2), $F (1, 52) = 44.57$, $p < .01$. The modality x test type interaction was also significant, $F (1, 52) = 7.97$, $p < .01$; subjects were more confident in responding to sentences when the test item was new (11.7) than when the test item was old (10.7), but there was no such difference in responding to pictures (12.3 and 12.5 respectively). The type of test x intervening item interaction was also significant, $F (1, 52) = 12.78$, $p < .01$; subjects were more confident in responding to old test items (11.9) than to new test items (11.5) when an irrelevant item had intervened but were more confident in responding to new test items (12.5) than old test items (11.3) when a relevant item had intervened. This interaction is illustrated in Figure 4. The order x test item interaction was also significant, $F (3, 52) = 3.51$, $p < .05$. Because of the significance of the intervening item x test type interaction, an additional analysis was carried out on these data. The confidence ratings on new test items only were computed for correct vs. incorrect responses under the conditions of the relevant vs. irrelevant intervening items. No significant differences resulted from the simple effects tests on these data.
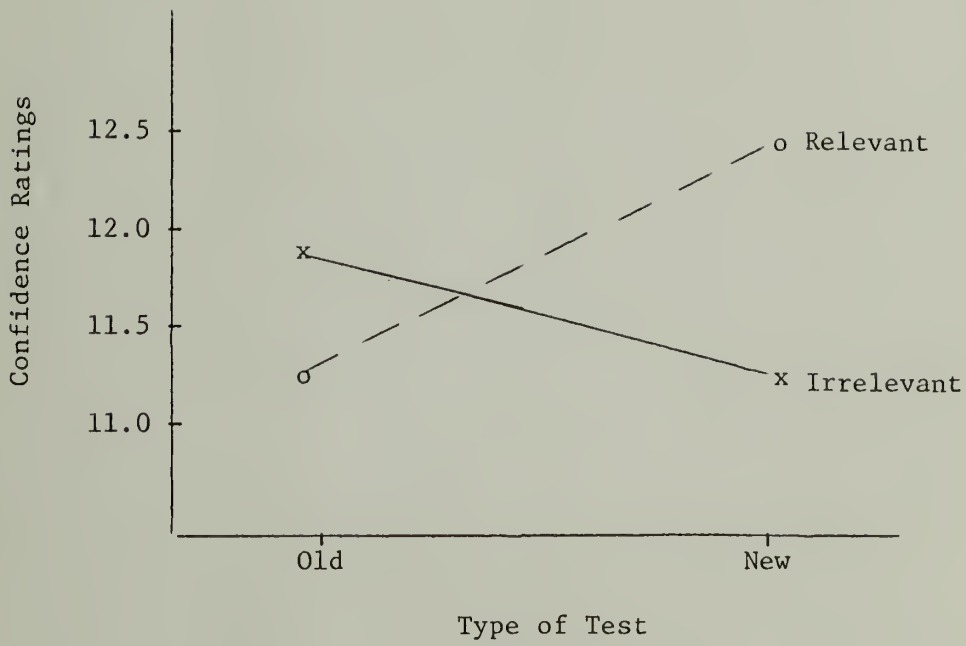
Figure 4. Confidence ratings as a function of type of test and intervening item

DISCUSSION

The major purpose of this study was to determine if semantic integration occurs in memory across modalities. If subjects had integrated the original item with the semantically relevant intervening item presented in the opposite modality, then sensitivity to a changed test item would be expected to be less than if integration had not taken place. In the absence of integration of the original and the intervening items, the decision as to whether the test item was old or new would be expected to be made solely on the basis of memory of either the original item alone or (assuming that modality information is not retained) on the basis of the intervening item alone. In either case, the type of intervening item would have little effect.

The analysis of the d' data supports the hypothesis that semantic integration does occur between information presented verbally and information presented pictorially. The critical main effect of type of intervening item was significant. Subjects were less sensitive to changes between the original item and the test item when a relevant item had intervened than when an irrelevant item had intervened. This result supports the integration hypothesis because each changed test item depicted the integration of an original item and a relevant intervening item. Subjects' lesser d' scores under the conditions of the relevant intervening items would thus suggest that the mental representation of the original item was more similar to the test item than it would be under the conditions of the irrelevant intervening item. This change in the mental representation can be described as an integration of the two semantically relevant items which were presented in different modalities.

The predicted outcomes are examined more directly in considering the hit and false alarm data. The original predictions, as specified in Table 1 were the were the following: (1) that the probability of a hit would be greater when an irrelevant item intervened than when a relevant item intervened and (2) that the false alarm rate would be greater when a relevant item intervened than when an irrelevant item intervened. The results, as presented in Table 4 followed the pattern of these predictions with differences in the probability of a hit significant, but differences in the probability of a false alarm nonsignificant. The intervention of a relevant item thus significantly decreased the probability of a subject responding "old" to an old item, but did not affect the probability of a subject responding "old" to a new item.

The effect of modality, although not directly related to the initial hypotheses in this study, was significant and merits discussion. The significant effect of modality based on the B values indicates that subjects had clear differences in response bias to the pictorial and verbal materials. The direction of the response bias might be sufficient to explain the significant main effects of modality on hit and false alarm data.

The significant response bias in the absence of a similar effect of d' indicates that the subjects were utilizing a specific response strategy with the pictorial items rather than responding "old" or "new" with equal probability. That is, when the subjects were responding to a pictorial test item, there was a greater probability of responding "old" than "new." This bias to respond "old" did not exist with sentences. Because there were no obvious manipulations within this experiment which would have

differentially affected B for pictures and sentences, this result must be attributed to properties of either the individual modalities, or the materials used in this study. The significant main effect of modality with confidence ratings in favor of high confidence for judgments regarding pictures relative to sentences, would support this interpretation.

Experiment II

INTRODUCTION

An alternative explanation of the data in Experiment I is that sub-
jects in the relevant intervening item condition were deciding if each
test item were old or new by comparing the item with their memory of the
intervening item only. This explanation assumes then, (1) that memory
for the original items is not available at the time of test and (2) that
the test item and the intervening item are compared on the basis of their
semantic similarity and that memory for the modality of the intervening
item did not endure, while memory for the semantics of the item did.

To test this alternative explanation, a second experiment was carried
out. The procedure in this experiment was similar to that utilized in
Experiment I with the exception that subjects were presented only irrele-
vant intervening items and then test items which were either identical to
the original items, similar to the originals but with the modality changed,
or new items. The task of the subjects was to classify each test sentence
into one of these three categories. The alternative explanation would be
rejected (1) if memory for the original items were high at the time of test
or (2) if memory for modality were poor and subjects tended to erroneously
classify modality-changed items as new.

METHOD

Subjects

Thirty-eight undergraduate students in psychology courses at the
University of Massachusetts served as subjects. They were run in groups
of size six to eight.

Design and Materials

The principle difference between Experiment I and the current experiment is that in this study, subjects were tested on their ability to independently retain semantic and modality information about sentences and pictures in the absence of relevant intervening items. A three factor design was used with within subjects variables of modality [pictorial and verbal) and test type (old, modality-changed and meaning changed (new)]. The materials were arranged in two separate orders to establish a between-subjects variable of order of presentation. Nineteen subjects were included in each of these two conditions.

The same materials were used in the two experiments. In this study, however, the 24 items presented in the presentation phase were the S_2 and P_2 items from each set, rather than the S_1 and P_1 items. The modality-changed test items were then the RS and RP items corresponding to the items in the presentation phase. The meaning-changed items were selected from the set of semantically irrelevant items in the same mode as the corresponding test sentence or picture. The 24 intervening items in this study were 12 sentences and 12 pictures, all semantically irrelevant to the presentation and test items.

Procedure

The procedure in this experiment was the same as that used in the first experiment with one exception. In this study, the subjects were instructed to indicate on their response protocol sheet whether each test sentence or picture was identical to a previously presented item (old), semantically similar to a previously presented item but with the modality-changed (changed-modality) or semantically dissimilar to a previous item (new). Subjects also indicated their confidence in making each decision on a five point rating scale. The three-minute backward counting delay

task was again included before the test phase.

RESULTS

The data were scored on the basis of percent accuracy and accuracy for confidence. Since analyses of these two measures produced essentially the same results, only the percent accuracy data will be presented.

The results of the analysis of variance on the percent accuracy data are presented in Table 5. The main effect of modality was significant, F $(1, 36) = 12.82$, $p < .01$. Subjects were more accurate in categorizing pictures (85.5%) than sentences (77.6%). This result is consistent with the hit data reported in the first study. The main effect of type of test was also significant, F $(2, 72) = 24.12$, $p < .01$. In order of response accuracy, the percent accuracy for the three types of test items were old (90.5%), semantically new (87.2%), and modality-changed (67.1%). The second order interaction of modality x type of test was significant, F $(2, 72) = 15.96$, $p < .01$. The nature of this interaction is illustrated in Figure 5. Additional interactions of order x modality, F $(1, 36) =$ 15.82, $p < .01$, and order x type of test, F $(2, 72) = 3.60$, $p < .05$ were significant. The order effects in this experiment are uninterpretable and offer no insight of psychological importance.

Because the purpose of the second experiment was to examine the subjects' ability to separately discern meaning changes and modality changes in the sentences and pictures presented in the first experiment, an additional analysis was carried out on erroneous responses to modality-changed test items only. The proportion of total errors was greater for erroneous responses of "new" than "old" for both pictures and sentences. These data appear in Table 6. An analysis of variance was then carried out on the

Table 5

Analysis of Variance for Percent Accuracy Data

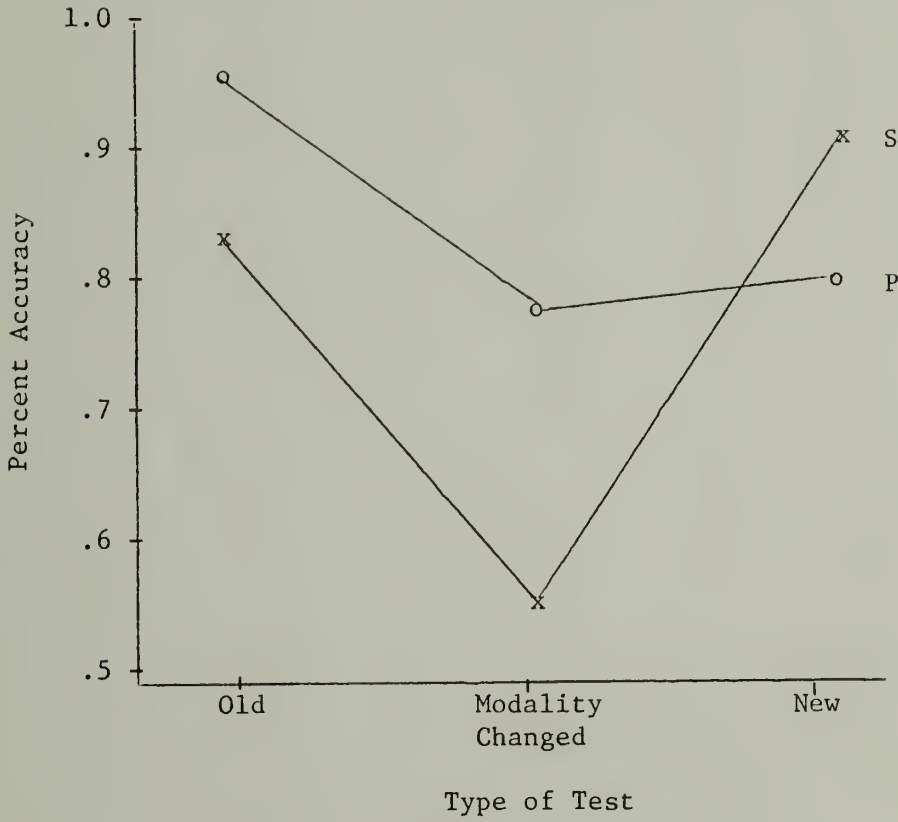| Source of Variance	df.	MS	F
Order (O)	1	.2807	.29
Modality (M)	1	5.6842	12.82**
Type of Test (T)	2	19.4342	24.12**
S (O)	36	.9795	
OM	1	7.0175	15.82**
OT	2	2.8991	3.60*
MT	2	9.0395	15.96**
SM (O)	36	.4435	
ST (O)	72	.8056	
OMT	2	1.2412	2.19
SMT (O)	72	.5663	

Figure 5. Percent accuracy data as a function of modality and type of test

Table 6

Mean Percent Errors on Changed Modality Items as

a Function of Modality and Type of Error

	Erroneous Response	
	"Old"	"New"
Pictures	3%	26%
Sentences	3%	68%

average percent errors per subject. The independent variables in the

analysis were order (two orders), modality (sentences and pictures) and

nature of the erroneous response ("old" response to the modality-changed

item or "new" response to the modality-changed item). Because two of the

subjects made no erroneous responses on modality-changed test items, the

sum of the average error percentages in this analysis of slightly less

than 100%. The results of this analysis are presented in Table 7. There

was a significant main effect of modality, $F (1, 36) = 35.30$, $p < .01$, in

the direction that the average percent error on modality-changed items was

greater for sentences (72.6% per subject) than for pictures (22.1%). The

main effect of nature of erroneous responses was also significant, $F (1,

36) = 223.72$, $p < .01$. Subjects were significantly more likely to classify

changed-modality items as "new" items (89.6% per subject) than as "old"

items (5.1%). The nature of the significant modality x nature of error

interaction, $F (1, 36) = 29.48$, $p < .01$, suggests that differential erro-

neous classification of changed-modality items as either "old" or "new"

was greater in the verbal modality (3% vs. 70%, respectively) than in the

pictorial modality (3% vs. 20%, respectively).

Additional significant effects resulted in the interaction of order

x modality, $F (1, 32) = 12.59$, $p < .01$, and order x modality x nature of

error, $F (1, 36) = 12.51$, $p < .01$.

DISCUSSION

This experiment presented a test of alternative explanation for the

data in Experiment I. The alternative explanation was that, in the rele-

vant intervening item condition, subjects were deciding if each test item

were old or new by comparing the item with their memory of the intervening

item.

Table 7

Analysis of Variance on Erroneous Responses

to Modality Changed Test Items

Source of Variance	df.	MS	F
Order (O)	1	.1053	2.14
Modality (M)	1	10.5263	34.3**
Type of Error (E)	1	44.2368	223.7**
S (O)	36	.5496	
OM	1	· 5.9211	12.59**
OE	1	.4211	2.77
ME	1	10.5263	29.48**
SM (O)	36	.4876	
SE (O)	36	.5928	
OME	1	5.9211	12.51**
SME (O)	36	.5431	

This explanation assumes first, that memory for the originally presented items is not available at the time of test. Data in Experiment II refute the validity of this assumption. The mean percent accuracy for old test items was 90.50%.

The more important assumption in the alternative explanation is that memory for the modality of the intervening items is poor. The test of this assumption is in the accuracy with which subjects classify modality-changed test items. This would indicate subjects' memory for the meaning of an item, independent of memory for modality. The significant effect of type of test in Experiment II is primarily accounted for the by depressed performance of modality-changed items (67% accuracy). This accuracy level is lower than would be expected if the alternative explanation were correct. A more specific analysis of the data makes this alternative explanation even less convincing. The analysis of the type of errors made on the modality-changed items indicated a significant main effect of type of error-- 6% of the errors were responses of "old" to modality-changed items and 94% of the errors were responses of "new" to these test items. Subjects were not then, in general, mistaking modality-changed test items for previously seen old items as the alternative explanation suggests. On the contrary, there was a greater probability that modality-changed test items were being erroneously classified as new items. On the basis of the results of the second experiment, the alternative explanation for the results of Experiment I seems unlikely.

GENERAL DISCUSSION

The specific predictions of integration made in Experiment I, as specified by the hit rate and false alarm rate probabilities in Table 1,

were not fully realized. Presenting a relevant intervening item in the opposite modality, between the original and test items did reduce the probability of a hit to the old test items as predicted, but did not significantly affect the probability of a false alarm.

In an attempt to specify the processes utilized by the subjects under the conditions of Experiment I, a mathematical model was developed. There are two primary results in this experiment which any process model must account for. First, when an intervening item was relevant, the probability of a hit decreased and the probability of a false alarm increased relative to when an intervening item was irrelevant. This result is also reflected in the decrease in d' values when a relevant item intervened, as compared to when an irrelevant item intervened. Second, subjects had a strong bias to respond "old" to pictures relative to sentences.

The model assumes that the subjects are making the decision on each test item on the basis of either memory of the original item alone (with probability r), or insufficient memory of the original item (with probability $1-r$). In the later case, several factors may be operating. The subject may have integrated aspects of the original item with aspects of the intervening item. The probability of this process occurring is i. If the subject does not remember the original item (with probability $1-r$) and has not integrated the original item and the intervening item (with probability $1-i$) then the subject responds by guessing (g). By definition, only a response of "old" can result in a hit or a false alarm. Thus, in the conditions of interest, g is actually the probability of guessing "old" and will thus be respecified as g_o.

More formally stated, the model asserts that:

1. P(Hit/Relevant) = r + (1-r) (1-i) g_o

2. P(Hit/Irrelevant) = r + (1-r) g_o

3. P(F.A./Relevant) = [i + (1-i) g_o] (1-r)

4. P(F.A./Irrelevant) = (1-r) g_o

The three parameters, $\underline{r}$, $\underline{i}$, and $\underline{g_o}$, were estimated separately for pictures and sentences using the Stepit program (Chandler, 1965). The predicted values are presented in the first column of Table 8 to be compared with the obtained values in the second column. The estimated parameter values computed for pictures and sentences are presented in Table 9.

How well does the model account for the results? First, the parameter-free prediction that the probability of a hit is greater when an irrelevant item intervenes than when a relevant item intervenes is correct [i.e., r + (1-r) g_o > r + (1-r) (-i) g_o]. Second, quantitative fits to the data are quite good. Third, as indicated in Table 9, the probability of guessing "old" is greater for pictures than for sentences (i.e., g_o predicted for pictures = .787; g_o predicted for sentences = .389). The significant main effect of modality on B values suggests the necessity of this difference in g_o in the model.

This model captures intuitions regarding the process of integration, fits the data well, and allows some correct parameter-free predictions. However, it is admittedly oversimplified. Some of these oversimplifications merit discussion.

Perhaps the most obvious oversimplification in the model is in the use of the integration parameter, $\underline{i}$. As broadly defined in the introduction of this paper, integration occurs when two or more propositions which were presented as separate, make contact with each other in memory and

Table 8

Predicted and Obtained Hit and False Alarm Rate Values

as a Function of Type of Intervening Item and Modality

	Pictures		Sentences	
	Predicted	Obtained	Predicted	Obtained
P(Hit/Relevant)	.780	.780	.663	.631
P(Hit/Irrelevant)	.900	.900	.671	.702
P(F.A./Relevant)	.403	.405	.190	.173
P(F.A./Irrelevant)	.371	.369	.175	.190

Table 9

Estimated Parameter Values for Proposed Model

	Modality	
	Pictures	Sentences
r	.529	.496
i	.325	.465
g_o	.787	.347

resultingly are considered as related aspects of some greater memory. Representing the process of integration with one parameter leaves unexplained questions such as: Are modality tags lost after integration occurs? Is memory for the meaning of the separate items retained after integration? Is the product of integration the union, the intersection, or some other combination of the two semantically relevant items? This model assumes that integration occurs on the semantic or propositional level, which is independent of memory for modality of the presented items. This assumption is supported by the significant effect of intervening item in the present experiment. However, an independent test of the parameter, i, is necessary to clarify the more specific aspects of the integration process. Extending the research design of the present study, the degree of integration might be independently manipulated by (1) varying the similarity or extent of overlap between the original item and the intervening item; (2) comparing the effect of the relevant intervening item when it is in the different vs. the same modality as the original item; (3) varying the amount of time and the number of items intervening between each original and intervening item; (4) varying the direction of integration by selecting intervening items which provide more or less information than the relevant original item; (5) presenting related materials similar to those used by Bransford and Franks (1971) but in mixed verbal and pictorial modalities. Memory would then be tested with a recognition test comprised of pictures and sentences which integrate information previously presented as separate items in mixed modalities. Future research will hopefully elucidate the effects of some of these variables on the process of integration, thereby providing a more specific definition of integration.

Another example in which the proposed model has slighted accuracy for the sake of simplicity and utility is in the use of a single parameter, g_o to represent the probability of guessing, "old." It is implied by the model that the probability of g_o is independent of the type of intervening item and type of test. This assumption ignores the possibility that these factors may affect the subjects' guessing strategies. For example, in the case where a subject does not remember the original item in a set, but does remember the content and modality of the intervening item, if the test item is the same as the intervening item, but in the opposite modality, the subject may have enough information to correctly classify the test item as a new item, based entirely on its relationship to the intervening item.

Presumably g_o could be independently manipulated by (1) varying the relative response payoff for hits and false alarms and (2) varying the ratio of old to new responses. Although the properties of the parameter, g_o are not as relevant to the constructive process per se as are other parameters, a serious consideration of the proposed model would warrant independent tests of g_o.

The parameter r, too, would be tested independently of i and g_o. The most straightforward way to vary memory of items presented is to vary the time delay between the presentation and test of the original item without varying the temporal position of the intervening item. It should be noted, regarding the role of memory in the present study, that although the modality variable did increase the probability of responding "old" to pictures relative to sentences, it did not have a significant effect on d'. The absence of a d' superiority of pictures over sentences in this study appears contrary to results of previous studies confirming the superiority of picture memory over sentence memory. This result suggests that although

wholistic memory for pictures is exceptional and endures over time, per-
haps memory for specific details in pictures fades relatively quickly.

This discussion suggests that future research in this area is neces-
sary to independently estimate the values of the parameters, $\underline{r}$, $\underline{i}$, and $\underline{g}_o$
to separate component operations within each of these three basic processes,
and to more specifically characterize the process of integration.

SUMMARY

The results of this study suggest that information presented in seman-
tically relevant sentences and pictures is integrated in memory, despite
differences in the modality of presentation. The presence of a relevant
intervening item between the original and the test items decreased both
the values of d' and the probability of a hit relative to the effect of
the irrelevant intervening item. The lack of a significant increase in
the probability of a false alarm is considered to be a statistical con-
founding or a Type II error. The three parameter model presented to ac-
count for the processes operating in this experiment does fit the data
well, but additional research is necessary to provide a better descrip-
tion of the features of these parameters, in particular $\underline{i}$, the integra-
tion parameter.

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APPENDIX

Stimulus Materials

<u>Pictorial Items</u>

1. P_1: A picture of a modern house with shrubs around it.

   S_1: The modern house was surrounded by flowers.

   P_2: A picture of a modern house with flowers around it.

2. P_1: A picture of a woman in a long skirt.

   S_1: The woman's long skirt was torn at the hem.

   P_2: A picture of a woman in a long skirt with a tear in it.

3. P_1: A picture of a fireplace with a wall clock beside it.

   S_1: The clock beside the fireplace was a cuckoo clock.

   P_2: A picture of a fireplace with a cuckoo clock beside it.

4. P_1: A picture (from behind) of a man and a woman walking with arms around each other.

   S_1: The couple was holding hands as they walked.

   P_2: A picture of the same couple walking, holding hands.

5. P_1: A picture of two dogs playing with a bone.

   S_1: The two dogs were playing with a ball.

   P_2: A picture of two dogs playing with a ball.

6. P_1: A picture of a flag furling above a courthouse.

   S_1: The flag furled from the pole beside the courthouse.

   P_2: A picture of a flag furling next to a courthouse.

7. P_1: A picture of a mailman surrounded by children.

   S_1: The little boys surrounded the mailman.

   P_2: A picture of a mailman surrounded by little boys.

8. P_1: A picture of stacks of books on a table.

   S_1: On top of the table were two candles amidst the stacks of books.

   P_2: A picture of stacks of books and two candles on a table.

9. P_1: A picture of several rings on a woman's hand.

      S_1: The woman with several rings, also wore a bracelet.

      P_2: Picture of a hand with several rings and a bracelet.

10. P_1: A picture of a viola leaning against a chair.

      S_1: The viola was leaning against a box.

      P_2: A picture of a viola leaning against a box.

11. P_1: A picture of a car parked by a tree.

      S_1: The car by the tree had ski-racks on it.

      P_2: A picture of a car with ski-racks parked by a tree.

12. P_1: A picture of a man in a suit and a turtleneck shirt.

      S_1: The man in the suit had on a dark tie.

      P_2: A picture of a man in a suit and a dark tie and dress shirt.

Verbal Items
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1. S_1: Several people were admiring the bridge.

   P_1: Picture of people admiring a wooden covered bridge.

   S_2: Several people were admiring the covered bridge.

2. S_1: The girl enjoyed playing the sport.

   P_1: Picture of a girl playing tennis.

   S_2: The girl enjoyed playing tennis.

3. S_1: The bird was perched atop the tree.

   P_1: Picture of an eagle perched on top of a tree.

   S_2: The eagle was perched atop the tree.

4. S_1: The stream ran beneath the house.

   P_1: Picture of a stream running beneath a log cabin.

   S_2: The stream ran beneath the log cabin.

5. S_1: The woman entered the chapel.

   P_1: Picture of a nun entering a chapel.

   S_2: The nun entered the chapel.

6. S_1: The boys paddled past the breaking waves.

   P_1: Picture of boys on surf boards paddling past waves.

   S_2: The surfers paddled past the breaking waves.

7. S_1: The dim light illuminated the lodge.

   P_1: Picture of a lodge-like room with a gas lantern glowing.

   S_2: The lantern illuminated the lodge.

8. S_1: The man presented an enjoyable concert.

   P_1: Picture of a man playing a piano with people in the audience.

   S_2: The pianist presented an enjoyable concert.

9. S_1: The cook put the utensil on the kitchen counter.

   P_1: Picture of a cook putting a pan on a kitchen counter.

   S_2: The cook put the pan on the kitchen counter.

10. S_1: The youngster played with his new toy.

    P_1: Picture of a young boy playing with a truck.

    S_2: The youngster played with his new truck.

11. S_1: The insect moved across the wall.

    P_1: Picture of a spider moving across the wall.

    S_2: The spider moved across the wall.

12. S_1: The vase of flowers was in the center of the table.

    P_1: Picture of a vase of daisies in the center of a table.

    S_2: The vase of daisies was in the center of the table.

Irrelevant Intervening Items Used in Experiment I

Sentences--

1. The alpines surrounded the hikers.

2. The secretary typed the letter.

3. The caddy followed the golf ball.

4. The tractor dug the hole.

5. The doctor examined the cut arm.

6. The wash hung on the clothesline.

Pictures--

1. A picture of a young man playing a guitar.

2. A picture of a sailboat on the water.

3. A picture of a boy riding a bicycle.

4. A picture of a coffee cup next to a coffee pot.

5. A picture of a skyscraper in a city.

6. A picture of leafy trees being tossed by the wind.