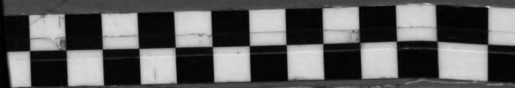




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LOCATION-BASED MENTAL MODELS IN FACT RETRIEVAL

By

Gabriel Allen Radvansky

A THESIS

Submitted to

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ABSTRACT

LOCATION-BASED MENTAL MODELS IN FACT RETRIEVAL

By

Gabriel Allen Radvansky

Explanations of data from fact retrieval experiments, such as fan effect studies, have been based on propositional network models of human cognition, such as ACT*. This thesis demonstrates that there are aspects of the representation used in fact retrieval that are not readily accounted for by such a theory. In particular, information in memory is organized preferentially in terms of specific situations. This organization was found in the results of four experiments using location as the basis for defining a situation. Subjects retrieved facts about several people or objects associated with a single location faster than facts about several locations associated with a single person or object. This effect is termed a *location effect*. It is argued that the representations used are mental models rather than labeled associations between the critical concepts.

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Location-based Mental Models in Fact Retrieval

CHAPTER I

INTRODUCTION

A fundamental question in psychology is and has been: How is knowledge organized and represented? The study of fact retrieval from long-term memory is one method of investigating this issue because the pattern of performance on fact retrieval tasks is assumed to reflect memory's organization. Propositional network (e.g., Anderson, 1976, 1983; Anderson & Bower, 1973; Collins & Loftus, 1975; Quillian, 1968), and mental model (Garnham, 1987; Johnson-Laird, 1983) theories are examined in this paper as potential explanations. The discrimination between these two theories is done using the fan effect paradigm of experimentation, a classic method of studying memory organization. The general issue addressed is whether the representation has properties attributable to a mental model. The specific issue is whether location can provide the basis upon which a mental model can be built.

Propositional Network Theory

The notion of a *proposition* as used in the present context is, in general, "... a configuration of elements which (a) is structured according to **rules of formation**, and (b) has a **truth value**.

Intuitively, a proposition conveys an assertion about the world" (Anderson & Bower, 1973, p. 3). Propositions are to be considered as the abstract idea units of human cognition.

The propositional theory that will often be referred to is the network theory developed by J.R. Anderson and collaborators (e.g., Anderson, 1976, 1983; Anderson & Bower, 1973). The propositional network is an integral part of the various Adaptive Control of Thought (ACT) (Anderson, 1976, 1983) theories of cognition, culminating in the highly successful ACT* version (Anderson, 1983). This theory is selected as a reference because it is the most thoroughly worked out propositional theory to date.

The representational format of interconnected propositions in ACT* is considered the vehicle of thought, the mentalese by which all knowledge is represented (Anderson, 1976). ACT*'s propositional network is composed of a set of concept nodes connected via associational links. The nodes of the network represent concepts, individuals, and so forth. The nodes themselves possess no meaning. Instead, the functional association of nodes produces structures that are meaningful. Two or more nodes need to be associated in order to form a propositional

structure which represents a larger concept.

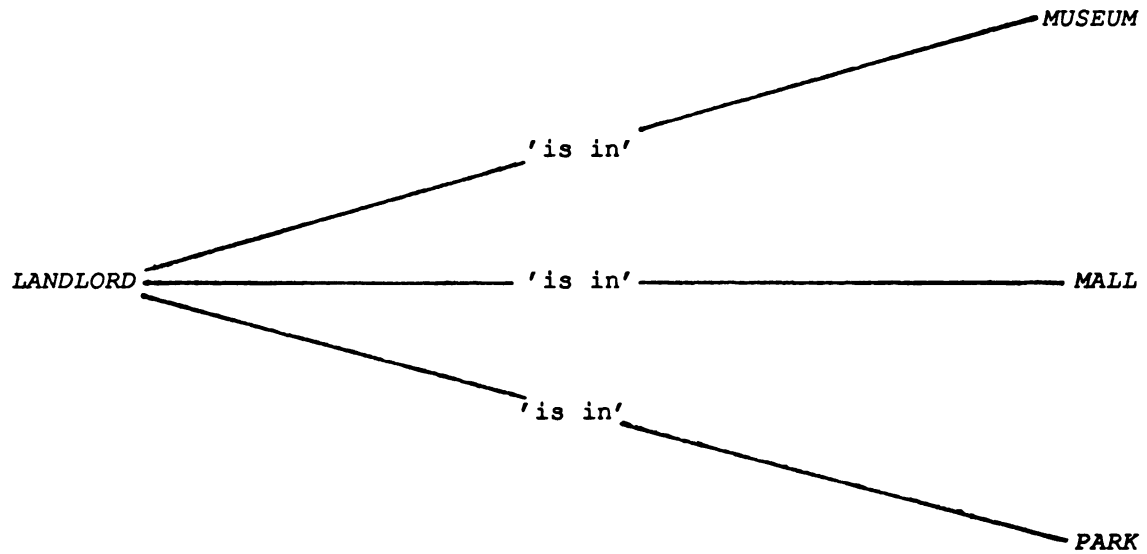
This model is offered as an effective and economical means of representing information in memory. An illustration of this representational form's economy is the fact that the node for *landlord* need only occur once in the network to be linked to a number of other nodes (e.g., *museum*, *mall*, *park*) rather than storing the concept node *landlord* separately for each proposition it is used in. *Landlord* could be connected to *museum*, *mall*, and *park* each by a different "is in" association link thus allowing the network to be effective as well as economical. (This example is an oversimplification of the capabilities of propositional networks, but is sufficient for present purposes.) The structure of propositional networks is illustrated in Figure 1.

 Insert Figure 1 about here

Retrieval of facts stored in the network is accomplished through the activation of the appropriate nodes and links in memory. The activated nodes represent the concepts of the proposition being retrieved, such as the nodes for *landlord* and *museum* in confirming the assertion "The landlord is in the museum". Once the source nodes are themselves stimulated, activation spreads through the links of these nodes to related concept nodes (Anderson, 1976, 1983; Anderson & Bower, 1973; Quillian, 1968), a process commonly referred to as *spreading activation*. This spreading activation is a parallel process performed by a set of procedures acting upon the otherwise passive network. During fact retrieval, if a person were verifying that the assertion

Figure 1

Sample propositional network with different types
of links off of a single concept.



"The landlord is in the museum" is true, the nodes for *landlord* and *museum* would be concurrently activated. Activation would then spread simultaneously from each of these nodes, through all of the proper network connections, until the two areas of spreading activation intersected. This intersection would be the basis of an affirmative response concerning the presence of the fact in memory (Anderson, 1983).

If the two concepts are not associated, either directly or indirectly, then the activation spreading off of them would never intersect. Rather than indefinitely allocating mental capacity to these spreads in a futile hope that they might eventually intersect and reveal a meaningful structure, the search would be terminated after an appropriate wait time (Anderson, 1983). This also helps to reduce the possibility of the occurrence of false intersections through intermediate connections.

Fan Effect Paradigm

A "fan" off of a concept refers to the number of associations that are linked to that concept in memory. Consider the following sentences:

- 1 *The landlord is in the museum.*
- 2 *The tailor is in the mall.*
- 3 *The bartender is in the park.*
- 4 *The bartender is in the elevator.*

In sentences 1 or 2 there is only one association with each of the main concepts (e.g., *landlord* and *museum*) and hence, a fan of 1 for each of them. However, sentences 3 and 4 both possess the concept, *bartender*. This concept has a fan of 2 denoting the number of associated concepts (*in the park & in the elevator*). A **fan "effect"** is a retrieval time

increase accompanying an increase in fan. Additionally, larger fans produce greater error rates. So, in the above example it would take longer to retrieve the fact "the bartender is in the park" than "the tailor is in the mall".

In typical fan effect experiments (e.g., Anderson, 1974; King & Anderson, 1976) subjects first memorize a list of sentences (facts). Later, during a recognition test, they are asked to decide whether probe sentences had been memorized. The time required to make such decisions, as well as the errors made, are the measures against which the theory of representation is evaluated.

The fan effect was originally predicted by, and used to defend, propositional network theory (Anderson, 1974; Anderson & Bower, 1973). ACT* explains the fan effect as resulting from the increase in the number of links that must be explored. Although there is a parallel search of all of the links off an activated node, the search time is longer for a greater fan because of a limited amount of capacity that can be expended to search the connections. A greater number of connections divide up the capacity more finely and the retrieval time is consequently lengthened.

In previous person-location fan effect experiments (Anderson, 1974), there was an undiscussed tendency for facts to be retrieved faster when a single location was associated with several people rather than vice versa, with mean differences of 77 ms (Exp. 1) and 124 ms (Exp. 3) in fans of up to 3. This reduced retrieval time occurring for fans off of a location concept compared to fans off of a person (or

object - see below) concept will be referred to as the *location effect*. Anderson's data are only suggestive, not conclusive, of an effect of a by-location grouping on retrieval because there is no direct test of this aspect of the data.

A problem for ACT* is that, if there is a location effect, the theory does not predict it. ACT* states that all of the concept nodes in a memory probe are activated in parallel. The activation then spreads equally along the association paths to related nodes until they intersect or a wait time has elapsed. If this is true, then there will be no difference in the RTs of location and person fan effects.

ACT* has been given a tri-code representation by Anderson (1983). This is the product of thinking that propositional notation does not adequately represent all of the information that can be contained in memory. The three forms of representation of ACT* are abstract propositions, temporal strings, and spatial images. This combination of representations may be sufficient to explain such things as a location effect in fact retrieval. Unfortunately, not enough information is provided concerning temporal strings and spatial images to allow the theory to be sufficiently predictive. The propositional representation is the dominating form in the theory and the only portion used to explain the fan effect. Because of this, the other two portions of the ACT* theory will be ignored.

Mental Models

Mental models are considered as an alternative to propositional networks as a form of mental representation (e.g., Garnham, 1987; Johnson-Laird, 1983; Perrig & Kintsch, 1985; vanDijk & Kintsch, 1983). Mental models are cognitive representations directly modeling the real world properties and relationships of a particular situation. Though the concept of mental models is not fully developed and is sometimes vague (cf. Glenberg, Meyer, & Lindem, 1987), the particular aspects of mental models relevant to the present studies will be made clear by considering select defining properties and constraints. In the present context, the most important idea is that "... a single state of affairs is represented by a single mental model even if the description is incomplete or indeterminate" (Johnson-Laird, 1983, p. 408). This is in contrast to propositional networks where many situations may be represented simultaneously due to the nature of network structure. Consider the following sentences:

The piano is being moved.
The piano is being played.

These two ideas would typically give rise to two separate mental models because they describe two different situations (Barclay, Bransford, Franks, McCarrell, & Nitsch; 1974). In a propositional network, however, there could be two concept nodes, for *move* and *play* respectively, associated with the concept node for *piano*. If the node

piano were activated, activation would spread to both *move* and *play*. The activation of *piano* has simultaneously activated descriptions of two separate situations. A mental model theory would argue that when a person thinks about a piano being moved it is not likely that they will also think of the piano as something to be played, whereas the propositional network theory seems to argue that both situations are likely to be simultaneously activated.

The creation of mental models from text information can be seen in studies such as those of Garnham (1981) and Bransford, Barclay, and Franks (1972). These studies demonstrate that sentence information integrated with world knowledge is used to construct wholistic representations, such as mental models, rather than relying solely on propositional information. Garnham (1981) had subjects listen to a list of sentences. When asked to identify the sentences heard, the errors were largely in the selection of sentences that described the same situation as the correct choice. For example, if the subject heard *The hostess bought the mink coat from the furrier* the error most often made, compared with other sentences about the hostess and the furrier, was in choosing *The hostess bought the mink coat at the furrier's*. This error occurs because the sentence describes the same situation as the correct choice, a result consistent with the notion that the subjects are using mental models.

Glenberg et al. (1987) demonstrated that the retrievability of information is based on the prominence of an item in the mental model and not on the information's position in the presented text. In

comparing two versions of a text, which were identical in propositional structure, they found that information from a version in which items were described as being spatially associated (near one another) were retrieved faster than information from versions in which the items were described as more spatially removed. This further demonstrates the importance of mental models for discourse comprehension.

Mental Models of Locations

The goal of this paper is to show that mental models are used in the representation of text organized in terms of single situations. In order to give a diagnostic for the use of mental models, it is assumed that a location can provide the basis around which a mental model is organized, a foundation upon which it can be built. So, a situation based mental organization will be demonstrated here in terms of locations. The process of fact retrieval will be used to investigate such an organization.

If location is the basis of a mental model, and if several entities can fit into one location, there is need to build only a single mental model incorporating all items associated with that location. On the other hand, several locations would be represented with several models. If one person or object is associated with multiple locations then an equivalent number of mental models will be created. These mental models themselves may be associated in memory, but all of the information is not unified in a single model.

There are some constraints on mental model representations. For instance, when presented with the following sentences it is likely that

a different model will be built for each of these situations, even though they all occur in the same location:

The police officer is in the phone booth.
The banker is in the phone booth.
The athlete is in the phone booth.

In the real world it is not often that more than one person will be in a phone booth at one time, unless it is part of some college stunt.

Fact Retrieval Involving Mental Models

It is necessary to consider how fact retrieval would proceed using mental models as a representational form. The retrieval process theorized must indicate the operations undertaken when both single and several mental models are involved. A formulation of these processes will allow predictions of how behavior in a fact retrieval task demonstrates the use of mental model representations. Consider that a person has memorized the following facts:

The landlord is in the museum.
The bartender is in the museum.
The tailor is in the museum.
The yuppie is in the mall.
The yuppie is in the park.
The yuppie is in the elevator.

Mental models are assumed to be formed in working memory as coherent wholes and then stored in long-term memory as such. Each mental model can be considered a distinct memory trace. The first three sentences can be considered to be parts of a single mental model because it is conceivable to have three people in a single location such as a museum. The information contained in these sentences would therefore be stored in long-term memory as single mental model. The next three

sentences are more likely to give rise to three different mental models since they cannot be conceived of as a single state of affairs.

Fact retrieval involving mental models is theorized here to be a process in which a mental model must reach some threshold level of activation before it can enter working memory. If more than one mental model is receiving activation from a memory probe then they will all draw on the same limited supply of activation, competing to reach the level of activation needed to enter working memory. This process is similar to those described by multiple trace theories of retrieval (e.g., Hintzman, 1986). It is assumed that activation is allocated to models in a continuous fashion. It is also assumed, for tasks such as the ones described in the present experiments, that the activation is divided into two portions, half for the location concept (e.g., *the museum*) and half for the non-location concept (e.g., *the landlord*).

Consider that the task is to retrieve the fact *The landlord is in the museum*. This is a single model condition. The mental model for *museum* is the only one representing that concept, so it receives the full allotment of activation for the location concept. The non-location concept, *landlord*, is also part of only one mental model, the *museum* mental model. Therefore this model receives all of the activation for the non-location concept. At a point in time (time T) 100% of the activation needed to reach threshold will all have been channeled into this mental model, allowing it to enter working memory. The fan effect in this condition will be greatly reduced, if not eliminated. The retrieval of information from long-term memory will be the same

regardless of the number of non-location concepts associated with a location because there is no competition for activation from other memory traces. There is always only one memory trace that is being allocated activation, so there will be no difference in retrieval time.

On the other hand, consider that the fact to be retrieved is *The yuppie is in the park*. This is a multiple model condition. The location concept, *park*, is again represented by only a single mental model and it receives all of the activation allocated to the location concept. The situation differs for the activation for the concept *yuppie*. This concept is associated with several mental models in long-term memory (i.e., those for *park*, *mall*, and *elevator*). Each of the models defined by these locations will receive a third of the activation for *yuppie*. So, at time T the *park* model has only 66.67% ($50\% + 16.67\%$) of the activation needed to enter working memory. Because the appropriate model has more activation (the *mall* and *elevator* models have 16.67% of threshold activation by time T) it will reach threshold sooner than the competing models and enter working memory to confirm the fact. The addition of other mental models consuming activation slows retrieval down. The more mental models receiving activation, the less activation the correct trace is receiving and retrieval time increases accordingly. This explains the occurrence of the fan effect for multiple model conditions.

When comparing single and multiple model conditions, with equal sized fans for both location and non-location concepts, the single model condition will produce a smaller fan effect. This is the location

effect described above. In addition to change in retrieval time, there is an increased possibility of errors in multiple model situations due to residual activation in an inappropriate model. By adopting the position that mental models are used in fact retrieval, it is predicted that the location effect will be found for fan effect experiments involving locations. More precisely, RTs for verifying a probe from a single model (SM) condition (i.e. more than one non-location concept is associated with a single location) will be faster than for verifying a probe from a multiple model (MM) condition (a single item is associated with several locations) and the SM condition will have a smaller fan effect. Four experiments have been conducted to test this prediction.

The paradigm used in all of these studies is based on the fan effect experiments conducted by Anderson (1974). In those experiments subjects were presented with a list of sentences about a person in a location. Across the list of sentences fans of one to three were generated for both person and location concepts. All combinations of sizes of person fans and location fans were used. The present experiments differ only slightly from this experimental methodology. Because all of the experiments share many features in common the general methods and baseline data about subjects will be reported first.

CHAPTER II

GENERAL METHODOLOGY OF EXPERIMENTS

Method

Subjects. All of the subjects were recruited from the Michigan State University subject pool and were required to be native speakers of English. Subjects were all given class credit for their participation except for the subjects in the 1000 ms SOA condition of Experiment 3 who were paid \$10 each.

Materials. The methodology largely paralleled that of Anderson (1974). Sentences were always created through random pairings of subjects and predicates. Important changes to the Anderson (1974) experimental method were: (i) The largest fan was 4 instead of 3. The larger fan was used to make a location effect more prominent. (ii) The combinations of person and location fans analyzed in this study were: 1-1, 1-2, 2-1, 1-3, 3-1, 1-4, & 4-1 (# of locations per person/object - # of people/ object per location). These combinations were selected to reflect a pure effect of either location fan or person/object fan (no combinations of multiple locations with multiple people/ object). In particular, these combinations allow for a direct comparison of fans off of location and non-location concepts. The design illustrated in Table

1 was used to create the study sentences. Lower case letters indicate a non-location concept and upper case letters represent a location concept. The same design for study list construction was used in all experiments.

 Insert Table 1 about here

Procedure. Subjects were tested individually in a single session. At the beginning of the procedure each subject was administered the vocabulary section of the Wexler Adult Intelligence Scale - Revised (WAIS-R). This was done in order to detect any subjects low in verbal ability who might subsequently have difficulty due to the verbal nature of the materials. The designated cut-off was a score of 30 out of a possible 70.

Subjects were then presented with study lists of 26 sentences with the instruction to memorize them as efficiently as possible (but see Experiment 2). The sentences were displayed one at a time for 7 seconds each on a monochrome (green) screen controlled by an Apple IIe computer. The sentences appeared halfway down the screen beginning on the left-hand edge. A 40-column presentation mode was used. Within the constraints of the design, each subject learned a different set of study sentences. After going through the entire list of sentences in a random order, the subjects were presented with a series of test questions (also in a random order). The questions were of the form "Who is in the location?" or "Where is the person/object?" for each location and person/object, respectively. The study-test procedure was repeated

Table 1

Design for the Generation of a Subject's Study List.

<u>1-1</u> aA hH	<u>1-2</u> bB iI	<u>1-3</u> cC jJ	<u>1-4</u> dD kK
<u>2-1</u> eE lL			<u>2-4</u> eD lK
<u>3-1</u> fF mM		<u>3-3</u> fJ mC	<u>3-4</u> fD mK
<u>4-1</u> gG nN	<u>4-2</u> gB nI	<u>4-3</u> gC nJ	<u>4-4</u> gD nK

X-X indicates (number of locations)-(number of people/objects)

until the subject was able to answer all of the test questions correctly twice in a row. This insured that the subjects had memorized, and could retrieve, the entire list. A different random order was provided for the presentation of each study and each test trial.

Once the sentences had been memorized, subjects were given a recognition test in which they were asked to verify whether each of a series of probe sentences had been studied. "Studied" was indicated by pressing a button on a game paddle held in the right hand, while "not studied" was indicated by pressing one in the left. A practice period of 18 trials was provided to familiarize the subjects with using the paddles in this manner. On the practice trials the computer displayed either "SENTENCE STUDIED" or "SENTENCE NOT STUDIED", and subjects had to press the appropriate button. The "studied" probes in the recognition test were the sentences from the appropriate cells (1-1, 1-2, 1-3, 1-4, 2-1, 3-1, and 4-1) in the study list, two sentences per fan combination. The "unstudied" probes were repairings of people and locations from within the same cell. For example, if the two "studied" sentences from within a cell were sentences 1 and 2, the "unstudied" sentences would be 3 and 4.

1 The landlord is reading a novel in the park.

2 The tailor is tying his shoes in the mall.

3 The landlord is reading a novel in the mall.

4 The tailor is tying his shoes in the park.

The order of probe presentation was random. The computer recorded RTs and error rates.

As in previous fan effect research, RT was considered the primary

dependent measure. Errors were also analyzed, but more to identify subjects or conditions that might be deviant. For instance, a high number of errors for a subject might indicate some problem had occurred, such as incomplete memorization of the study list, misunderstanding of the instructions, apathy toward the task, and so on. A cut-off of 10% errors on the recognition trials was established. Subjects received feedback immediately after a trial if the response was incorrect to keep the subjects attentive. The feedback consisted of the presentation of a line that read either "**ERROR* SENTENCE STUDIED" or "**ERROR* SENTENCE NOT STUDIED", whichever was appropriate. This message was presented for 500 ms. For purposes of analysis, errors included not only incorrect responses, but also RTs shorter than 500 ms and longer than 10,000 ms.

At the end of the recognition test, subjects were again presented with the test questions used in the list learning period. This was done to verify that all of the facts were still in memory since, as noted above, not all of the materials were used in the recognition test. The entire procedure lasted approximately one and a half to two hours.

General Results

The means and standard deviations for the WAIS-R vocabulary test, number of cycles through the study-test portion of the experiment and number of errors on the post-test are presented in Table 2. In Experiments 1b, 2 and 3 the between group differences involving these measures were not significant. The WAIS-R vocabulary scores are typical for students at Michigan State University. The minimal variation in the number of cycles needed to memorize the lists indicates that the

subjects were approximately equal in their memorization skills. The small number of errors on the post-test indicates that the subjects were able to retain all of the information in memory even though only a subset of the studied sentences was tested. These data show that subjects were generally uniform across studies and conditions but provide no further information regarding questions of interest and will not be mentioned later in the paper.

Insert Table 2 about here

Table 2

Means and standard deviations (in parentheses) of WAIS-R
vocabulary test scores, number of cycles through study-test, and
number of errors on post-test.

<u>Exp.</u>	<u>WAIS-R</u>	<u>No. of Cycles</u>	<u>Post-test</u>
1a	49.5 (7.5)	6.2 (1.9)	0.42% (0.79)
1b	45.6 (6.5)	4.4 (1.1)	0.34% (1.49)
OS	46.8 (6.1)	4.3 (0.8)	0.00% (0.00)
LS	44.5 (7.0)	4.9 (1.3)	0.34% (1.90)
2	43.2 (6.4)	5.2 (1.2)	0.19% (1.45)
Location	43.3 (7.0)	5.1 (0.8)	0.56% (1.04)
Object	42.8 (6.5)	5.5 (1.6)	0.16% (0.53)
Neutral	43.7 (6.0)	5.0 (1.0)	0.96% (2.15)
3	48.4 (7.0)	4.7 (1.1)	0.80% (1.18)
250 ms SOA	48.5 (6.8)	4.7 (1.1)	0.64% (1.20)
500 ms SOA	46.5 (6.1)	4.6 (1.2)	0.40% (1.10)
1000 ms SOA	50.3 (7.4)	4.8 (1.0)	0.88% (1.24)

CHAPTER III
EXPERIMENT 1A

Method

Subjects. Thirty-two individuals, ranging from 18 to 23 years of age were tested. Four additional subjects had to be replaced for exceeding the cut-off for the number of errors during the decision trials.

Design and Materials. The design of the experiment was a 2 (studied/unstudied decisions) X 2 (SM/MM) X 4 (fan) repeated measures design. The sentences were created using a person as the subject of the sentence and a location as the predicate. The method of describing the person was always by occupational title, for example "the tailor" or "the fireman". The locations were common ones such as "park", "elevator", and "garage". The study list sentences were of the form "The person is doing an activity in/at the location." The sentences contained the locative prepositions "in" and "at" equally often.

An activity was assigned to each person concept to prevent the subjects from forming subgroups based on anything other than person or location. For example, the subject may try to help their memorization of the facts "The landlord is in the museum", "The bartender is in the

museum" and "The tailor is in the museum" by elaborating and having the landlord and bartender talking to one another. The difficulty with this is that the tailor is not involved in this conversation. If a mental model representation is involved, not only is there the state of affairs of the three individuals sharing a location, but the landlord and the bartender are in a separate situation from that of the tailor; the tailor could be placed in a separate mental model from the other two. Subject generated subgroupings such as this would make detection of an organization by location based situations more difficult to uncover. Assigning separate activities to each individual makes such arrangements less likely. However, this use of activities was dropped in the subsequent experiment with no change in performance. The following sentences are examples of those used in Experiment 1a:

The landlord is reading a novel in the museum.
The bartender is sleeping in the museum.
The tailor is tying his shoes in the museum.
The yuppie is eating in the mall.
The yuppie is eating in the park.
The yuppie is eating in the elevator.

Note that the people are not intuitively pre-associated with the location. Also, the activities are not specific to any person or location. The activity paired with a person is used at every occurrence of that person in a list.

Procedure. There were four presentations of each probe yielding a total of 112 trials. Halfway through the recognition test a break occurred which provided a rest period for the subjects if they so

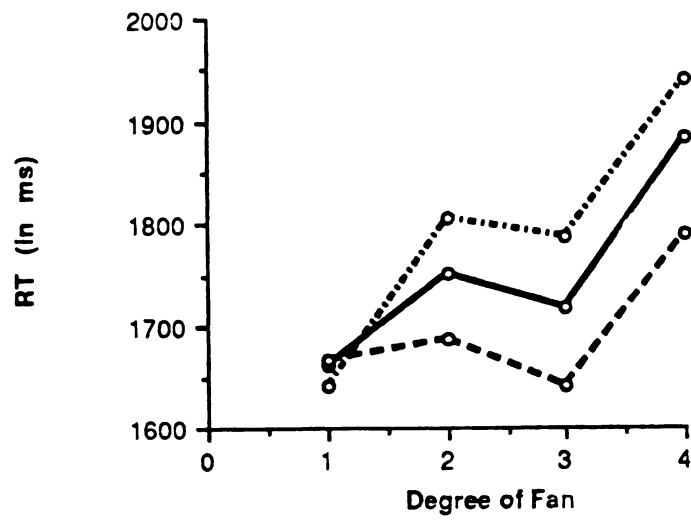
desired. Additionally, at the end of the procedure, for this and the next experiment, subjects were presented with a questionnaire asking them to describe the strategies they used in memorizing the study lists. The results of these questionnaires provided no consistent and predictive information and so will not be mentioned again.

Results

For this and subsequent experiments, analyses involving the location effect did not include the data from the cell in which a single person or object was associated with a single location (1-1), but all other analyses did unless noted otherwise. This was done because this cell was common to both the SM and MM conditions and would complicate their comparison. Also, for each subject within each cell of the overall design for each experiment, RTs that exceeded the 2.5 standard deviation of the cell were trimmed to the 2.5 standard deviation value. The only experiment which actually resulted in having data trimmed was Experiment 2. Less than 2% of the RTs in that experiment were trimmed. The RTs and error rates for each cell of the design of this and subsequent experiments are given in Appendix A.

Studied/unstudied probe differences and fan effect. The cell means are summarized in Figures 2 and 3. The data were submitted to a 2 (studied/unstudied decisions) X 4 (fan) repeated measures ANOVA. Figure 2 demonstrates, perhaps more clearly than Figure 3, that subjects were slower to decide that a probe sentence was unstudied rather than studied $F(1,127) = 37.80, p < 0.001, MSe = 64666$. Mean RTs were 1706 and 1829 ms for studied and unstudied probe trials, respectively.

Figure 2

Fan EffectExperiment 1a

—○— Fan
- -○- - Fan (studied)
...○... Fan (unstudied)

 Insert Figure 2 about here

Figure 2 also illustrates the RTs for increasing fan. The analysis revealed that there is an RT increase accompanying an increase in the fan $F(3,381) = 41.58$, $p < 0.001$, $MSe = 48871$. Neuman-Keuls tests showed that most of the mean RTs were significantly different from each other (See Table 3). There was also an interaction of the fan effect with studied/unstudied probe decisions $F(3,381) = 19.48$, $p < 0.001$, $MSe = 22642$. The fan effect for unstudied probes, 299 ms, was substantially greater than that for studied probes, 125 ms.

 Insert Table 3 about here

Location effect analysis. A 2 (SM/MM cells) X 2 (studied/unstudied decisions) X 3 (fan) repeated measures ANOVA was performed to assess the location effect. Figure 3 depicts the RTs for both the SM and MM conditions. The interesting comparison to make on this graph is the relationship between a pair of matched lines. An example would be to compare the two solid lines denoting the combined MM conditions and the combined SM conditions. Of course, both of these lines share a common point (at 1-1). Other than that, the mean RT for the SM condition was consistently lower than that for the MM condition. Contrary to a spreading activation, network theory of fact retrieval, subjects retrieved facts faster when a single location was associated with several people than vice versa $F(1,31) = 31.01$, $p < 0.001$, $MSe = 130904$. The mean difference of SM and MM cells was 206 ms.

Table 3

Neuman-Keuls tests of fan degrees for all experiments.

Experiment 1a

	Degree of fan	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
RT (in ms):		<u>1662</u>	<u>1752</u>	<u>1720</u>	<u>1883</u>
	1	--	90*	58	221*
	2		--	-32	131*
	3			--	163*

Experiment 1b

RT (in ms):		<u>1604</u>	<u>1807</u>	<u>1796</u>	<u>1899</u>
	1	--	203*	192*	295*
	2		--	-11	92
	3			--	103

Experiment 2

RT (in ms):		<u>1529</u>	<u>1644</u>	<u>1733</u>	<u>1732</u>
	1	--	115*	204*	203*
	2		--	89*	88*
	3			--	-1

Experiment 3

RT (in ms):		<u>1315</u>	<u>1376</u>	<u>1437</u>	<u>1406</u>
	1	--	61*	122*	91*
	2		--	61*	30
	3			--	-31

*p < .05

Note. The numbers in the table reflect the difference in RTs (in ms) between the two fan degrees.

There were no interactions involving the location effect including the important interaction of the location effect with the fan effect needed to demonstrate the retrieval time difference between single and multiple model situations. Neuman-Keuls tests were likewise unsupportive of this effect (see Table 4). However, orthogonal comparisons were made between the SM and MM conditions with the 1-1 cell mean as a control. The MM condition was significantly different from the 1-1, $F(1,31) = 23.06$, $p < 0.001$, $MSe = 636940$, while the SM condition was not. This suggests that there was a decreasing retrieval rate for the MM conditions while it was stable for the SM condition.

 Insert Table 4 and Figure 3 about here

Error Analysis. The average percentage of errors made by the subjects in the decision trials was 3.8% (SD 2.6). There were equal percentages of errors made in both the studied and unstudied conditions (Ms = 3.9%, SDs 1.5 and 1.6 respectively). There were no significant effects involving decision trial errors.

Discussion

The results of this experiment suggest that the propositional network theory does not adequately explain all of the data obtained from a fan effect experiment. While the fan effect itself is explained quite adequately, the location effect is not at all derivable from such a theory at present.

A mental model theory provides a much richer account of the obtained results. Since people experience the world in terms of single

Table 4

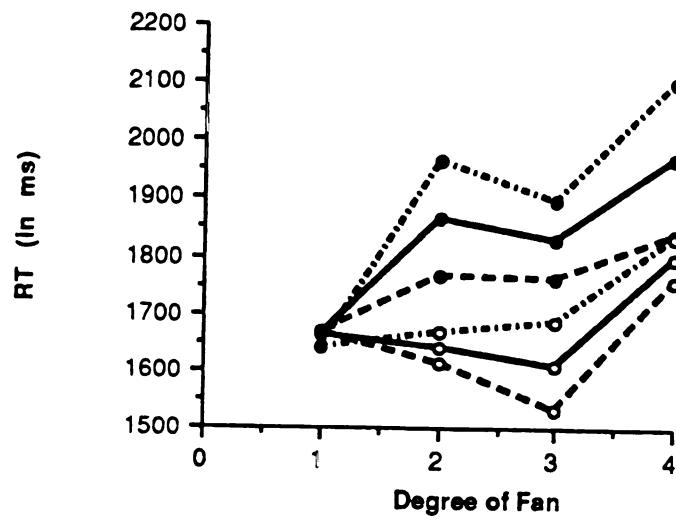
Neuman-Keuls tests for fans for SM and MM conditionsall experiments

<u>SM</u>				<u>MM</u>			
Fan degree				Fan degree			
	2	3	4		2	3	4
Experiment 1a							
RT:	<u>1641</u>	<u>1610</u>	<u>1796</u>		<u>1864</u>	<u>1830</u>	<u>1970</u>
2	--	-31	155*		--	-34	106
3		--	186*			--	140*
Experiment 1b							
RT:	<u>1676</u>	<u>1690</u>	<u>1708</u>		<u>1937</u>	<u>1902</u>	<u>2089</u>
2	--	14	32		--	-35	152
3		--	18			--	187*
Experiment 2							
RT:	<u>1546</u>	<u>1576</u>	<u>1542</u>		<u>1742</u>	<u>1890</u>	<u>1923</u>
2	--	30	-3		--	148*	181*
3		--	33			--	33
Experiment 3							
RT:	<u>1330</u>	<u>1323</u>	<u>1300</u>		<u>1421</u>	<u>1551</u>	<u>1512</u>
2	--	-7	-30		--	130*	91*
3	--	--	-23		--	--	-39

* $p < .05$

Note. The numbers in the tables reflect the difference in RTs (in ms) between the two fan degrees.

Figure 3

Location EffectExperiment 1a

—○— SM
 —●— MM
 - -○- - SM (studied)
 - -●- - MM (studied)
○..... SM (unstudied)
●..... MM (unstudied)

states of affairs within locations, representations of situations are constructed by-location. The organization of mental models around locations produces the location effect.

Finding a location effect is problematic for the propositional network idea of memory organization so popular in cognitive psychology. However, there is the possibility that the obtained result may be due to the specific stimulus materials used or it may be due to a type I error. More evidence is required to put the mental model view on firmer ground. For this reason, Experiment 1b was conducted.

CHAPTER IV

EXPERIMENT 1B

This experiment was a replication of the previous experiment with only a change in the materials used. To be specific, objects replaced people in the study sentences, and the locations served as the grammatical subject of the sentences for half of the participants. These changes were made to demonstrate that the location effect is not limited to a particular type of memorized sentences (i.e. animate subject, location in predicate position).

Method

Subjects. Thirty-two individuals, from 18 to 24 years of age were recruited for this experiment. Five additional subjects were replaced, 3 for exceeding the cut-off for errors on the recognition test and the other 2 for not meeting the criterion on the WAIS-R vocabulary test.

Design and Materials. The design of the present experiment was a 2 (sentence type) X 2 (studied/unstudied decision) X 2 (SM/ MM) X 4 (fan) mixed design. The first was a between-subjects variable, whereas the rest were within-subjects variables.

In order to be certain that all of the materials used in this study were sensible with both the object and the location serving as the

subject of the sentence, a normative study was conducted in which 50 subjects rated sentences for sensibility. The subjects were undergraduates recruited from the subject pool at Michigan State University and given class credit for their participation. These subjects did not participate in any other portion of this study.

For the norming study, the sentences included all possible paired combinations of the 20 locations and 20 objects. There were two forms of each object-location combination: "The object is in the location." and "The location has the object." Some examples of the sentences used in this study are:

The pay phone is in the stadium.
The ceiling fan is in the cleaner's.
The airport has the revolving door.
The truck stop has the bulletin board.

This generation procedure produced a list of 800 sentences. These sentences were then randomly assigned to one of ten lists with the only constraint being that equal numbers of each sentence type were represented. Each list also contained a set of 20 blatantly nonsensical sentences, such as "The sports car is in the sewer," thus making each list 100 sentences long. The nonsense sentences were included in an attempt to get the subjects to more fully attend to the task. A 5-point rating scale was used with 1 designated as "sensible" and 5 as "not sensible". Subjects were encouraged to use the entire scale. Each sentence was rated by five individuals.

From these sentence ratings mean sensibility scores were obtained for each sentence. The mean rating across sentences was 2.3, not

including fillers. Those sentences with mean ratings of 2.9 or lower were selected for use as stimuli for the experiment since these were felt to be sensible enough that subjects would incur no difficulty in reading and understanding them. This generated a list of 587 possible sentences. From this list of possible sentences, 32 unique lists were generated for the experiment according to the design described in Experiment 1a.

Procedure. The procedure for the present experiment was identical to Experiment 1a with the exception of the modified stimulus materials. Subjects were also divided into two groups. One group received object-subject sentences (OS) while the other group received location-subject sentences (LS).

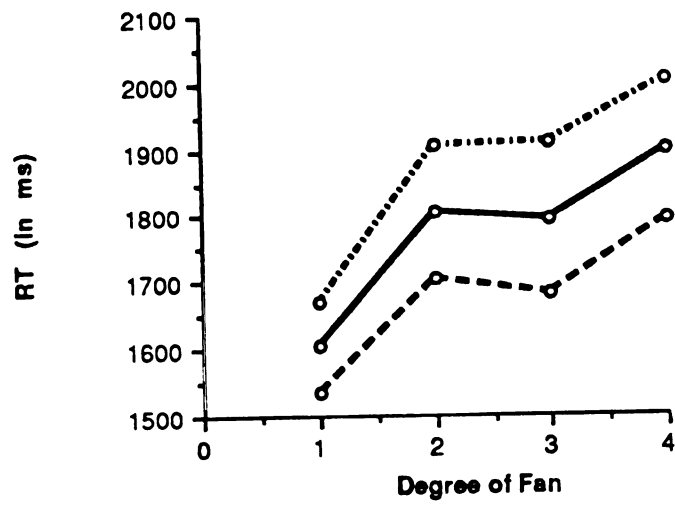
Results

Studied/unstudied probe differences and fan effect. The results for this experiment are summarized in Figures 4 and 5. Figure 4, depicts the effect of studied versus unstudied probe decisions, as well as illustrating the general fan effect of the studied, unstudied, and combined conditions. These data were submitted to a 2 (sentence type) X 2 (studied/unstudied decisions) X 4 (fan) mixed ANOVA. Subjects were quicker to decide that a probe was a studied sentence as opposed to an unstudied one $F(1,30) = 19.15, p < 0.001, MSe = 126360$. Mean RTs for studied and unstudied trials were 1700 ms and 1902 ms, respectively.

 Insert Figure 4 about here

Subjects also showed a fan effect $F(3,90) = 7.61, p < 0.001, MSe =$

Figure 4

Fan EffectExperiment 1b

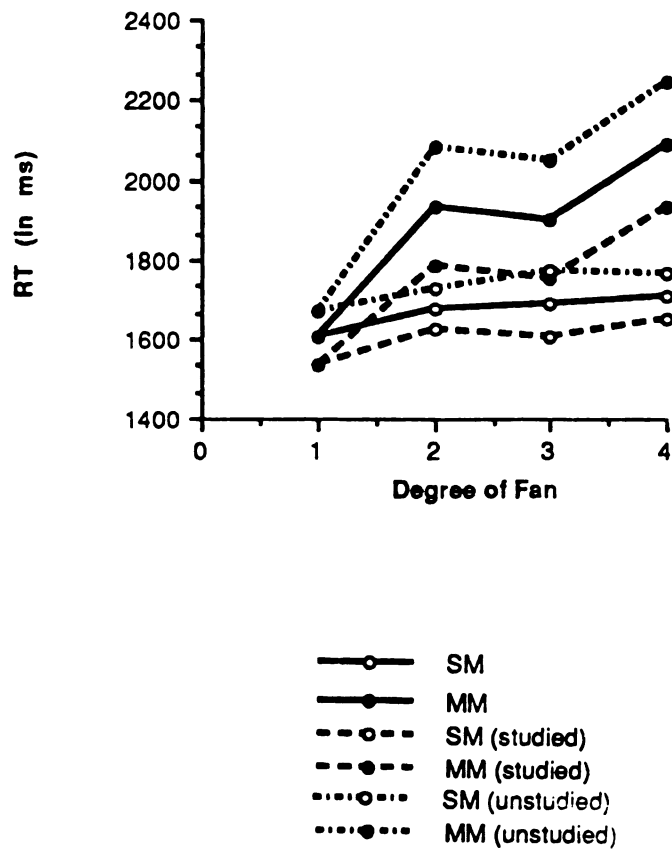
—○— Fan
- - -○- - Fan (studied)
...○... Fan (unstudied)

128586. Neuman-Keuls tests showed that only the fan-1 RTs differed significantly from the other conditions (see Table 3). Also, contrary to what was found in Experiment 1a, no interaction of studied/unstudied probe type with the fan effect was found ($F < 1$).

Location effect analysis. The RT data were also submitted to a 2 (sentence type) X 2 (studied/unstudied decision) X 2 (SM/ MM) X 3 (fan) ANOVA. Once again, by looking at Figure 5 and comparing the SM with the MM conditions from any of the three sets of lines, we see that the MM conditions produced consistently longer RTs than the SM conditions. The location effect was significant, $F(1,30) = 37.29$, $p < 0.001$, $MSe = 209222$. The mean difference between the SM and MM cells was 285 ms. There was also a marginally significant interaction of location effect with studied/unstudied probe decisions, $F(1,30) = 3.93$, $p < 0.06$, $MSe = 718296$. The location effect for unstudied decisions (372 ms) was much larger than for studied decisions (199 ms).

Again, the location effect by fan effect interaction was not significant, $F(2,60) = 1.13$, $p > .10$, $MSe = 12767284$. However, Neuman-Keuls tests showed that while the SM RTs did not differ from one another, for the MM RTs the fan-4s were significantly greater than the fan-3s (see Table 4). Also comparison tests with the 1-1 cell as a control, like those done for Experiment 1a, showed a difference between the MM condition and the 1-1 cell, $F(2,30) = 11.65$, $p < 0.001$, $MSe = 1714684$, but not with the SM condition. These last two results are consistent with the prediction that the retrieval time will increase for the MM condition but not for the SM condition.

Figure 5

Location EffectExperiment 1b

 Insert Figure 5 about here

Sentence subject type. There were no significant effects of having either the object versus the location serve as the subject of the sentences. While the LS group was slightly slower on average than the OS group on the recognition test (1785 ms versus 1817 ms), this difference was not significant ($F < 1$). Fan effects within each of the two conditions were significant [$F(3,45) = 4.84$, $p < 0.05$, $MSe = 61837$ for OS and $F(3,45) = 3.25$, $p < 0.05$, $MSe = 66749$ for LS], as was the location effect [$F(1,15) = 15.34$, $p < 0.01$, $MSe = 119524$ and $F(1,15) = 22.37$, $p < 0.001$, $MSe = 92601$ for OS and LS respectively], see Figures 6 and 7. The results of the Neuman-Keuls tests for differing degrees of fan were similar those for combined sentence type RTs. So, the grammatical form of the sentences appears to have little bearing on the way facts were stored and retrieved.

 Insert Figures 6 and 7 about here

Error Analysis. The average percentage of errors made by the subjects in the decision trials was 3.2% (SD 2.2). There were slightly, but not reliably ($F < 1$), more errors in the unstudied ($M = 3.4\%$, SD 3.0) than in the studied condition ($M = 3.0\%$, SD 2.7). One difference from Experiment 1a is that there were more errors in the MM conditions with a mean of 4.8% errors per subject, than in the SM conditions with a mean of 2.1% errors per subject, $F(1,30) = 11.06$, $p < 0.01$, $MSe = 0.87$. The only other notable result in the error analysis was a marginally

Figure 6

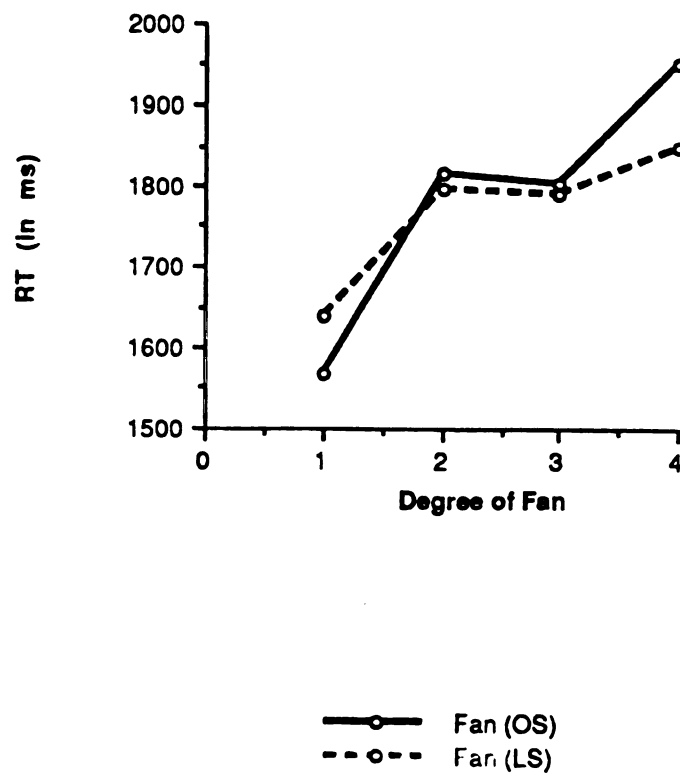
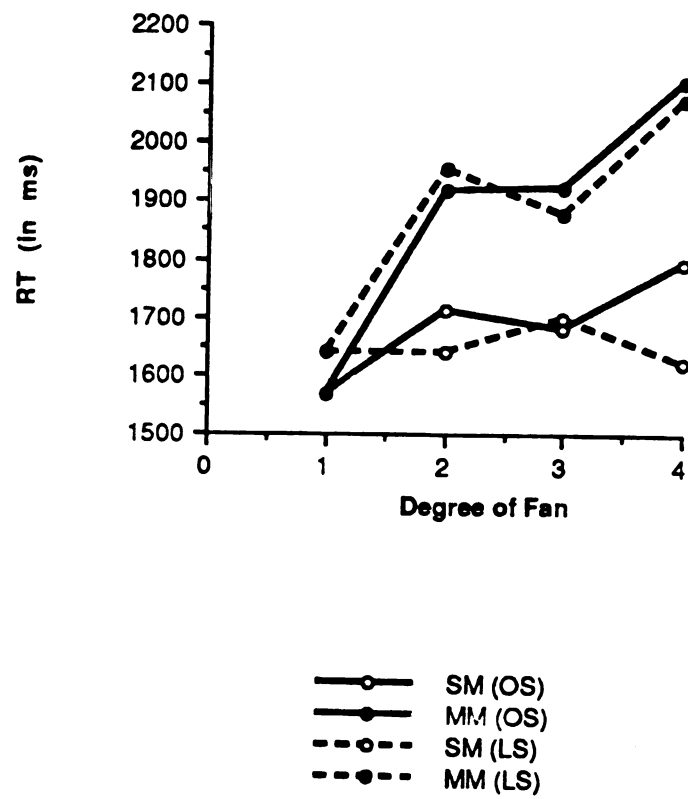
Fan Effect by Sentence TypesExperiment 1b

Figure 7

Location Effect by Sentence TypesExperiment 1b

significant fan effect, $F(3,90) = 2.29$, $p < 0.09$, $MSe = 1.813$. The percentage of errors increased with increasing fan. The means were 1.8, 2.8, 3.1, and 4.5% for fans from 1 to 4 respectively. The obtained differences in the error rates are consistent with the RT data in this respect. There is no evidence of a speed-accuracy trade-off, rather an increase in error rate appears to accompany an increase in RT.

Discussion

The findings from this experiment are more interpretable in terms of a mental model theory of representation than a propositional network theory for the same reasons as given for the previous experiment. The data reflect a tendency to organize and retrieve facts by location. A propositional network view is at a disadvantage in trying to explain such data.

In addition, this experiment has shown that the location effect is not the result of a specific category (people) filling the slot designated for the associate of the locations. It would appear that anything that can be said to be contained in a location -- within restrictions, such as the phone booth example above -- will result in the obtained pattern of retrieval times. This experiment also provided evidence that the location effect is not merely due to the syntactic structure of the materials since the same effect was found when the location served as the syntactic subject of the sentences as when it served as the prepositional phrase.

STABILITY OF LOCATION ORGANIZATION

According to the mental model view the organization of information by a non-location concept instead of by locations is less likely since people or objects do not define separate situations as strongly as locations do. This is not to say that people cannot organize information in memory centering on a non-location concept. Rather, location provides a stronger basis for organization with the type of sentences used for these experiments. Location information is used as the basis of the organization of representations and this organization is largely inflexible.

CHAPTER V

EXPERIMENT 2

This study was devised to assess whether the organization of representations around locations is easily altered. That is, can subjects organize their representations around objects rather than locations, reversing the location effect? The experimental procedure was identical to the previous experiments except that the subjects were given specific instructions on the method by which they should organize the facts in memory as they study.

Subjects were divided into three groups, each instructed to memorize in a different manner. In the "location" group, the subjects were explicitly instructed to group the items in terms of the location that the items are in during the list learning period. The "object" group subjects were instructed to group information in terms of the object and its associates. The "neutral" group subjects were told only to memorize the sentences as efficiently as possible with no indication of how they should group the facts.

Assuming the primary form of the representation used in fact retrieval is a mental model, three results are expected. First, the pattern of RTs for the location group should not differ from either the neutral group or the previous experiments. If location is preferred,

the neutral group, given a choice of organizing based on either location or object, will choose location. Second, the location and neutral groups may show a greater location effect than the object group. Finally, the object group will not show a reversal of the location effect due to the object grouping strategy at memorization. At worst, object organization will attenuate the location effect making it negligible because the subject would be treating each instance of an object as a separate situation and, hence, generating a separate mental model.

Method

Subjects. This experiment used 72 subjects, 24 in each instruction group. Two additional subjects were replaced for failing to meet the criterion on the WAIS-R vocabulary test.

Design and procedure. The design of this study was a 3 (memorization instructions) X 2 (studied/unstudied decision) X 2 (SM/MM) X 4 (fan) mixed design with repeated measures on the last 3 variables. This experiment is identical to the previous two with the exception of the memorization instructions. The experimental materials were the normed sentences of the form "The object is in the location" from Experiment 1b. Additionally, all three groups received the same set of sentences, though these sets differed for subjects within a group. This was intended to reduce any variability caused by having different sentence sets across groups. Before beginning to memorize the sentences the subjects were given the instruction to "... try to organize these facts in your mind in terms of the locations/objects" (entire

instructions are given in Appendix B). Subjects were also reminded of the memorization strategy at the beginning of each cycle of the study-test portion of the experiment. At the end of the experiment the subjects were asked three questions: 1) When an object was associated with multiple locations was it considered to be the same or different instances of the object for each of the locations? 2) When a location was associated with multiple objects was it considered to be the same or different instances of the location for each of the objects? 3) Were the memorizing strategy instructions followed during the study-test portion of the experiment? (Neutral group was not asked this question.)

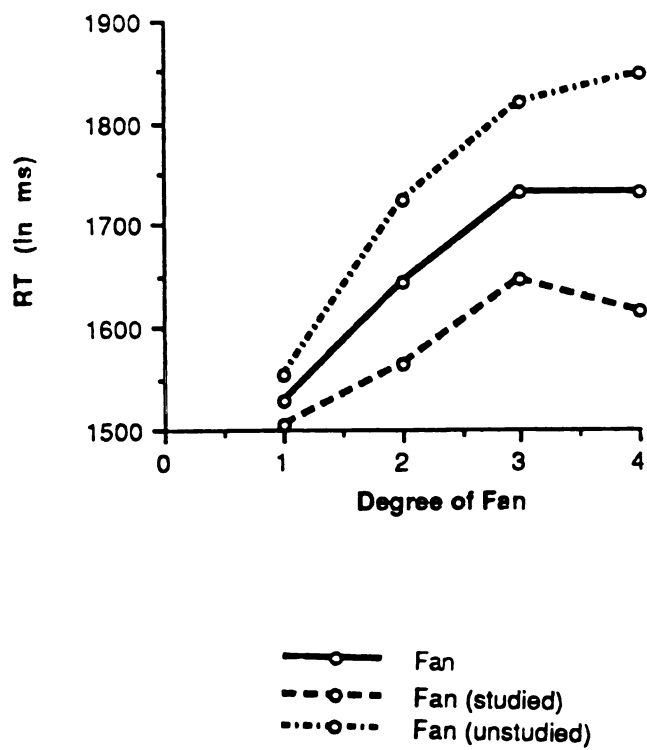
The first question will be referred to as the object question, the second as the location question, and the third as the instructions question. The procedure for the experiment was the same as previous experiments in all other respects.

Results

Studied/unstudied probe differences and fan effect. Less than 2% of the data were trimmed according to the 2.5 SD within cell trim. The results are summarized in Figures 8 and 9. The RT data were submitted to a 3 (instruction type) X 2 (studied/unstudied decisions) X 4 (fan) mixed ANOVA. Figure 8 clearly illustrates the fact that studied decisions occurred more rapidly than unstudied decisions, $F(1,69) = 599.832$, $p < 0.001$, $MSe = 91244.468$. The mean RT for studied trials was 1582 ms compared with 2199 ms for the unstudied trials.

 Insert Figure 8 about here

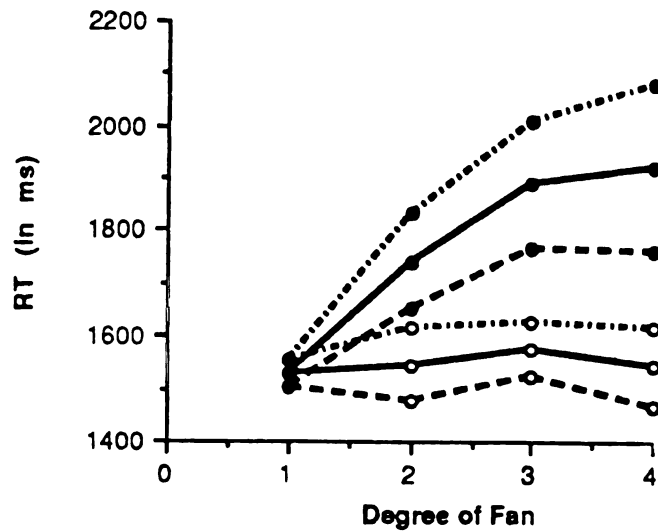
Figure 8
Fan Effect
Experiment 2



Subjects again showed the classic fan effect $F(3,207) = 378.648$, $p < 0.001$, $MSe = 101915.461$. Neuman-Keuls tests revealed that the retrieval times differed between each of the fan levels except between the fan-3 and fan-4 conditions (see Table 4). Consistent with Experiment 1a and contrary to Experiment 1b there was an interaction of fan and studied/ unstudied decisions, $F(3,207) = 558.869$, $p < 0.001$, $MSe = 61769.375$. The fan effect was greater for unstudied probe decisions (368 ms) than for studied probe decisions (112 ms).

Location effect analysis. The RT data were submitted to a 3 (instruction type) X 2 (studied/unstudied decision) X 2 (SM/MM) X 3 (fan) ANOVA. Once again, by looking at Figure 9 and comparing the SM and the MM conditions it can be seen that the MM conditions consistently produced longer RTs than the SMs. The location effect was significant $F(1,69) = 7.31$, $p < 0.001$, $MSe = 144490$. The mean difference between the SM and MM cells was 297 ms. There were two interactions present involving the location effect. The first was with the studied/unstudied probe decisions, $F(1,69) = 14.74$, $p < 0.001$, $MSe = 52629$. The location effect for the unstudied decisions (358 ms) was larger than that for the studied decisions (237 ms). The other interaction that was finally significant was the Location Effect X Fan Effect interaction, $F(2,138) = 5.63$, $p < 0.01$, $MSe = 111628$. This indicates that the size of the fan effect was greater for the MM condition than for the SM condition as would be expected because multiple model search takes increasingly longer than single model search as fan increases. The fan effect was not significant for the SM condition, $F < 1$, but was for the MM

Figure 9
Location Effect
Experiment 2



—○— SM
 —●— MM
 - -○- - SM (studied)
 - -●- - MM (studied)
 ···○··· SM (unstudied)
 ···●··· MM (unstudied)

condition $F(2,138) = 10.60$, $p < 0.001$, $MSe = 62751$. This conclusion was further supported by Neuman-Keuls tests showing that there were no significant differences between any of the SM cells but there were with the MM cells (see Table 5). The attainment of the Location Effect X Fan Effect interaction and the cleaner results of the Neuman-Keuls tests is attributed to the increased power due to more trials per cell and more subjects in this experiment compared to Experiments 1a and 1b.

 Insert Figure 9 about here

Instruction type. There were no significant effects involving the type of memorizing instructions that the subjects received. The location effect was significant for each of the different instruction groups, [$F(1,23) = 39.34$, $p < 0.001$, $MSe = 84008$ for the location group, $F(1,23) = 63.965$, $p < 0.001$, $MSe = 40047.076$ for the object group, and $F(1,23) = 40.36$, $p < 0.001$, $MSe = 92679.697$ for the neutral group], as was the fan effect [$F(3,69) = 153.46$, $p < 0.001$, $MSe = 80129.705$ for the location group, $F(3,69) = 121.65$, $p < 0.001$, $MSe = 103538$ for the object group, and $F(3,69) = 112.56$, $p < 0.001$, $MSe = 131697.31$ for the neutral group], see Figures 11 and 10 respectively. Neuman-Keuls tests revealed differences similar to the tests for the combined conditions.

 Insert Figures 10 and 11 about here

Error Analysis. The average percentage of errors made by the subjects on the decision trials was 2.5. The error rates in the unstudied ($M = 2.5\%$) and studied ($M = 2.4\%$) conditions were comparable

Figure 10
Fan Effect by Instruction Type
Experiment 2

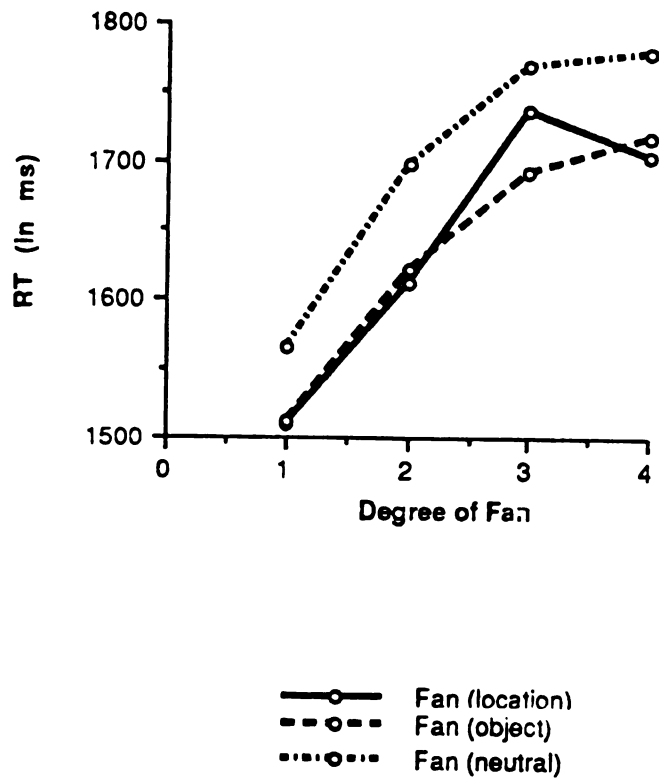
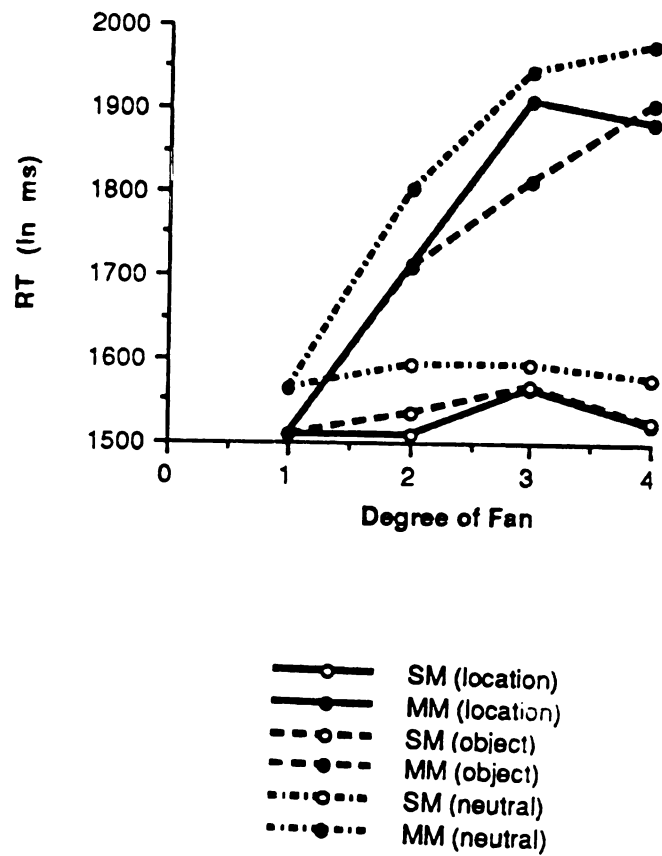


Figure 11
Location Effect by Instruction Type
Experiment 2



($F < 1$). There was a fan effect, $F(3,207) = 3.28$. The percentage of errors increased with increasing fan: The means were 1.8, 2.2, 2.9, and 3.0% for fans from 1 to 4, respectively. The pattern of errors was also similar to Experiment 1b in that there were more errors in the MM conditions (3.5%) than in the SM conditions (1.8%), $F(1,69) = 15.21$, $p < 0.001$, $MSe = 39.99$. The location effect also interacted with studied/unstudied probe decision, $F(1,69) = 5.24$, $p < 0.05$, $MSe = 37.61$. There was a greater increase in the number of errors from the SM to the MM condition in the unstudied probe decisions (1.4 to 4.1%) compared to the studied (2.3 to 3.0%). $p < 0.05$, $MSe = 13.74$. There was no significant effect of instruction type on error rate, $F(2,69) = 2.38$, $p > .10$, $MSe = 1328$, although the location and object group had fewer errors (2.2% for both) than the neutral group (3.0%). The obtained differences in the error rates are consistent with the RT data. There is no evidence for a speed accuracy trade-off occurring with these subjects under these conditions.

Comparisons of responses to post-test questions. Two subjects in the neutral instruction group were not asked the post-test questions due to experimenter error. Therefore, the following analyses exclude these two subjects. We will consider each of the questions in turn.

For the object question the majority of the subjects responded that they considered it to be the same object in each of the locations it was associated with (60.0%). This pattern of responses was true for both the location (58.3%), and object groups (75.0%), but not for the neutral instruction group (45.5%). Chi-square tests did not show any

significant differences. An ANOVA using the response to this question (same or different) as a between subjects factor found no differences in reaction times during the recognition test.

For the location question 95% of the subjects said that they considered the location to be the same when multiple objects associated with it. Of the 4 subjects who reported that the location was different, 1 was in the location instruction group and the other 3 were in the neutral instruction group.

When asked if they followed the instructions given to them during the study portion of the experiment, in the location group, only 1 reported not doing so, whereas in the object group, 10 reported not doing so. The response to the instructions question was not correlated with type of response on the other questions. When the subjects in the object group who reported not following instructions were removed the location effect remained significant, $F(1,13) = 33.3$, $p < 0.001$, $MSe = 431843$.

Discussion

This experiment has demonstrated that subjects appear to be obligated, to some extent, to organize their mental representations in terms of situations defined by the location even when given instructions to group the information in terms of the object in the sentences. Simple voluntary control over the process is limited. One subject in the object group who reported not following the instructions said that it was "too difficult" to group the information in that way, so she grouped in terms of the location. Even though some subjects did not

follow instructions in the object group, those who reported using the instructed strategy still showed the location effect.

Arguments can certainly be made that the attempt to get the subjects to organize by object was weak and that more intensive methods could have been employed. Such an effort might include presenting the location and object groups with only the appropriate half of the questions during the test portion of the study-test procedure (i.e., "Where was the object?" questions only for the object group), or presenting all the locations associated with an object at once during study and vice-versa. However, the present experimental methods do seem to have had some impact on how subjects tried to organize the learning material. Evidence for this includes the fact that more subjects in the object group, compared to the other two, tended to consider the object to be the same instance when it was associated with multiple locations. Despite this, the location effect was not weakened in this group. The present study shows that the location effect is not a chance result of a group of subjects using the first strategy that comes to mind, grouping by location, but that this tendency is more deeply rooted within the system.

CHAPTER VI

EXPERIMENT 3

The assumption that subjects use mental models of situations defined by locations in fact retrieval experiments leads to specific predictions about the effect on retrieval time of presenting either a location or a non-location cue before the memory probe. By making it more likely that the desired information will be in working memory, a precue in a fact retrieval task provides the subject with a device for reducing retrieval time. There are four cases to be considered:

- 1) a location precue presented for a probe from a several objects-single location condition (SM-location cue),
- 2) an object precue presented for a probe from a several objects-single location condition (SM-object cue),
- 3) a location precue presented for a probe from a single object-several locations condition (MM-location cue),
- 4) and, an object precue presented for a probe from a single object-several locations condition (MM-object cue).

In cases 1 and 2, under normal (non-cued) circumstances there is little or no fan effect. The presentation of either a location or an object cue should not alter that pattern of retrieval times across degrees of fan. Both of these cue types channel activation to the

appropriate model in memory. Since this model is the only one that receives activation anyway, all these cues do is to bring it closer to threshold, thereby speeding overall retrieval time.

In the third case, a fan effect is obtained in uncued conditions. A location cue should cause partial activation of the model needed to make the decision prior to probe presentation bringing it close to reaching threshold. Because that model is so close to threshold the normal division of activation is of little consequence and there will be a reduced or minimal fan effect.

As with the last case, the fourth case is normally expected to show a fan effect. It differs in that even with the presence of a cue there will be no change in the fan effect despite a decrease in overall retrieval time. The object cue causes activation to be sent to each of the models associated with that object. Activation must still be divided up at the time of presentation of the probe since no single model has yet been selected as having more activation than any of the rest, and the fan effect remains.

Another way of stating these predictions is to consider the effect of each cue type on the location effect. The location effect should remain for the neutral and object cue conditions because the MM conditions for both should still show fan effects. The location effect will be reduced or eliminated for the location cue condition because this change in the MM condition brings the RTs closer to that of the SM condition, thereby reducing or eliminating the location effect.

So, basically, it is predicted that the object and location cues

will provide faster RTs overall and the fan effect for the MM-location cue condition will be reduced. This last point will also be reflected in a reduction of the location cue condition's location effect.

A propositional network view predicts a different pattern of results: The four conditions outlined above should benefit equally. This is because propositional networks, of the form typified by ACT*, provide an equal amount of facilitation for a precue of any type (Anderson, 1974). A precue activates one of the nodes in the propositional structure and activation begins to spread from there, thereby facilitating retrieval. Since this activation spreads bidirectionally and in parallel it makes no difference which of the nodes is activated ahead of time.

The present study used cue-probe SOAs of 250, 500, and 1000 ms. The different SOAs were used to more effectively detect the nature of the benefit gained by a precue. In a study by Whitlow (1984) investigating focused search within a propositional network, it was found that different cue-probe SOAs have no effect on the fan effect, other than an overall facilitation of RTs and occasionally an increase in the fan effect. Sentence subject precues with 0 to 2700 ms SOAs were used along with sentences in the form "The occupation verbed the object." So, the SOA levels used in the present study are within a range such that they should not alter the fan effect.

Method

Subjects. Seventy-two subjects, 24 in each SOA group were recruited for this experiment. Eight subjects were replaced for having

too many errors on the recognition test and an additional 2 subjects were replaced for failing to meet the criterion for the WAIS-R vocabulary test.

Design and procedure. The design of this experiment was a 3 (SOA) X 2 (sentence type) X 2 (studied/unstudied decision) X 2 (SM/MM) X 4 (fan) X 3 (cue) mixed design with the first two variables tested between subjects. Sentences were taken from the pool developed for Experiment 1b. The procedure was largely identical to previous experiments except for the addition of the cue. During the recognition test, each probe received a location, object, or a neutral (the word READY) cue preceding the target sentence by either 250, 500, or 1000 ms. Subjects were instructed to use the cue in helping them make the studied/ unstudied decision. There were 4 trials of each cue type for each probe sentence resulting in a 336 item recognition test. Subjects were allowed a self-timed break after every 84 trials. The ordering of the sentences and cue types was random.

The cues were presented halfway down on the left hand side of the screen. This was the same screen location as the beginning of the probe sentence. This positioning may have provided a benefit for one cue type over another since it was closer to the first concept word in the probe sentence. The actual distance from the beginning of the cue to the initial letter of the concept word in the probe sentence was four spaces, approximately 3 cm (the word "The" and a space). In order to control for the possibility that the proximity of a cue to the location of the same word in the probe sentence may effect performance, both LS

and OS sentences were used as in Experiment 1b.

Results

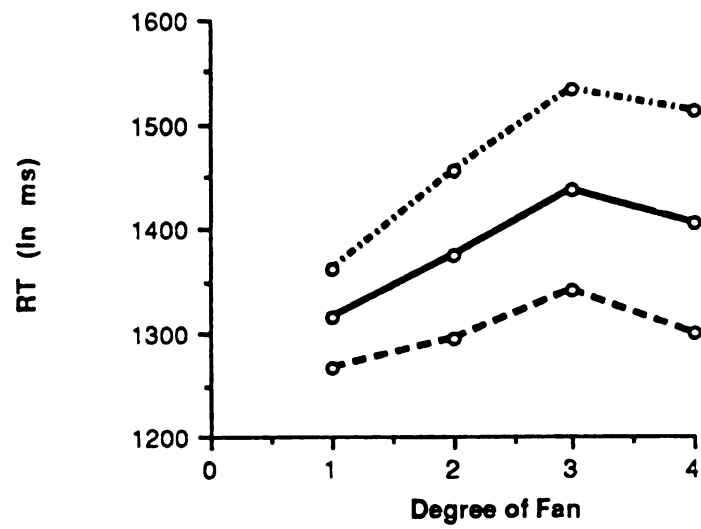
Studied/unstudied probe differences and fan effect. Instead of designating the lower end cutoff at 500 ms as in previous experiments it was lowered to 400 ms because of the cues. The RTs collected in this experiment were faster than the previous ones and a 500 ms cutoff would have eliminated a substantial portion of the data. The RT data were submitted to a 3 (SOA) X 2 (sentence type) X 2 (studied/unstudied decision) X 3 (fan) X 3 (cue type) ANOVA. The main effect of SOA and most of the major interactions involving SOA were not significant ($F_s \leq 1.74$). Therefore, in what follows SOA is considered only in those few cases in which it did have an impact.

The results for this experiment are summarized in Figures 12 and 13. As can be observed by looking at Figure 12, the studied probe decisions were faster than those for the unstudied probes, $F(1,66) = 189.02$, $p < 0.001$, $MSe = 61921$ ($Ms = 1301$ and 1466 ms, respectively).

Insert Figure 12 about here

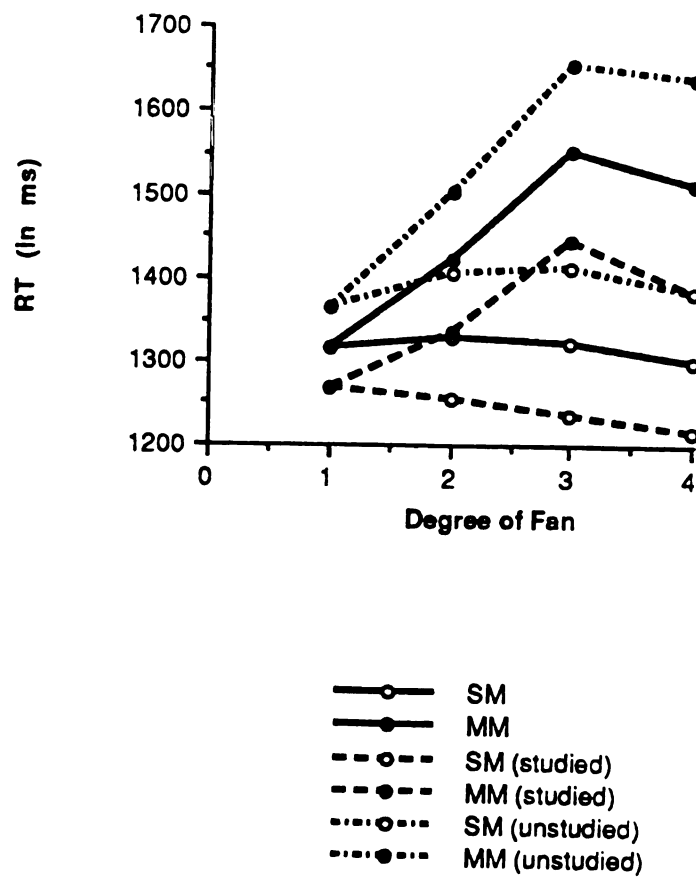
There was a fan effect, $F(3,198) = 9.67$, $p < 0.001$, $MSe = 121244$, and the results of Neuman-Keuls tests are presented in Table 3 for differences between fan degrees. There was also an interaction of the fan effect with studied/unstudied probe decisions with a more pronounced fan effect for unstudied probe decisions compared to studied probes, $F(3,198) = 4.98$, $p < 0.01$, $MSe = 56242$. The fan effect was significant in both conditions with $F(3,198) = 2.66$, $p < 0.05$, $MSe = 73346$ for

Figure 12

Fan EffectExperiment 3

—○— Fan
- -○- - Fan (studied)
...○... Fan (unstudied)

Figure 13

Location EffectExperiment 3

studied and $F(3,198) = 12.02$, $p < 0.001$, $MSe = 104160$ for unstudied probes.

Location Effect. As can be seen in Figure 13, the location effect was significant, $F(1,66) = 89.57$, $p < 0.001$, $MSe = 226197$, with SM condition being faster than MM condition on average (176 ms). The Location Effect X Fan Effect interaction was also significant, $F(2,132) = 7.60$, $p < 0.001$, $MSe = 161129$. The fan effect was significant only for the MM condition, $F(2,132) = 9.75$, $p < 0.001$, $MSe = 33180$. Neuman-Keuls tests showed significant differences in the MM condition (see Table 4).

Insert Figure 13 about here

Effects of cue type. The pattern of RTs for each cue type can be seen for fan effect in Figure 14, and the location effect overall and for each SOA in Figure 15. There was a main effect of cue type, $F(2,132) = 220.12$, $p < 0.001$, $MSe = 50732$, with object cues producing the fastest RTs ($M = 1284$ ms), location cues the next fastest RTs ($M = 1323$ ms) and neutral cues the slowest RTs ($M = 1543$ ms). Neuman-Keuls tests showed that these were all significantly different from one another. Additionally, cue type interacted with SOA, $F(4,132) = 8.21$, $p < 0.001$, $MSe = 50733$. Neuman-Keuls tests for each SOA group revealed that this was because the location and object cue conditions were significantly different from each other only in the 1000 ms SOA condition.

Figure 14

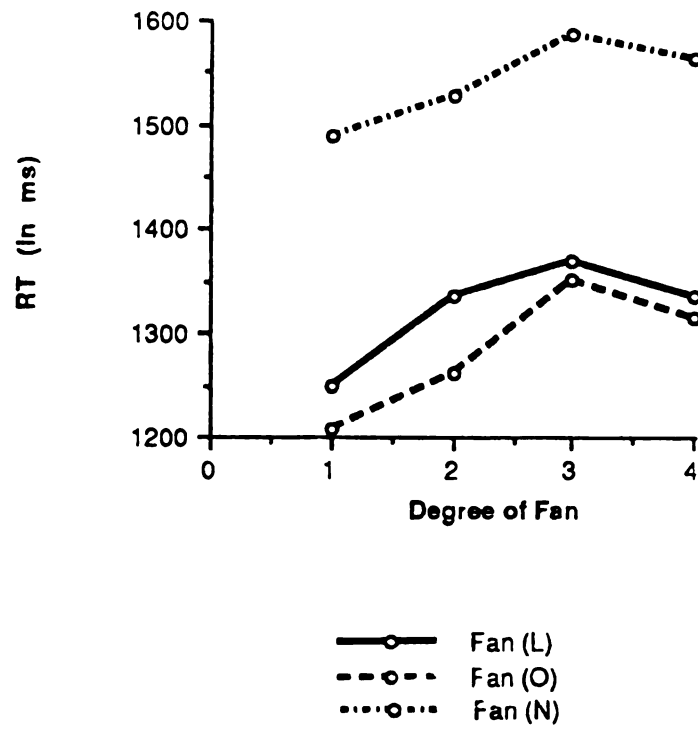
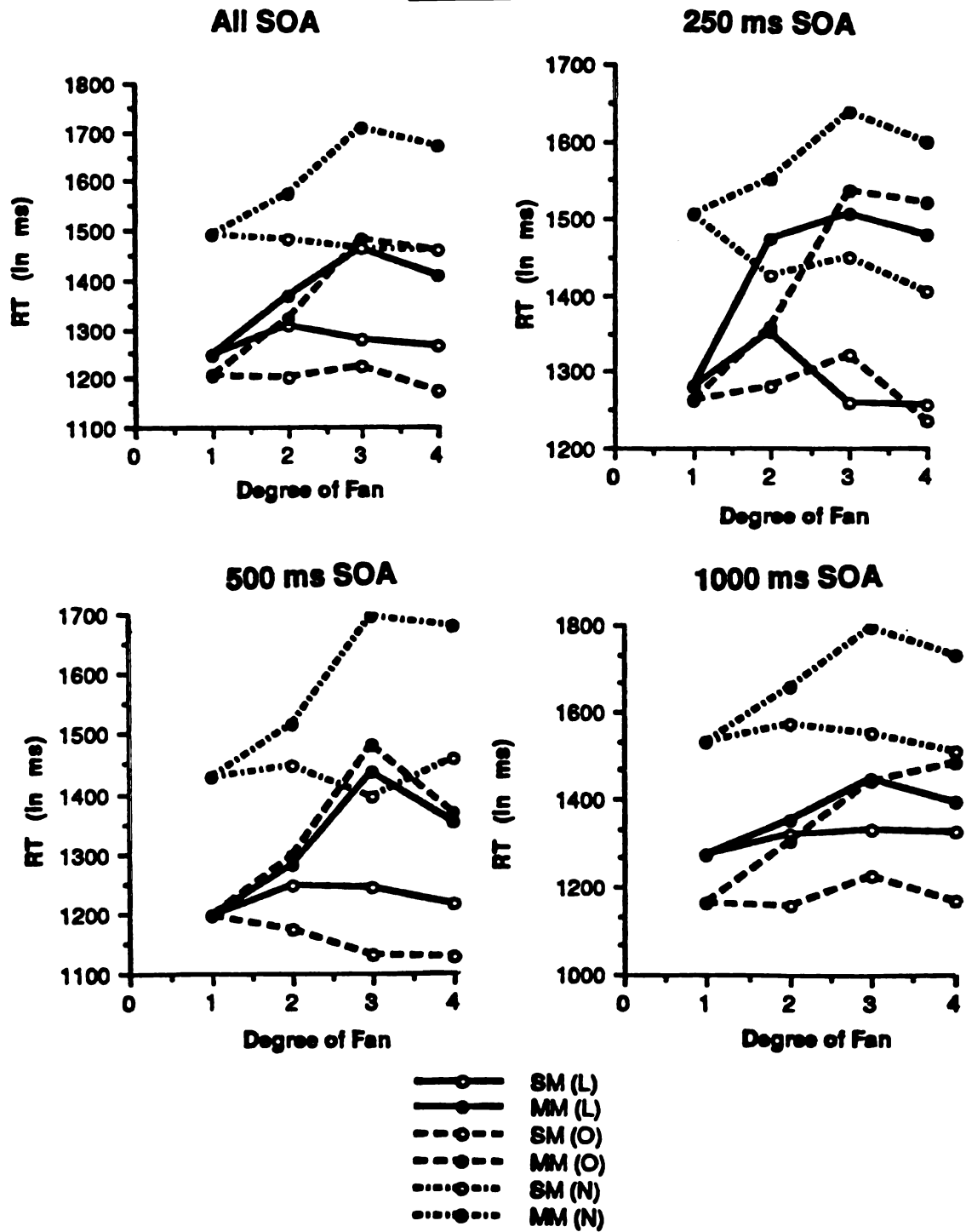
Fan Effect by Cue TypeExperiment 3

Figure 15

Location Effect by Cue TypeExperiment 3

 Insert Figures 14 and 15 about here

In examining the effects of cue type, the neutral cue condition results will provide the baseline data.

The SM-neutral cue condition produced no fan effect, $F < 1$. This is consistent with the finding of Experiment 2. For both the SM-location cue and SM-object cue cases, as predicted, there was also no fan effect, $F_s \leq 1.08$.

The MM-neutral cue fan effect was significant, $F(2,132) = 6.50$, $p < 0.01$, $MSe = 53922$. Neuman-Keuls tests showed that the fan-2 condition was significantly faster than the fan-3 and fan-4 conditions. This is also consistent with Experiment 2. For the MM-location cue case there was also a fan effect, $F(2,132) = 3.10$, $p < 0.05$, $MSe = 52451$, although it was just significant. Neuman-Keuls test showed that the only significant difference between the decision times was between the fan-2 and fan-3 conditions. The prediction that the fan effect for the MM-location cue condition would be reduced or eliminated was not supported.

The MM-object cue fan effect was significant, $F(2,132) = 10.65$, $p < 0.001$, $MSe = 51387$, and Neuman-Keuls tests were similar to most other conditions and other experiments where fan effects were found. This is consistent with the predictions.

Even though the difference between the size of the fans for the MM-location and MM-neutral cue conditions was not significant, the difference between the MM-location and MM-object conditions (138 ms) was, $F(1,71) = 4.17$, $p < 0.05$, $MSe = 82252$. This suggests that these

two cue types had different effects on the fan effect.

The other method of addressing the effect of cue type was to look at the location effects. The Location Effect X Cue Type interaction was significant, $F(2,132) = 7.73$, $p < 0.001$, $MSe = 54851$. This was also further qualified by an SOA X Location Effect X Cue Type interaction, $F(4,132) = 2.77$, $p < 0.05$, $MSe = 53581$. This can be accounted for by the change in the location effect in the location cue condition as discussed below.

The location effect was significant for the neutral cue condition, $F(2,66) = 56.97$, $p < 0.001$, $MSe = 126795$, as it has been in all of the preceding experiments with a difference of 183 ms. Additionally, the Location Effect X Fan Effect interaction was also significant, $F(2,132) = 5.17$, $p < 0.01$, $MSe = 89293$ as it was in Experiment 2. This is further supported by the fact, as mentioned above, that the fan effect for the SM condition was not significant, whereas it was for the MM condition.

For the location cue, the location effect was significant, $F(2,66) = 31.12$, $p < 0.001$, $MSe = 116922$, with an average difference of 130 ms between the SM and MM conditions. As noted above, the location effect differed in the different SOAs for this cue type. The location effect was significant for the 250, $F(2,22) = 54.46$, $p < 0.001$, $MSe = 51139$, and 500 ms SOA groups, $F(2,22) = 8.12$, $p < 0.01$, $MSe = 131765$, with differences of 197 and 122 ms, respectively. However, the location effect was not significant for the 1000 ms SOA group, $F(2,22) = 2.15$, $p > .10$, $MSe = 167864$, with a difference of 71 ms between the SM and MM

conditions. The Location Effect X Fan Effect interaction was marginally significant over all SOAs ($p < 0.06$) and was not significant for any of the individual SOA groups. This finding supports the predictions, particularly for the 1000 ms SOA group.

The location effect was also significant for the object cue condition, $F(2,66) = 111.17$, $p < 0.001$, $MSe = 92180$. The average size of the effect was 218. The Location Effect X Fan Effect interaction was also significant, $F(2,132) = 6.39$, $p < 0.01$, $MSe = 89300$. The interaction is also well supported by the fan analyses and Neuman-Keuls tests for the MM-object cue and MM-location cue conditions. These results all conform to the predictions.

Sentence type. There was no main effect of sentence type. However, there was an interaction with cue type, $F(2,132) = 6.42$, $p < 0.01$, $MSe = 50732$. The OS sentence group had equal RTs for both location and object cues (1276 ms for both) while the LS sentence group had faster RTs with the object cue (1293 ms) than with the location cue (1371 ms). The reason for this difference is not readily apparent. However, in general, these results parallel those of Experiment 1b in terms of the effect of the different sentence types.

Error Analysis. The average percentage of errors made by subjects on the decision trials was 3.1 (SD 1.9). There was no main effect of SOA. More errors were made when the probe was a studied sentence (3.3% errors) rather than an unstudied sentence (2.9% errors). This pattern of errors is different from the previous three experiments, but the difference was not significant.

There was a marginally significant fan effect for errors ($p < 0.06$) with 2.9, 2.6, 3.3, and 3.6% errors for fans from 1 to 4 respectively. There was also a significant interaction of fan effect with SOA, $F(6,198) = 3.22$, $p < 0.01$, $MSe = 36$. Both the 250 and the 500 ms SOA conditions showed significant standard fan effect patterns ($F(3,66) = 3.24$, $p < 0.05$, $MSe = 2941$ and $F(3,66) = 2.94$, $p < 0.05$, $MSe = 1306$ for 250 and 500 ms SOA groups respectively), but the 1000 ms SOA pattern was erratic with mean percentages of 3.6, 2.7, 3.6, and 2.2 for fans of 1 to 4 respectively. Additionally there was an interaction of fan effect with studied/unstudied probe decisions, $F(3,198) = 3.31$, $p < 0.05$, $MSe = 8090$. There was a fan effect only for the unstudied decisions, $F(3,207) = 4.57$, $p < 0.01$, $MSe = 43$.

More errors were made in the MM condition than in the SM condition (a difference of 1.7%), $F(1,66) = 22.16$, $p < 0.001$, $MSe = 83$. The location effect also interacted with the studied/unstudied probe decisions, $F(1,66) = 6.50$, $p < 0.05$, $MSe = 58$. The location effect was greater for unstudied decisions (0.9%) than studied decisions (2.5%).

The main effect of cue type on the number of errors made was not significant, with 2.8% errors for location cue, 3.5% for object cue, and 3.2% for the neutral cue. In terms of the 4 critical cases under consideration, the fan effect was only significant for MM-object cue case, $F(2,132) = 4.69$, $p < 0.05$, $MSe = 39$. Also, the location effect was only significant for the object cue condition, $F(1,69) = 11.37$, $p < 0.01$, $MSe = 39$, with more errors made in the MM condition.

There was no main effect of sentence type. However, the Sentence

Type X SOA X Cue Type interaction reached significance, $F(4,132) = 3.13$, $p < 0.05$, $MSe = 3494$. The OS sentence groups had fewer errors except for the neutral cue condition of the 250 and 1000 ms SOA groups and the location cue condition for the 1000 ms SOA group.

Overall, the error patterns for this experiment reflect the RT patterns on most of the more important effects. There was also little evidence that subjects were making a speed-accuracy trade-off.

Discussion

It was predicted that subjects' RTs would show a benefit for the object and location cues. Also predicted were a reduced or eliminated fan effect for the MM-location cue condition as well as a reduced or eliminated location effect for the location cue condition. Not surprisingly, the first prediction was well supported. However, the support for the second prediction is ambiguous.

On the one hand, the fan effect for the MM-location cue condition was significant and was not different from the MM-neutral cue condition. However, the location effect for the location cue was reduced. Furthermore, as the size of the SOA increased the size of the location effect decreased until it was eliminated for the 1000 ms SOA group. Further support for the prediction is that the Fan Effect X Location Effect interaction was significant for the neutral cue condition, but not for the location cue condition.

These findings are not in clear support of the predictions made by either the mental model or the propositional network theories. It would appear, however, by looking at Figure 15 that despite the fact that no

statistical tests supported this, the fan effect for the MM-location cue condition was gradually reduced as SOA lengthened, but less so for the MM-object cue and the MM-neutral cue conditions. In contrast, the change in the location effect with increasing SOA was significant. In fact, if the 1000 ms SOA group were the only one considered, all of the predictions would be confirmed (the MM-location cue fan effect was not significant within any of the SOA groups).

Still, the answer to the predictions is not as clear as one would hope. It may be the case that since mental models are rather large and complex cognitive structures that they would require a large amount of time and activation to show a substantial effect of the sort investigated. It may be that the best route to pursue in assessing these predictions would be to test another group of subjects at a longer SOA (e.g., 1500 ms). This should give the mental models sufficient time to be cued. Additionally, twice as many items should be included in the 1-1 cell to be randomly divided up between the SM and MM conditions. This would allow for all four fan levels to be included in analyses involving the location effect.

CHAPTER VII

CONCLUSIONS

These four studies have shown that a mental model representation is employed in cognitive tasks. Subjects automatically engage in comprehension of text (the facts) at a level much deeper than necessary. All that was required was that a surface structure or simple propositional representation be stored and retrieved from long-term memory for successful performance. In fact, the latter is what propositional network theory states would happen. What seems to have occurred instead was that mental models of the situations described were created. When two or more facts were consistent with a single situation, even when noncontiguous in the presentation order, they were integrated into a single representation of a single state of affairs. These single situation representations were then stored in and retrieved from long-term memory as coherent wholes. Importantly, even if other representational forms may have been generated, this was the one used. This memory organization and retrieval process is the explanation for the location effect.

Jones and Anderson (1987) obtained results that parallel the results of the present study. The primary focus of Jones and Anderson's

two experiments was to compare long- and short-term memory retrieval. Of interest here is the long-term memory retrieval portion of the experiments. The stimulus materials consisted of a set of facts with fan sizes of 1, 3, and 6. For half of the person-words their associated predicates were unrelated to one another (e.g., research, police, and forest) and for half they were related (e.g., rifle, hunter, forest). Related material consistently produced shorter RTs than unrelated material (though this difference was only significant in Experiment 2). Additionally, visual inspection (neither the Fan Effect X Relatedness interaction nor the fan effects for the two relatedness conditions was reported) reveals unrelated sets produced increased RTs with increasing fan while the related sets produced RT patterns that were comparatively flat (see Figure 16).

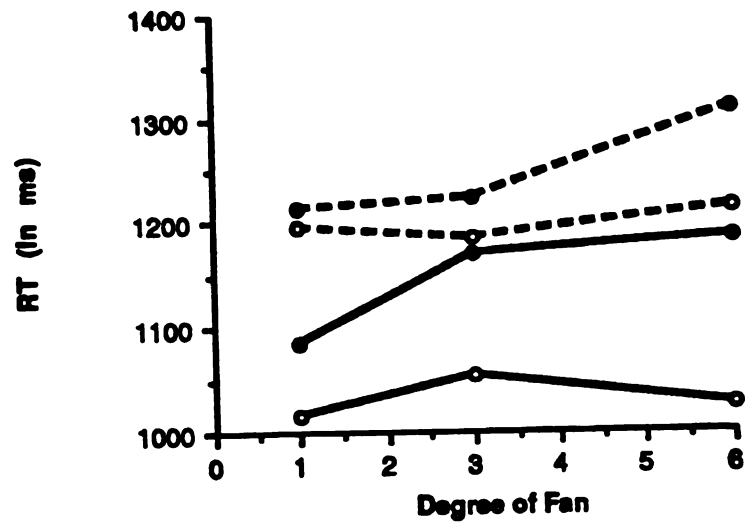
 Insert Figure 16 about here

Jones and Anderson (1987) use what is referred to as an "indirect pathway model" to explain these findings. This is basically a horse race model involving two retrieval processes, an item-by-item process and a relatedness-judgment process. The item-by-item process is the explanation for the standard fan effect of spreading activation being divided up more finely with increasing fan. The relatedness-judgment process accounts for the absence of a fan effect in the related sets. The related sets' predicates are said to have a large number of pre-experimental associations. These associations are activated along with the experimental links in the fact retrieval process. Though the

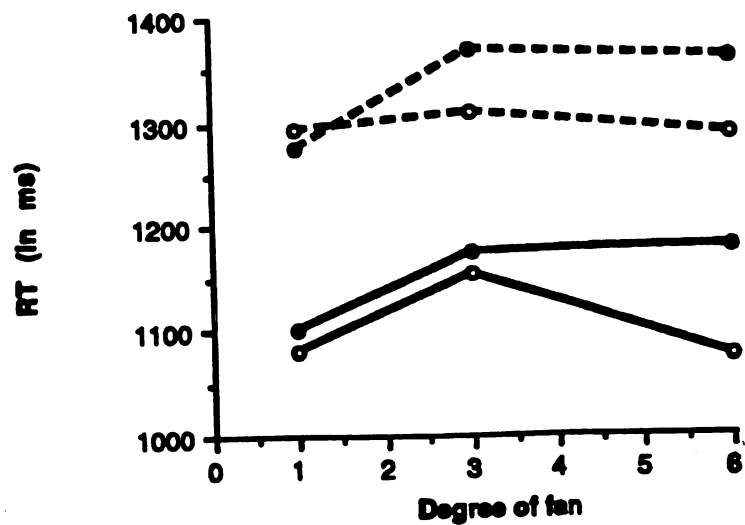
Figure 16

Results from the Jones and Anderson (1987) Study

Experiment 1



Experiment 2



- Related (studied)
- -○- - Related (unstudied)
- Unrelated (studied)
- -●- - Unrelated (unstudied)

activation is divided up by the increased number of links, large numbers of these links are associated with the two critical concepts. The increased number of incidental links makes a rapid intersection of the spread of activation more likely, through indirect pathways, thus eliminating the fan effect.

Although this explanation may be adequate for the materials used by Jones and Anderson (1987), it cannot be extended to the materials used in the present paper. The people or objects associated with a single location do not have large numbers of pre-experimental associations with each other or the locations. So, the indirect pathway explanation is found to be lacking.

The mental model theory, however, can account for both sets of experiments quite efficiently. For the Jones and Anderson (1987) materials, the related predicates can be easily considered as belonging to a single situation and could therefore be incorporated into a single mental model. The unrelated materials do not lend themselves to an obvious single situation structure, so several mental models must be created. The rest is the same as described for the present paper's experiments.

By adding the appropriate productions to act on a propositional network to generate a location effect it may be possible to preserve models such as ACT* as the form of mental representation used by cognitive tasks such as fact retrieval. The difficulty with this approach is that it is cumbersome and entirely post hoc.

With discourse materials at least, it appears that the most

profitable approach for looking at the form of the representation used in fact retrieval, and other cognitive tasks as well, is the mental model view. However, some have argued that propositional representations are well known and can be adapted to represent any desired situation and should be retained in favor of less well known representational schemes such as mental models (Kintsch, 1988; Rips, 1985). The present studies are evidence that this line of reasoning is not productive and that mental models do provide cognitive psychology with a predictive paradigm. Specifically, it is possible to predict various characteristics of the mental model representation and how these characteristics affect cognitive processes.

APPENDICES

Appendix A

Mean RTs (in ms) and error rates (in percentages) per subject by cell.

	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u> *
Experiment 1a				
<u>Reaction times</u>				
Studied	1670	1613	1533	1758
Unstudied	1654	1668	1687	1835
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		1766	1762	1841
Unstudied		1963	1897	2100
<u>Error rates</u>				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	4.7	2.7	3.1	3.1
Unstudied	4.7	3.1	2.7	4.3
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		3.5	4.7	5.1
Unstudied		3.1	4.3	4.7
Experiment 1b				
<u>Reaction times</u>				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1536	1623	1608	1652
Unstudied	1672	2087	2050	2243
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		1787	1755	1936
Unstudied		2087	2050	2243
<u>Error rates</u>				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	2.4	3.1	0.8	2.4
Unstudied	1.2	1.2	2.4	2.7
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		4.7	3.5	4.3
Unstudied		5.9	11.4	8.6

Experiment 2Reaction times

Location Instructions				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1516	1476	1536	1439
Unstudied	1505	1546	1595	1606
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		1628	1793	1727
Unstudied		1800	2026	2042
Object Instructions				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1458	1477	1540	1490
Unstudied	1504	1592	1596	1563
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		1598	1673	1751
Unstudied		1821	1954	2060
Neutral Instructions				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1537	1478	1500	1475
Unstudied	1593	1706	1687	1679
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		1727	1837	1811
Unstudied		1882	2053	2147

Error Rates

Location Instructions				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	2.6	2.3	2.3	1.8
Unstudied	1.6	0.3	0.8	1.8
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		2.3	2.3	1.8
Unstudied		1.8	5.2	3.6
Object Instructions				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1.0	1.8	1.8	1.6
Unstudied	1.3	0.5	1.8	0.8
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		3.1	2.6	2.6
Unstudied		1.3	6.0	6.3
Neutral Instructions				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1.8	2.3	2.6	3.6
Unstudied	2.6	2.6	1.8	2.3
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		4.4	3.6	3.9
Unstudied		3.1	3.4	5.7

Experiment 3Reaction times

250 ms SOA -- Location cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1203	1283	1155	1147
Unstudied	1354	1419	1367	1377
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		1325	1366	1377
Unstudied		1620	1647	1585
250 ms SOA -- Object cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1194	1205	1211	1174
Unstudied	1331	1355	1430	1281
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		1244	1358	1410
Unstudied		1469	1680	1629
250 ms SOA -- Neutral cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1415	1335	1376	1361
Unstudied	1331	1517	1523	1449
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		1512	1575	1488
Unstudied		1592	1701	1708
500 ms SOA -- Location cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1182	1122	1171	1064
Unstudied	1209	1371	1313	1364
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		1246	1336	1218
Unstudied		1315	1539	1484
500 ms SOA -- Object cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1125	1078	1042	1034
Unstudied	1268	1263	1220	1218
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		1138	1412	1241
Unstudied		1448	1553	1490
500 ms SOA -- Neutral cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1408	1350	1312	1361
Unstudied	1449	1544	1480	1561
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		1433	1604	1572
Unstudied		1597	1791	1788

1000 ms SOA -- Location cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1267	1253	1275	1239
Unstudied	1276	1385	1389	1415
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		1321	1322	1235
Unstudied		1382	1568	1552
1000 ms SOA -- Object cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1106	1116	1094	1109
Unstudied	1222	1199	1354	1233
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		1227	1354	1233
Unstudied		1386	1527	1597
1000 ms SOA -- Neutral cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1507	1558	1475	1458
Unstudied	1559	1589	1629	1560
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		1583	1692	1543
Unstudied		1729	1899	1921

Error rates

250 ms SOA -- Location cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	1.0	2.6	2.1	3.6
Unstudied	2.1	1.6	1.6	4.7
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		3.6	2.1	3.6
Unstudied		2.1	3.1	7.8
250 ms SOA -- Object cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	3.1	1.0	1.0	2.1
Unstudied	3.6	2.6	4.7	2.6
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		3.6	3.6	4.2
Unstudied		1.6	9.9	6.3
250 ms SOA -- Neutral cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	3.1	3.1	4.2	4.7
Unstudied	1.0	2.1	2.6	2.1
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		4.7	1.0	3.6
Unstudied		2.1	3.6	6.8

500 ms SOA -- Location cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	3.6	3.1	2.6	1.6
Unstudied	2.1	1.0	1.0	2.6
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		3.6	2.1	2.1
Unstudied		3.6	2.1	7.3
500 ms SOA -- Object cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	2.6	1.6	1.0	3.1
Unstudied	0.5	3.6	3.6	2.6
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		2.1	4.2	4.7
Unstudied		1.6	4.2	11.5
500 ms SOA -- Neutral cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	4.7	5.2	3.1	2.1
Unstudied	3.1	0.5	1.6	1.6
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		3.1	7.3	3.6
Unstudied		1.6	4.7	6.3
1000 ms SOA -- Location cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	3.1	3.1	3.6	3.1
Unstudied	2.1	1.0	1.6	0.5
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		4.2	4.2	1.6
Unstudied		4.2	2.1	3.1
1000 ms SOA -- Object cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	7.8	3.6	3.1	2.6
Unstudied	2.1	1.6	3.1	1.0
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		3.1	5.2	3.6
Unstudied		4.2	4.7	3.1
1000 ms SOA -- Neutral cue				
	<u>1-1</u>	<u>1-2</u>	<u>1-3</u>	<u>1-4</u>
Studied	4.7	0.5	3.1	2.6
Unstudied	2.1	1.0	1.0	1.0
		<u>2-1</u>	<u>3-1</u>	<u>4-1</u>
Studied		3.6	4.7	2.1
Unstudied		2.6	6.3	2.6

* X-X = number of locations - number of people/objects

Appendix B

Instructions used in Experiment 2.

For the first part of the experiment we would like you to try to memorize a list of facts. These facts are about some objects and locations. We would like you to try to organize these facts in your mind in terms of the locations/We would like you to try to organize these facts in your mind in terms of the objects/We would like you to try to memorize these facts as efficiently as possible. These facts will be presented on the computer screen and will advance automatically. This constitutes the study period of the experiment.

Following the study period, you will be given a test period. During this time you will be presented with questions in the form "What is in the park?" or "Where is the marble statue?". You are then to tell the experimenter all of the facts that were presented about the object or location.

After the test period you will return to the study period. This study-test procedure will continue until all of the test questions can be answered correctly, twice in a row. At that time we will proceed to the recognition test. Remember to try to organize the facts in your mind in terms of the location, this will be important for a later part of the experiment/Remember to try to organize the facts in your mind in terms of the object, this will be important for a later part of the experiment/ Remember to try to memorize the facts as efficiently as possible. If you have questions at any time feel free to ask the experimenter.

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